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Synthesis, Evaluation of Environmental and Economic Aspects of Biodiesel in India

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Abstract

The demand for diesel is five times higher than the demand for petrol in India. But while the ethanol industry is mature, the biodiesel industry is still in its infancy. India's current biodiesel technology of choice is the transesterification of vegetable oil. The government has formulated an ambitious National Biodiesel Mission to meet 20 per cent of the country's diesel requirements by 2024-2025. Since the demand for edible vegetable oil exceeds supply, the government has decided to use non-edible oil from Jatropha curcas seeds as biodiesel feedstock. Extensive research has shown that Jatropha offers the following advantages: it requires low water and fertilizer for cultivation, is not grazed by cattle or sheep, is pest resistant, is easy propagated, has a low gestation period, and has a high seed yield and oil content, and produces high protein manure.

Keywords: *Biodiesel, Transesterification, Jatropha curcas*

Introduction

The current manufacturing cost of ethanol and biodiesel in India is about Rs.72/litre, roughly the same as petrol and diesel. This puts biofuels in a favorable position for meeting India's energy needs, especially as the cost of petroleum is expected to continue its upward trend. In addition to providing energy security and a decreased dependence on oil imports, biofuels offer several significant benefits such as reduced emission of pollutants and greenhouse gases and increased employment in the agricultural sector[1].

In India ethanol is produced by the fermentation of molasses – a by-product of sugar manufacture. India is the fourth largest ethanol producer after Brazil, the United States and China, its average annual ethanol output amounting to 1,900 million litres with a distillation capacity of 2,900 million litres per year[2]. For a 5 per cent ethanol blend in petrol nationally, the ethanol required would be 640 million litres of ethanol in 2006-2007 and 810 million litres in 2011-2012. Current capacity can potentially satisfy this demand.

The cost of ethanol production can be decreased by using improved agricultural practices to increase sugarcane yield and deploying energy-efficient ethanol dehydration methods like pressure-swing adsorption and membrane separation. Restrictive government policies need to be reformed to loosen constraints on ethanol production.

India is now the world's largest sugar consumer and this has put added pressure on the ethanol industry. As agricultural research has amply demonstrated, sweet sorghum and tropical sugar beet are cost-effective feedstock

crops that may substitute for sugarcane. Furthermore, exciting new biotechnology involving enzymatic reaction and fermentation has made it possible to use readily available cellulosic material like wood and crop residue for ethanol production. Also, trade in ethanol can play an important part in helping meet India's ethanol requirements. India's trade policies do not have to be protectionist, but should rather be aimed at spurring domestic growth[3].

The National Biodiesel Mission was implemented in two stages:

1. A demonstration project carried out over the period 2003-2007 aimed at cultivating 400,000 hectares of Jatropha to yield about 3.75 tons oilseed per hectare annually. The project will also demonstrate the viability of other aspects like seed collection and oil extraction. In addition, the government will build a transesterification plant.
2. A commercialization period during 2007-2012 continued Jatropha cultivation and installs more transesterification plants which will position India to meet 20 per cent of its diesel needs through biodiesel.

National Policy on Biofuels:

Biofuels have garnered global attention in recent times and it is imperative to keep up with the pace of developments in the field of biofuels. Biofuels are of strategic importance in India and augers well with the initiatives of the Government.

India still relies heavily on crude oil imports for its domestic consumption requirements. However, fluctuating crude oil prices in the world market could affect the developing countries significantly. Biofuels program 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. The National Biofuels Draft Policy came to light in 2007 and was launched by 2009[4].

The objective of the National Policy on Biofuels 2018: The policy is aimed at taking forward the indicative target of achieving 20% blending of biofuels with fossil-based fuels by 2030. The policy intends to ensure the adequate and sustained availability of domestic feedstock for biofuel production, increasing farmers' income, import reduction, employment generation and waste to wealth creation. This policy clearly exhibits the Centre's push towards strengthening the energy infrastructure of the country while promoting the agenda of sustainability.

Salient Features of the National Policy on Biofuels

The policy categorizes biofuels into:

1. Basic biofuels – First Generation (1G) bioethanol & biodiesel
2. Advanced biofuels – Second Generation (2G) ethanol, Municipal Solid Waste (MSW) and drop-in fuels
3. Third Generation Biofuels – Bio-CNG

The categorization aids in the extension of appropriate financial and fiscal incentives under each category.

1. The policy expands the scope of raw materials to be used for ethanol production by allowing the use of Sugarcane Juice, **sugar-containing materials** like Sugar Beet, **starch containing materials** like Cassava, **damaged food grains** like broken rice, and rotten potatoes which are unfit for human consumption.
2. The Policy allows the usage of surplus food grains for the production of ethanol to be used for blending with petrol. This is to ensure that the farmers get the appropriate price for their produce during the surplus production phase.
3. The Policy indicates a viability gap funding scheme for 2G ethanol Bio refineries of Rs.5000 crore in 6 years in addition to additional tax incentives, higher purchase price as compared to 1G biofuels. The policy places a thrust on Advanced Biofuels[5].
4. Setting up of supply chain mechanisms for biodiesel production from non-edible oilseeds, used cooking oil, and short gestation crops are encouraged under the Policy.

5. The Policy enlists all the roles and responsibilities of all the concerned Departments/Ministries with respect to biofuels to provide synergy in the efforts.

Benefits of National Policy of Biofuels

The National Policy of Biofuels offers the following benefits:

1. It reduces the country's dependence on imports.
2. It promotes a cleaner environment: It results in a reduction in the burning of crops, as the agricultural waste/residue is converted to bioethanol.
3. The re-use of cooking oil presents grave health hazards, however, it's a potential feedstock for biodiesel.
4. It also aids in Municipal Solid Waste (MSW) management. There are technologies available that can convert waste/plastic in the MSW to biofuels. One ton of such waste has the potential to provide around 20% reduction in fuels.
5. The process of production of biofuels will aid in the creation of jobs.
6. The conversion of surplus grains and agricultural biomass can help in price stabilization and thereby provide an additional source of income to the farmers.

The work carried out up to now in biodiesel development consists of developing high oil- yielding varieties of Jatropha, plantation of Jatropha by government-sponsored agencies, setting up of pilot plants on transesterification, running tests with locomotives and road vehicles using 5 per cent biodiesel blend, and organizing seminars by NGOs to expand awareness of the biodiesel programme[6].

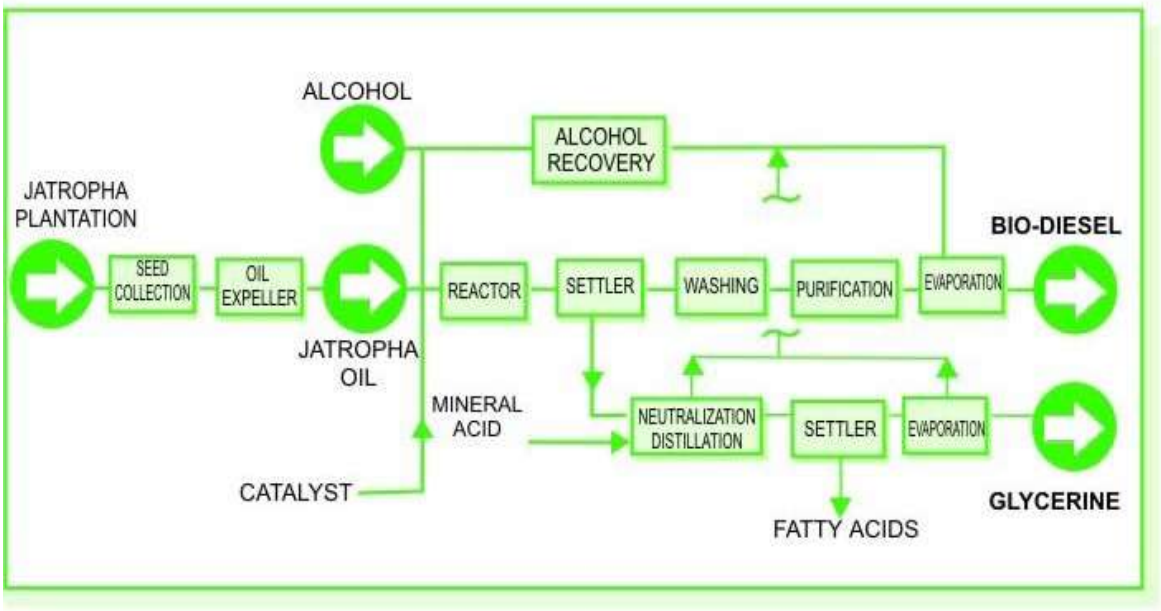
Commercial biodiesel plants are now been installed in India. However, two plant projects have secured financial backing and came on stream and produced 300 t/day plant and a 30 t/day plant, both located in the southern State of Andhra Pradesh. The main problem in getting the biodiesel programme rolling has been the difficulty in initiating the large-scale cultivation of Jatropha because farmers do not consider Jatropha cultivation rewarding enough[7]. The government needs to sponsor confidence-building measures such as establishing a minimum support price for Jatropha oilseeds and assuring farmers of timely payments.

In conclusion, the biofuels industry is poised to make important contributions to meet India's energy needs by supplying clean, environmentally-friendly fuel. The ethanol industry, though mature, can benefit from improved agricultural practices in sugarcane cultivation, more efficient production processes and the use of alternate feedstock including cellulosic material. On the other hand, the biodiesel industry is at the incubation stage and large-scale Jatropha cultivation and the infrastructure for oilseed collection and oil extraction must be established before the industry can be placed on a rapid-growth track.

Extraction of Biofuel

Biofuels are going to play an extremely important role in meeting India's energy needs. The country's energy demand is expected to grow at an annual rate of 4.8 per cent over the next couple of decades. Most of the energy requirements are currently satisfied by fossil fuels –coal, petroleum-based products and natural gas. Domestic production of crude oil can on fulfill 25-30 per cent of national consumption. In fact, the crude oil imports are expected to total 147 million tons (Mt) in 2006-2007. With the ever-escalating crude oil prices, if one assumes a price of $57/barrel ($420/ton), the estimated crude oil import bill for 2006-2007 would be $61.74 billion, about 10 per cent of the country's Gross Domestic Product[8].

Ethanol, currently produced in India by the fermentation of sugarcane molasses, is an excellent biofuel and can be blended with petrol. Likewise, biodiesel which can be manufactured by the transesterification of vegetable oil can be blended with diesel to reduce the consumption of diesel from petroleum.



The Government of India has developed an ambitious National Biodiesel Mission[5] to meet 20 per cent of the country's diesel requirements by 2011-2012. Since the demand for edible vegetable oil exceeds supply, the Government decided to use non-edible oil from Jatropha Curcas oilseeds as biodiesel feedstock. Extensive research has shown that Jatropha Curcas offers the following advantages: it requires low water and fertilizer for cultivation, not browsed by cattle or sheep, pest resistant, easy propagation, high seed yield and ability to produce high protein manure[9].

The National Biodiesel Mission will be implemented in two stages:

1) A demonstration project carried out between 2003-2007, which will cultivate 400,000 hectares of land and yield about 3.75 tons oilseed per hectare annually. The expected annual biodiesel production from the project is 1.2 t/ha/year for a total of 480,000 tons per annum. The Government will build a transesterification plant with a biodiesel production capacity of 80,000 ton/year as part of the demonstration project[10].

2) A commercialization period from 2007-2012 continued from Jatropha cultivation and install more transesterification plants which helped India to meet 20 per cent of its diesel needs through biodiesel.

Ethanol is produced in India by the fermentation of molasses, a by-product in sugar manufacture. The yield of sugarcane in India varies from an average of 77 tons/ha in tropical states to about 52 tons /ha in subtropical states. The yield of sugar on average is approximately 105 kg per ton of cane. About 40 kg of molasses is produced per ton of cane from which about 10 litres of ethanol can be obtained. If the sugarcane is directly and fully used in ethanol manufacture, the yield of ethanol is 70 litres per ton[11].

The cost of molasses in India varies widely across different states; in past years it has been as low as Rs. 50/ton and as high as Rs. 2,000/ton). A sizeable part of the cost is central excise duty, sales tax, transportation cost, etc., and the statutory controlled sugarcane and sugar prices. The international price of molasses, which was $50/ton in 2004, has doubled to $100/ton. Assuming a molasses price of Rs 3,000/ton ($66.67/ton) and a yield of 220 litres of ethanol per ton, the feedstock cost would be Rs. 23.64/litre ethanol[12].

Conclusion

Benefits & Economic aspects of the use of biofuels in India:

1. Reduced emission of harmful pollutants

Ethanol and biodiesel are both oxygenated compounds containing no sulphur. These fuels do not produce sulphur oxides, which lead to acid rain formation. Sulphur is removed from petrol and diesel by a process called hydro-desulphurization. The hydro-desulphurization of diesel causes a loss in lubricity, which has to be rectified by introducing an additive. Biodiesel has natural lubricity, and thus no lubricity-enhancing additive is required.

Since ethanol and biodiesel contain oxygen, the amount of carbon monoxide (CO) and unburnt hydrocarbons in the exhaust is reduced. With the introduction of ethanol in Brazil, CO emission from automobiles decreased from 50 g/km in 1980 to 5.8 g/km in 1995. The emission of nitrogen oxides (No_x) from biofuels is slightly greater when compared to petroleum, but this problem can be ameliorated by using de-No_x catalysts which work well with biofuels due to the absence of sulphur.

One of the disadvantages in using pure ethanol is that aldehyde emissions are higher than those of gasoline, but it must be observed that these aldehyde emissions are predominantly acetaldehydes. Acetaldehydes emissions generate less adverse health effects when compared to formaldehydes emitted from gasoline engines.

Table 1 shows how the automotive emissions using 22 per cent ethanol and 100 per cent hydrated ethanol compare with the legal limits in Brazil and India.

Table 1. Comparison of emissions from 22 per cent ethanol (E22) and 100 per cent hydrated ethanol (E100) with legal limits

Parameter	E22	E100	Legal Limits, Brazil	Legal Limits, India (Euro III/Bharat III)
Carbon Monoxide (g/km)	0.76	0.65	2.00	2.3
Unburned Hydrocarbons (g/km)	0.13	0.15	0.30	0.20
No_x (g/km)	0.45	0.34	0.60	0.50
Aldehydes (g/km)	0.004	0.02	0.03	
Evaporatives (g/test)	0.86	1.6		
Particulate Matter (g/km)	0.08	0.02		
Sulphur Dioxide (g/km)	0.064	0		

Source: CETESB

Table 2. Biodiesel emissions compared to conventional diesel

Emissions	**B100 (100 per cent biodiesel)**	**B20 (20 per cent biodiesel)**
Regulated Emissions		
Total Unburned Hydrocarbons	-93 per cent	-30 per cent
Carbon Monoxide	-50 per cent	-20 per cent
Particulate Matter	-30 per cent	-22 per cent
No_x	+13 per cent	+2 per cent
Non- regulated emissions	**B100 (100 per cent biodiesel)**	**B20 (20 per cent biodiesel)**
Polycyclic Aromatic Hydrocarbons (PAH)	-80 per cent	-13 per cent
NPAH (Nitrated PAH)	-90 per cent	-50 per cent

Life cycle emissions		
Carbon Dioxide (LCA)	-80 per cent	
Sulphur Dioxide (LCA)	-100 per cent	

2 .Increased employment

At the beginning of the new millennium, 260 million people in India did not have access to a consumption basket which defines the poverty line. India is home to 22 per cent of the world's poor. A programme that generates employment is therefore particularly welcome.

The biofuels sector has the potential to serve as a source of substantial employment. The investment in the ethanol industry per job created is $11,000, which is significantly less than the $220,000 per job in the petroleum field. In India, the sugar industry, which is the backbone of ethanol production, is the biggest agroindustry in the country. The sugar industry is the source of the livelihood of 45 million farmers and their dependents, comprising 7.5 per cent of the rural population. Another half a million people are employed as skilled or semi-skilled labourers in sugarcane cultivation.[13]

The first phase of the National Biodiesel Mission demonstration project will generate employment of 127.6 million person days in plantation by 2007. On a sustained basis, the program will create 36.8 million person days in seed collection and 3,680 person years for running the seed collection and oil-extraction centers[14].
Table 3 shows the estimated cumulative achievements of the project in terms of output and employment.

Table 3. Yearly and cumulative achievements of demonstration project

Year	Cumulative area (thousand hectares)	Availability of seed (million tons)	Expellers (number)	Plantation employment (million person days)	Seed collection employment (million person days)	Seed centre employment (person years)	Availability of oil (million tons)
2003	80	0	0	21	0	0	0
2004	240	0.200	20	45.9	1.6	160	0.048
2005	400	0.800	80	53	6.4	640	0.192
2006	400	1.600	160	7.68	12.8	1280	0.384
2007	400	2.000	200	0	16	1600	0.480
Cumulative Total				127.6	36.8	3,680	1.1104

Source: Planning Commission

3. Energy security and decreased dependence on oil imports

India ranks sixth in the world in terms of energy demand, accounting for 3.5 per cent of the world commercial energy demand in 2001. But at 479 kg of oil equivalent, the per capita energy consumption is still very low, and the energy demand is expected to grow at the rate of 4.8 per cent per annum. India's domestic production of crude oil currently satisfies only about 25 per cent of this consumption. Dependence on imported fuels leaves many countries vulnerable to possible disruptions in supplies which may result in physical hardships and economic burdens. The volatility of oil prices poses great risks for the world's economic and political stability, with unusually dramatic effects on energy-importing developing nations[15]. Renewable energy, including biofuels, can help diversify energy supply and increase energy security.

4. Improved social well-being

A large part of India's population, mostly in rural areas, does not have access to energy services. The enhanced use of renewables (mainly biofuels) in rural areas is closely linked to poverty reductions because greater access to energy services can:

1. Improve access to pumped drinking water. Potable water can reduce hunger by allowing for cooked food (95 per cent of food needs cooking);

2. Reduce the time spent by women and children on basic survival activities (gathering firewood, fetching water, cooking, etc.);

3. Allow lighting which increases security and enables the night time use of educational media and communication at school and home; and

4. Reduce indoor pollution caused by firewood use, together with a reduction in deforestation.

5. Increase in nutrients to soil, decrease in soil erosion and land degradation

In ethanol production from sugarcane, the by-products like vinasse (solid residue left after distillation) and filter cake contain valuable nutrients. Using these organic fertilizers instead of chemical fertilizers reduces the need for chemicals, which could be hazardous and avoids pollution of ground water and rivers. Table 5 developed by the International Crop Research Institute for Semi-Arid Tropics (ICRISAT) compares the nutrient content of filter cake obtained from various oilseeds in biodiesel manufacture with that of commonly used fertilizers like Di-Ammonium Phosphate (DAP) and Urea and demonstrates that the filter cake is an effective fertilizer:

Table 4. Comparison of oil seed filter cake nutrients with DAP and Urea

Source of fertilizer	Percentage Nitrogen	Percentage Phosphorous	Percentage Potassium
Pongamia Pinnata oilseed filter cake	3.95	0.52	0.42
Jatropha Curcas oilseed filter cake	4.44	2.09	1.68
Neem oilseed filter cake	5.0	1.0	1.5
Castor oilseed filter cake	4.37	1.85	1.39
Di-Ammonium Phosphate	18	20	0
Urea	46	0	0

6. Good fuel properties

Ethanol has a research octane number of 120, much higher than that of petrol, which is between 87 and 98. Thus, ethanol blending increases the octane number without having to add a carcinogenic substance like benzene or a health-risk posing chemical like methyl tertiary butyl ether (MTBE). The energy content of ethanol is only 26.9 MJ/kg compared to 44.0 MJ/kg for petrol. This would suggest that the fuel economy (km/litre) of a petrol-powered engine would be 38.9 per cent higher than that of an ethanol-powered engine. In actuality, this difference is 30 per cent since ethanol engines can run more efficiently (at a higher compression ratio) because of the higher octane rating. For a 10 per cent ethanol blend the fuel economy advantage of a petrol engine is only 3 per cent. The flammability limit of ethanol (19 per cent in air) is higher than that of petrol (7.6 per cent), and likewise the auto-ignition temperature of ethanol is higher than that of petrol (366 versus 300^{o}C). Thus, ethanol is safer than petrol due to the lower likelihood of catching fire. Ethanol's higher latent heat of vaporization and greater propensity to absorb moisture may lead to engine starting and corrosion problems, respectively, but none of these problems have manifested in the millions of hours of running automobile engines.

Biodiesel has good fuel properties, comparable to or even better than petroleum diesel. It has 10 per cent built-in oxygen content that helps it to burn fully. Its cetane number (an indication of its fuel burning efficiency) is 52 for biodiesel from Jatropha oil, higher than the 42 to 48 cetane number of most petroleum diesels. The esters of the long-chain fatty acids of biodiesel are excellent lubricants for the fuel injection system. It has a higher flash point than diesel, making it a safer fuel. Other advantages are the almost zero sulphur content and the reduced amount of carbon monoxide, unburned hydrocarbons and particulate matter in the exhaust. But there are a few technical issues that need to be resolved. Biodiesel has a high viscosity at low temperatures, leading to flow problems at

these temperatures. For long-term storage in hot, humid conditions, ethanol may require a biocide to prevent bacterial growth.

Table 5 shows the projected demand and supply of ethanol for blending in petrol (5 per cent ethanol – 95 per cent petrol).

Table 5. Projected demand and supply of ethanol for 5 per cent blending in petrol

Year	Petrol demand (Mt)	Ethanol demand (M L)	Molasses prodn. (Mt)	Ethanol production (M L)			Ethanol utilization (M L)		
				Molasses	Cane	Total	Potable	Industry	Balance
2011-2012	7.07	416.14	8.77	1775	0	1775	648	600	527
2016-2017	10.07	592.72	11.36	2300	1485	3785	765	711	2309
2021-2022	12.85	756.36	11.36	2300	1485	3785	887	844	2054
2026-2027	16.4	965.30	11.36	2300	1485	3785	1028	1003	1754

Source: Planning Commission

An economic analysis indicates that ethanol from sugarcane and biodiesel from Jatropha curcas can be manufactured at under Rs.80 /litre Current production cost of petrol and diesel from crude is Rs. 99.94 /litre, and with crude oil prices on an upward swing, the production costs of ethanol and biodiesel compare favorably with those of petrol and diesel. The ethanol cost price can be brought down further through the following options:

1. Allowing a market-based sugarcane price.

2. Combining ethanol manufacture with sugar manufacture, which would permit a major part of the cane cost to be off-loaded to sugar. For instance, a ton of sugarcane produces 105 kg sugar, and even if the sugar is sold at Rs 10/kg, this will be sufficient to pay for the cost of the sugarcane.

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