18 October 2006

ENGLISH ONLY

United Nations Conference on Trade and Development

An Assessment of the Biofuels Industry in India*

Prepared by

Joseph B. Gonsalves[1]
E-mail: gonsalvesj@hotmail.com

*The views expressed in this paper are those of the author and do not necessarily reflect the views of the United Nations.

[1] Consultant, United Nations Conference on Trade and Development, Geneva. The author wishes to thank Mr. Lucas Assunção, Climate Change Programme and Biotrade Initiative, UNCTAD, for helpful discussions.

UNCTAD/DITC/TED/2006/6

GE.06-52187

Contents

List of Figures

List of Tables

Executive summary

The current manufacturing cost of ethanol and biodiesel in India is about Rs. 21/litre ($0.46/litre), roughly the same as petrol and diesel. This puts biofuels in a favourable 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.

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. 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 saccharification 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.

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 2011-2012. 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.

The National Biodiesel Mission will be 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 will continue Jatropha cultivation and install more transesterification plants which will position India to meet 20 per cent of its diesel needs through biodiesel.

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.

Commercial biodiesel plants have not yet been installed in India. However, two plant projects have secured financial backing and are expected to come onstream in 2006 – a 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. 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 feedstocks 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.

Overview

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 only 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.[2] 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.

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. Ethanol and biodiesel are gaining acceptance worldwide as good substitutes for oil in the transportation sector. Brazil[3] uses pure ethanol in about 20 per cent of their vehicles and a 22 to 26 per cent ethanol-petrol blend in the rest of their vehicles. The United States and Australia use a 10 per cent ethanol blend. With a normal production rate of 1,900 million litres a year, India is the world's fourth largest producer of ethanol after Brazil, the United States and China. Beginning 1 January 2003, the Government of India mandated the use of a 5 per cent ethanol blend in petrol sold in nine sugarcane producing states. The Government will expand the 5 per cent ethanol mandate to the rest of country in a phased manner.

Biodiesel production is rapidly growing in Europe and the United States. Current estimates show production of 2.2 Mt/year in Europe[4], with Germany (1.1Mt/year), France (0.5Mt/year) and Italy (0.4Mt/year) being the leading producers. The European Union mandated that its members derive at least 2 per cent of their fuel consumption from biofuels by 2005 and 5.75 per cent by 2010. Biodiesel production is about 245,000 t/year in the United States.

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. 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 t/year as part of the demonstration project; and 2) a commercialization period from 2007-2012 will continue Jatropha cultivation and install more

---

[2] Planning Commission, Government of India. Report of the Working Group, Tenth Plan.
[3] UNCTAD. Biofuels – Advantages and Trade Barriers. Paper Prepared by Suani Teixeira Coelho, 4 February 2005. UNCTAD Document UNCTAD/DITC/TED/2005/1.
[4] Garafalo, R. (2004).
[5] Planning Commission, Government of India. Report of the committee on Development of Bio-Fuel, 16 April 2003.

transesterification plants which will position India to meet 20 per cent of its diesel needs through biodiesel.

An economic analysis indicates that ethanol from sugarcane and biodiesel from Jatropha Curcas can be manufactured at under Rs. 21/litre ($0.47/litre at an exchange rate of Rs 45/$). Current production cost of petrol and diesel from crude is $0.46/litre, and with crude oil prices on an upward swing, the production costs of ethanol and biodiesel compare favourably with those of petrol and diesel.

The following table shows the projected demand for petrol and diesel and the amount of ethanol and biodiesel required for 5, 10, and 20 per cent blending.

Table 1. Projected demand for petrol and diesel, and biofuels requirements

Year	Petrol demand Mt	Ethanol blending requirement (in metric tons)			Diesel demand Mt	Biodiesel blending requirement (in metric tons)		
		@ 5 per cent	@ 10 per cent	@ 20 per cent		@ 5 per cent	@ 10 per cent	@ 20 per cent
2006-2007	10.07	0.50	1.01	2.01	52.32	2.62	5.23	10.46
2011-2012	12.85	0.64	1.29	2.57	66.91	3.35	6.69	13.38
2016-2017	16.40	0.82	1.64	3.28	83.58	4.18	8.36	16.72

Source: Planning Commission, Government of India. Report of the Committee on Development of BioFuel, 16 April 2003.

The above demands are based on estimated growth rates of 7.3 and 5.6 per cent for petrol and diesel, respectively, in the 10th plan (2001-2002 to 2006-2007), 5.0 and 5.0 per cent in the 11th plan (2006-2007 to 2011-2012) and 5.0 and 4.5 per cent in the 12th plan (2011-2012 to 2016-2017).

Biofuels offer a number of environmental, social, and economic advantages, including lower emissions of harmful pollutants; decreased greenhouse gas emissions; increased employment; increased energy security, especially in rural areas; decreased dependence on oil imports; and good fuel properties for vehicles.

Our analysis indicates that while India has an ethanol distillation capacity of 2,900 million litres/year, sufficient to meet 5 per cent ethanol blending requirements, domestic sugarcane molasses might not represent a reliable feedstock, given the vagaries of the sugar industry and the dependence of sugarcane cultivation on monsoons. For instance in 2003-2004, the sugar output dropped to 15 Mt, molasses production sunk to 6.75 Mt, and the ethanol manufacturing level decreased to 1,518 million litres.[6] This caused India to import ethanol and molasses in 2003-2004. In addition to more efficient agricultural practices for improved sugarcane yield, crops like sweet sorghum and tropical sugar beet represent attractive alternate feedstock for ethanol. New exciting technologies like enzymatic fermentation of cellulose will, in the near future, enable ethanol to be manufactured at competitive prices from cheap, easily available material like wood and crop residue. In the meantime, ethanol imports can be used to satisfy some of India's ethanol demand, especially for 10 and 20 per cent ethanol blending. Brazil exported about 2 billion litres in 2004-2005, and other countries like Thailand, Mexico and Cuba are increasing production. Molasses imports from agro-industries in Asia can also augment India's ethanol production.

[6] Nigam, R. B. and P. K. Agrawal (2004).

In the biodiesel sector, India has taken the initial steps toward commercial production. The work accomplished so far includes developing high-yielding varieties of Jatropha, initiating Jatropha nurseries, setting up pilot-plants for biodiesel manufacture and testing biodiesel in public transport locomotives and buses. Phase I of the National Biodiesel Mission seeks to demonstrate the viability of all aspects of successful biodiesel manufacturing enterprise. The amount of land available for Jatropha cultivation is estimated at 13.4 million hectares, which could potentially yield 15 Mt/year of Jatropha oil. New infrastructure for seed collection, oil extraction, transesterification, biodiesel storage, blending with diesel and marketing is needed. But more importantly, large-scale cultivation of Jatropha must be established before biodiesel production can meet even a 5 per cent blending requirement nationally.

The lack of assured supplies of vegetable oil feedstock has stymied efforts by the private sector to set up biodiesel plants in India. So far only two firms, Naturol Bioenergy Limited (NBL) and Southern Online Biotechnologies, have embarked on biodiesel projects, both in the southern state of Andhra Pradesh. Naturol Bioenergy, a partnership between the Austrian biodiesel firm Energea Gmbh and the investment firm Fe Clean Energy, plans to install a 300 ton/day (90,000 t/year) biodiesel plant. The State Government allocated 120,000 hectares of land for Jatropha cultivation to the firm but cultivation has not yet begun. The farmers are demanding that the market set the oilseed price, but Naturol wants the government to fix a price to reduce its risks in production. Southern Online Biotechnologies has a 30 ton/day (9,000 t/year) project, which would require about 9,500 t/year of oil. It expects to get about 6,000 t/year through cultivation of Jatropha and Pongamia Pinnata oilseeds on wastelands, and plans to make up the balance through animal fats.

Because difficulties procuring oilseeds and lack of developed infrastructure may obstruct substantial biodiesel production by 2011-2012, importing biodiesel may become necessary, especially if the price of crude oil continues to rise. Europe and the United States are rapidly increasing production, but their biodiesel is mainly earmarked for domestic consumption. India’s biodiesel imports would probably come from developing countries.

Benefits from the use of biofuels in India

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-desulphurisation. The hydro-desulphurisation 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 2 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 2. 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 (2004).

Table 3 shows the results of the emission tests for pure biodiesel (B100) and 20 per cent biodiesel blend (B20) compared to conventional diesel.

Table 3. 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	

Source: Planning Commission (2003).

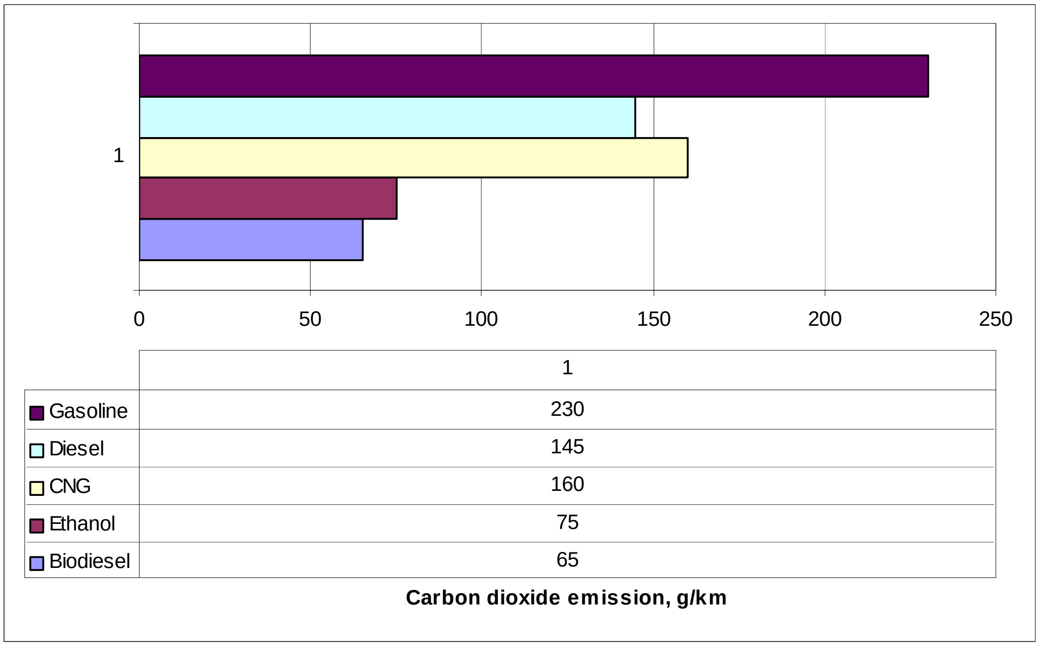
Reduction in greenhouse gas emissions

The net CO_2 emission of burning a biofuel like ethanol is zero since the CO_2 emitted on combustion is equal to that absorbed from the atmosphere by photosynthesis during the growth of the plant (sugarcane) used to manufacture ethanol. This is illustrated by the following equations:

$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6$ (plant sugar) $+ 6O_2$ (photosynthesis)
$C_6H_{12}O_6 + 3H_2O \rightarrow 3C_2H_5OH$ (ethanol) $+ 3O_2$ (hydrolysis and fermentation)
$3C_2H_5OH + 9O_2 \rightarrow 6CO_2 + 9H_2O$ (combustion of ethanol)

Life cycle analysis, from well to wheels, shows that ethanol has the lowest CO_2 emission among the major transportation fuels as shown in figure 1.

Figure 1. Carbon dioxide emission, life cycle analysis



Source: Planning Commission (2003).

Biofuels contribute significantly to climate change mitigation by reducing CO_2 emissions. Biodiesel projects can qualify as CDM projects and thus bring in additional income through the sale of certified emission reductions.

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.[7] 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 dependants, 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.[8]

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 centres. Table 4 shows the estimated cumulative achievements of the project in terms of output and employment.

[7] Uppal J. (2004).
[8] Ministry of Food and Agriculture, (2003).

Table 4. 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 (2003).

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. Renewable energy, including biofuels, can help diversify energy supply and increase energy security.

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:

- Improve access to pumped drinking water. Potable water can reduce hunger by allowing for cooked food (95 per cent of food needs cooking);
- Reduce the time spent by women and children on basic survival activities (gathering firewood, fetching water, cooking, etc.);
- Allow lighting which increases security and enables the night time use of educational media and communication at school and home; and
- Reduce indoor pollution caused by firewood use, together with a reduction in deforestation.

Lack of access to affordable energy services among the rural poor seriously affects their chances of benefiting from economic development and improved living standards. Women, older people and children suffer disproportionately because of their relative dependence on traditional fuels and their exposure to smoke from cooking, the main cause of respiratory diseases. Electricity through transmission lines to many rural areas is unlikely to happen in the near future, so access to modern decentralized small-scale energy technologies, particularly renewables (including biofuels), are an important element for effective poverty alleviation policies. A programme that develops energy from raw material grown in rural areas will go a long way in providing energy security to the rural people.

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 5. 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

Also the cultivation of land for sugarcane and oilseed-bearing crops contributes to a decrease in soil erosion and land degradation.

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 in Brazil.

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.

The ethanol industry in India

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.

Table 6 shows the projected demand and supply of ethanol for blending in petrol (5 per cent ethanol – 95 per cent petrol).

Table 6. 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
2001-2002	7.07	416.14	8.77	1775	0	1775	648	600	527
2006-2007	10.07	592.72	11.36	2300	1485	3785	765	711	2309
2011-2012	12.85	756.36	11.36	2300	1485	3785	887	844	2054
2016-2017	16.4	965.30	11.36	2300	1485	3785	1028	1003	1754

Source: Planning Commission (2003).

Table 6 is based on the following assumptions:

1. The area under cane cultivation is expected to increase from 4.36 Mha in 2001-2002 to 4.96 Mha in 2006-2007 which would result in an additional cane production of 50 MT.
2. About 30 per cent of cane goes for making gur (jaggery) and khandsari (unrefined sugar). If there is no additional increase in khandsari demand, sugar and molasses production would increase.
3. The present distiller capacity is for 2,900 million litres (M L) and looks to be sufficient for 5 per cent blend until 2016-2017.
4. An annual demand growth of 3 per cent for potable ethanol and 3.5 per cent for industrial ethanol.

Economics of ethanol production from sugarcane

The present price of sugarcane, as fixed by the central government under the minimum statutory price, is Rs. 695/ton ($15.45/ton) based on a sugar recovery of 8.5 per cent. At a 10.5 per cent recovery rate, the price of sugarcane, after state excise taxes, is Rs 900/ton ($20/ton). Assuming an ethanol yield of 70 litres/ton of cane, the raw material cost of ethanol is Rs 900/70 = Rs. 13/litre ($0.29/litre). After adding salary and wages of operational staff, capital related charges of investment, energy cost of producing anhydrous alcohol, cost of transport and marketing, the cost of producing ethanol directly from sugarcane is Rs 20/litre ($0.45/litre). This compares favourably with the current world price of petrol, $1.75/gallon

($0.46/litre). The ethanol cost price can be brought down further through the following options:

- Allowing a market-based sugarcane price.

- 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.

- Using the bagasse by-product and spent wash more efficiently. The spent wash, which is produced in large quantity (about 15 litres per litre of ethanol produced), can be subjected to anaerobic digestion that not only removes its BOD and COD but also provides valuable biogas (60 per cent methane). This biogas can be used to offset 67 per cent of the energy cost of making anhydrous alcohol through distillation. Plants can further use bagasse, which is left after crushing the cane, as boiler fuel for electricity generation at 97 kWh/ton of cane crushed.

Economics of ethanol production from molasses

The cost of molasses in India varies widely across different states; in past years it has been as low as Rs. 50/ton ($1.10/ton) and as high as Rs. 2,000/ton ($44.45/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. 13.64/litre ethanol ($0.30/litre). A detailed cost breakdown of a 9 million litre/year ethanol production plant is given in table 7.

Table 7. Economics of ethanol production from molasses			
		Stand alone distillery	Integrated with sugar production
Cost of molasses	Per ton	Rs. 3,000 ($66.67)	Rs. 3,000 ($66.67)
Transportation cost	Per ton	Rs. 150 ($3.33)	0
Total		Rs. 3,150 ($70.00)	Rs. 3,000 ($66.67)
		Stand alone	Integrated
Recovery of ethanol	litres	220	220
		Rs./litre	Rs./litre
Molasses cost after milling		14.32	13.64
Steam cost @ Rice Husk Rs. 500/ton		0.25	0
Power cost @ Rs. 4.50/KwH		0.59	0
Chemical cost		0.2	0.2
Labour cost		0.25	0.25
Repair and maintenance		0.15	0.15
Total direct cost		15.76	14.24
Finance and other costs			
Indirect costs, including overheads		0.56	0.28
Interest @12 per cent for borrowed capital of Rs.72 million (Debt/equity ratio=1.5)		0.96	0.96
Interest @12 per cent for working capital for one month of molasses and ethanol		0.2	0,2
Depreciation @ 10 per cent for Rs. 120 million		1.33	1.33
Total finance and other costs		3.05	2.77
Total costs		Rs. 18.81 ($0.42)	Rs. 17.01 ($0.38)

Source: Planning Commission (2003). Note: A molasses cost of Rs. 3,000/ton was used instead of Rs. 1,000/ton, in line with current prices.

The above table shows that the price of ethanol is highly dependant on the cost of molasses.

Competitiveness of India's sugar and ethanol industries and strategies to improve productivity and efficiency

The Indian sugar and ethanol industries are not competitive in international markets when compared to other major producers such as Brazil and the United States. India and Brazil are the largest sugar producers in the world with an output of about 21 Mt each in 2002-2003. However, with a weak monsoon, an excess supply of sugar stock and the availability of cheap sugar from overseas, India's sugar production declined to 15 Mt in 2003-2004. The current international sugar price is $0.26/kg or Rs. 11.88/kg. The ex-factory price of sugar in India was Rs 16/kg in 2001. While Brazil's cost of production of ethanol[9] is $0.20/litre, India's is

[9] European Union of Alcohol Producers. *The Economist*, (2005).

about $0.40/litre. India's uncompetitive productivity can be attributed to the following causes:

- Low cane yield per acre due to archaic farming practices, lack of irrigation and fertilizers;
- Depletion of ground water resources;
- Excessive dependence on the monsoons, which can be fickle and unreliable; and
- Lack of utilization of advanced technology in ethanol manufacture.

The following strategies can improve the efficiency of the sugar and ethanol industries:

- Improved agricultural practices to increase sugarcane yield;
- Cultivation of alternate feedstock crops like sweet sorghum and tropical sugar beet;
- Use of enzymatic fermentation of cellulose for ethanol manufacture; and
- Improved methods of producing anhydrous alcohol.

Improved agricultural practices[10]

The following are some of the improved agricultural practices that can be used:

- Use of different water saving irrigation methods;
- Inter-cropping with other crops;
- Planting only in autumn and spring planting seasons and no planting in summer;
- Biopest control;
- Biofertilizer;
- Employment of varieties according to agro-climatic conditions;
- Drought management practices for sugarcane;
- Ring pit method;
- Use of quality seed;
- Integrated weed management; and
- Employment of mechanization.

Cultivation of alternate crops like sweet sorghum and tropical sugar beet[11,12]

Sweet sorghum is a grass type plant, similar to sugarcane. It is suitable for India’s dry vast tracks with limited irrigation. It requires minimum purchased inputs (Rs. 13,375-17,820/ha against Rs. 41,750-48,250/ha for sugarcane). The crop has a four-month cycle permitting two crops per year. Sugar beet has high sugar content and is grown in the temperate climate of Europe. With proper genetics and cultivation practices, a variation of sugar beet, called tropical sugar beet, can be grown in India. Both sweet sorghum and tropical sugar beet offer advantages over sugarcane as explained in table 8.

[10] Singh, J. P. (2004).
[11] Seetharama N. (2004).
[12] Gokhale D. (2004).

Table 8. Comparison of sugarcane, tropical sugar beet and sweet sorghum			
	Sugarcane	***Tropical Sugar Beet***	***Sweet Sorghum***
Crop duration	About 12 – 13 months	About 5 – 6 months	About 3 ½ months
Growing season	Only one season	Throughout the year (10 months), except rainy period	All season - Kharif, Rabi and summer
Soil requirement	Grows well in loamy soil	Grows well in sandy loam. Also tolerates alkalinity.	All types of drained soil
Water management	Requires water throughout the year	Less water requirement. 40 –60 per cent compared to sugarcane	Less water requirement. Can be grown as rain-fed crop.
Crop management	Requires good management. Low fertilizer required. Less pest and disease complex.	More fertilizer requirement. Requires moderate management.	Low fertilizer requirement and less pest and disease complex. Easy management.
	Sugarcane	***Tropical sugar beet***	***Sweet sorghum***
Yield per acre	25 to 30 tons	30 to 40 tons	20 to 25 tons
Sugar content on weight	8 to 12 per cent	15 to 18 per cent	8 to 10 per cent
Sugar yield	2.5-4.8 tons /acre	4.5-7.2 tons/acre	2-3 tons /acre
Ethanol production directly from juice	1700 to 2700 litre / acre	2800 to 4100 litre / acre	1140 to 1640 litre / acre
Harvesting	Difficult and laborious	Very simple. Both manual and with simple small mechanical machine can be used.	Very simple. Both manual and with simple small mechanical machine can be used.

Use of enzymatic fermentation of cellulose for ethanol manufacture[13]

Lignocellulosic materials such as straw and wood, which are often available as wastes, are much cheaper than grain. Converting them to ethanol, however, requires complex and costly processes. The development of exciting, new technologies has made it possible for lignocellulosic materials to become economic as ethanol feedstocks.

Lignocellulosic materials contain two types of polysaccharides, cellulose and hemicellulose, bound together by a third component, lignin. From the point of view of ethanol fermentation, they are hard to work with for two reasons. First, the lignin protects the cellulose and hemicellulose from attack by enzymes. Second, when enzymes do manage to reach the cellulose and hemicellulose, they are hindered by the crystalline structure of these molecules.

The raw material is first pre-treated at 150-200^{o}C with steam or acid/alkali to dissolve some of the hemicellulose. Then enzymes called cellulase and hemicellulase are added to convert the cellulose and hemicellulose to fermentable sugars in a process called hydrolysis. Finally, newly developed yeast strains are introduced to ferment the sugars to ethanol. The yeast Xymomonas,[14] which is produced by recombinant technology, converts the glucose obtained from cellulose and the xylose derived from hemicellulose to ethanol. The Canadian biotech firm, Iogen, is developing the first commercial plant to manufacture ethanol through enzymatic fermentation of lignocellulosic materials. Xymomonas will be used in the

---

[13] Riso National Laboratory, Denmark. (2004).
[14] National Renewable Energy Laboratory, (2001).

fermentation. The biggest cost component in the enzymatic fermentation process is the price of the enzymes cellulase and hemicellulase. Biotech firms like Genentech and Novozym are developing low cost enzymes so that the production cost of ethanol can be brought down to $1/gallon.

Improved methods of producing anhydrous ethanol

Fermentation produces a 10 per cent solution of ethanol in water. For use as a fuel, this solution has to be concentrated to 99.8 per cent ethanol (anhydrous) for blending with petrol. Just distilling an aqueous solution of ethanol gives a 95 per cent ethanol solution. This is an azeotropic solution, and any further regular distillation does not increase the concentration of ethanol because the composition of the vapour in an azeotropic solution is the same as that of the liquid. A 95 per cent ethanol solution can be used as a straight fuel. For producing anhydrous ethanol, the following processes are used:

- Azeotropic distillation;
- Extractive distillation;
- Pressure Swing Adsorption (PSA) based on molecular sieves; and
- Membrane separation.

The first two methods are more commonly used and represent older generation technologies. In azeotropic distillation, an entrainer like cyclohexane or benzene is added to decrease the relative volatility of ethanol. Ethanol is recovered at 99.8 per cent purity at the bottom of the azeotropic distillation column. The water/entrainer solution is taken off at the top, the entrainer is recovered and recycled back to the azeotropic distillation column. In extractive distillation, an extracting agent like ethylene glycol is added to extract the water from the solution. Anhydrous ethanol is recovered at the top of the column. The water/ethylene glycol solution is sent to a vacuum column where ethylene glycol is separated and returned to the extractive distillation column.

In PSA/molecular sieve technology, the 95 per cent ethanol solution is vapourized and sent through a bed of molecular sieves at high pressure. Ethanol is adsorbed on the molecular sieves, and water passes through. On reducing the pressure, the ethanol is desorbed from the sieves and recovered as anhydrous ethanol.

Membrane separation[15] appears to be the most energy efficient process for anhydrous ethanol. The membrane consists of a zeolite having a pore size of 0.4 nano meter (nm, 10^{-9} meter). The ethanol molecule has a size of 0.45 nm and gets trapped in the membrane, while the water molecule passes through since its size is 0.25 nm. The ethanol is recovered from the membrane pores.

The distillation methods suffer from high operating costs and problems associated with an additional chemical (an entrainer or an extractive agent). The controls are complex and the distillation columns are difficult to operate at low flow rates. The PSA/molecular sieve process suffers from unwanted by-product formation (adsorbents act as catalysts for ethers), frequent regeneration and high capital, installation, maintenance and operation costs. Membrane separation has the lowest operating cost, is flexible and simple to use, and is easy to expand and maintain. It is the most efficient and cost-effective option.

[15] Goel M. (2004).

The difficulties faced by ethanol industry and some solutions

The overwhelmingly dominant factor in the production of ethanol in India is the price and availability of molasses. The 2003-2004 season drought resulted in a lower sugarcane crop and consequently, a decreased availability of molasses. The sugar output dropped to 15 Mt (normal 21 Mt), molasses production sunk to 6.75 Mt (normal 10 Mt), and the ethanol manufacturing level decreased to 1,518 million litres (normal 2,000 million litres). This led to a huge increase in India's molasses import demand and a concomitant upward pressure on the price of molasses.

The dynamics of the molasses/ethanol industry may be better understood in terms of Indian control policies. The Central government sets the policy regarding ethanol blending, but the State governments control the movement of molasses and often restrict molasses transport over State boundaries. State governments also impose excise taxes on potable alcohol sales, a lucrative source of revenue. Foreign liquor imports[16] are taxed at 290 per cent thus affording domestic potable alcohol the highest protection of any commodity in the Indian market. As a result 29 per cent of the alcohol produced is earmarked for potable alcohol, the largest such ratio anywhere in the world. The price of molasses[17] was deregulated in 1993 and shot up to Rs. 4,000/ton as a result. Price control was re-established the following year for 70 per cent of the molasses produced, but wide fluctuations still continue.

In order to protect themselves from the vagaries of molasses price-fluctuation, the alcohol-based fuel industry is calling for futures trading of the commodity to be allowed. This would take away the spikes in the prices as well as smooth the price graph to more realistic levels.

As the government contemplates introducing futures trading in sugar, it makes sense to extend futures trading to molasses as well, says an industry source. Futures trading will introduce a level playing field for all market participants, as well as make the whole process more transparent, the source added.

Currently, ethanol manufacturing is only based on molasses. One ton of sugarcane yields about 100 kg sugar and 40 kg molasses out of which 10 litres of ethanol can be extracted. If sugarcane juice were allowed for direct use in ethanol, then one ton of sugarcane would yield 70 litres of ethanol. Allowing primary sugarcane juice (the juice extracted from the first-pass crush of the cane) or at least secondary sugarcane juice (after the second crush) for ethanol manufacture, affords sugarcane farmers more options. Thus when sugar stocks are high or the sugar price is depressed, the sugarcane farmer can divert some of the cane for ethanol manufacturing and thus minimize his loss in earnings.

Due to the low supply of ethanol in 2003-2004, the government mandated 5 per cent ethanol blending program has sputtered. The ethanol requirement for 5 per cent blending in the nine States where blending was mandatory was 363 million litres in 2003-2004, but the oil companies could only procure 196 million litres. Recognizing the difficulties due to high ethanol prices and low availability, the Government of India amended[18] its 5 per cent blending mandate with the notification that 5 per cent ethanol blended petrol shall be supplied in identified areas if: (a) the indigenous price of ethanol offered for ethanol blended petrol

[16] Indian Express Press Report (1998).
[17] Bhandari R. C. (1995).
[18] Ministry of Petroleum and Natural Gas (2004).

programme is comparable to that offered by the indigenous ethanol industry for alternative uses; (b) the indigenous delivery price of ethanol offered for the ethanol blended petrol programme at a particular location is comparable to the import parity price of petrol at that location; and (c) there is adequate supply of ethanol.

The supply and price of ethanol can be stabilised if the government, the private sector and other stakeholders utilize alternative feedstock production methods such as sweet sorghum and tropical sugar beet. Use of energy-efficient methods for anhydrous alcohol like pressure-swing adsorption or membrane separation can greatly reduce the manufacturing cost of ethanol. Distilleries closed due to low demand of alcohol-based chemicals should be revived. Allowing cross-state movement of molasses and permitting ethanol to be manufactured from sugarcane juice (at least secondary juice) instead of just molasses would also help bring the cost of ethanol production down. Last but not least, a consistent policy in which the Central and State governments work towards common goals should be promulgated.

The biodiesel industry in India

The centrepiece of India's plans for biodiesel development and commercialization is the National Biodiesel Mission, formulated by the Planning Commission of the Government of India. The implementation of the project consists of two phases. In Phase I a demonstration project that will be carried out between 2003-2007. The project involves the development of Jatropha oilseed nurseries, the cultivation of 400,000 hectares with Jatropha, the setting up of seed collection and Jatropha oil expression centres, and the installation of a 80,000 Mt/year transesterification to produce biodiesel from Jatropha oil. Phase II will consist of a self sustaining expansion of the programme leading to the production of biodiesel to meet 20 per cent of the country's diesel requirements by 2011-12.

Feedstock for India's biodiesel

Biodiesel is typically made from vegetable oil though animal fat can also be used. Rapeseed oil[19] has 82 per cent of the share of the world's biodiesel feedstock, followed by sunflower oil (10 per cent), soybean (5 per cent) and palm oil (3 per cent). The choice of feed is country specific and depends on availability. The United States uses soybean, Europe rapeseed and sunflower, Canada canola, Japan animal fat and Malaysia palm oil. In India, non-edible oil is most suitable as biodiesel feedstock since the demand for edible oil exceeds the domestic supply. It is estimated that the potential availability of such oils in India amounts to about 1 million tons per year;[20] the most abundant oil sources are sal oil (180,000 t), mahua (180,000 t), neem oil (100,000 t) and Pongamia Pinnata, also known as Karanja oil (55,000 t). However, based on extensive research carried out in agricultural research centres, it was decided to use Jatropha Curcas oilseed as the major feedstock for India's biodiesel programme. Jatropha was originally developed in Central America and is a tree-borne oilseed which grows in dry, arid land.

[19] Riso National Laboratory, Denmark. *Riso Energy Report* 2 (2004).
[20] Mittelbach, M. and C. Remschmidt (2004, p.24).

Advantages of using Jatropha Curcas[21]

- The oil yield per hectare for Jatropha is among the highest for tree-borne oil seeds. The seed production ranges from about 0.4 tons per hectare per year to over 12 t/ha. There are reports of oil yields as high as 50 per cent from the seed. Typically, the seed production would be 3.75 t/ha, with an oil yield of 30-35 per cent, giving a net oil yield of about 1.2 t/ha.
- It can be grown in areas of low rainfall (200 mm per year), on low fertility, marginal, degraded, fallow and waste lands. Canals, roads railway tracks, borders of farmers' fields as a boundary fence/hedge in arid areas and even alkaline soils are appropriate for the crop.
- Jatropha is easily established in nurseries, grows relatively quickly and is hardy.
- Jatropha seeds are easy to collect as they are ready to be plucked before the rainy season and as the plants are not very tall.
- Jatropha is not browsed by animals.
- Being rich in nitrogen, the seed cake is an excellent source of plant nutrients.

Properties of Jatropha Oil

The component analysis[22] of Jatropha seeds (wt per cent) is as follows: moisture 6.2 per cent, protein 18 per cent, fat 38 per cent, carbohydrate 17 per cent, fibre 15.5 per cent, and ash 5.3 per cent. Jatropha oil mainly consists of tri-glycerides[23] of oleic acid (34-45 per cent), linoleic acid (31-43 per cent) and palmitic acid (14-15 per cent). The characteristics of raw Jatropha oil and transesterified Jatropha oil (biodiesel) are given below:

Table 9. Characteristics of raw versus transesterified Jatropha oil

	Jatropha oil, raw	Jatropha oil, transesterified
Density, g cm^{-3} at 20^{o}C	0.920	0.879
Flash point, ^{o}C	236	191
Cetane number, ISO 5165	23-41	51-52
Viscosity, mm^2/s at 30^{o}C	52	4.84
Neutralization number, mg KOH/g	0.92	0.24
Total glycerin, per cent		0.088
Free glycerin		0.015
Sulfur content, ppm		0-13
Sulfated ash, per cent		0.014
Methanol, per cent		0.06

Source: Pramanik, T. and S. Tripathi, 2005.

21 Planning Commission (2003).
22 Pramanik, T. and S. Tripathi, *Hydrocarbon Processing* (2005).
23 Mittelbach, M. and C. Remschmidt (2004).

Economics of biodiesel production from Jatropha

Table 10 gives a summary of the cost of biodiesel production.

Table 10. Summary of cost of biodiesel production			
	Rate (Rs./kg)	Quantity (kg)	Cost (Rs.)
Seed	5.00	3.28	Rs. 16.40
Cost of collection and oil extraction	2.36	1.05	Rs. 2.48
Less cake produced	1.00	2.23	-Rs. 2.23
Transesterification cost	6.67	1.00	Rs. 6.67
Less cost of glycerol produced	40 to 60	0.095	-Rs. 3.80 to -Rs. 5.70
Cost of biodiesel per kg			Rs. 19.52 – 17.62
Cost of biodiesel per litre (specific gravity of 0.85)			Rs. 16.59-14.98

Source: Planning Commission, 2003.

Processing large quantities of oil and the consequent production of glycerol will likely depress the price of glycerol. If new applications are found to create additional demand for glycerol, its price could be stabilized. The above table shows that the cost of the feed material is the dominating factor in determining the production cost of biodiesel. Even if we neglect the credit for glycerol recovery and sale, the cost of biodiesel from Jatropha oil at Rs. 21/litre ($0.47/litre) is very competitive with the manufacturing cost of petroleum diesel.

Manufacturing process for biodiesel

The most economical process for biodiesel manufacture is transesterification of vegetable oil by an alcohol, usually methanol. The chemical reaction is shown below and is commonly catalysed by an alkali such as potassium hydroxide. Methanol is preferred over ethanol because the costlier anhydrous ethanol is required instead of the readily available 95 per cent ethanol. The presence of water in 95 per cent ethanol drastically brings down the conversion of vegetable oil. Also the ethyl esters (biodiesel) are more soluble in the by-product glycerol, making purification of the biodiesel product more difficult. An alkaline catalyst like potassium hydroxide is preferred to an acid catalyst because the latter necessitates a higher reaction temperature, a greater reaction time, and is more corrosive. Acid catalysts are used when there is free-fatty acid in the oil, as in animal fats. Jatropha oil contains very little free fatty acids.

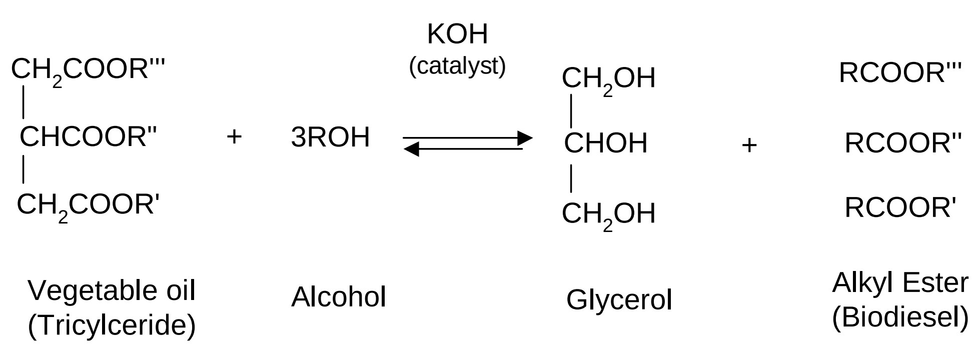
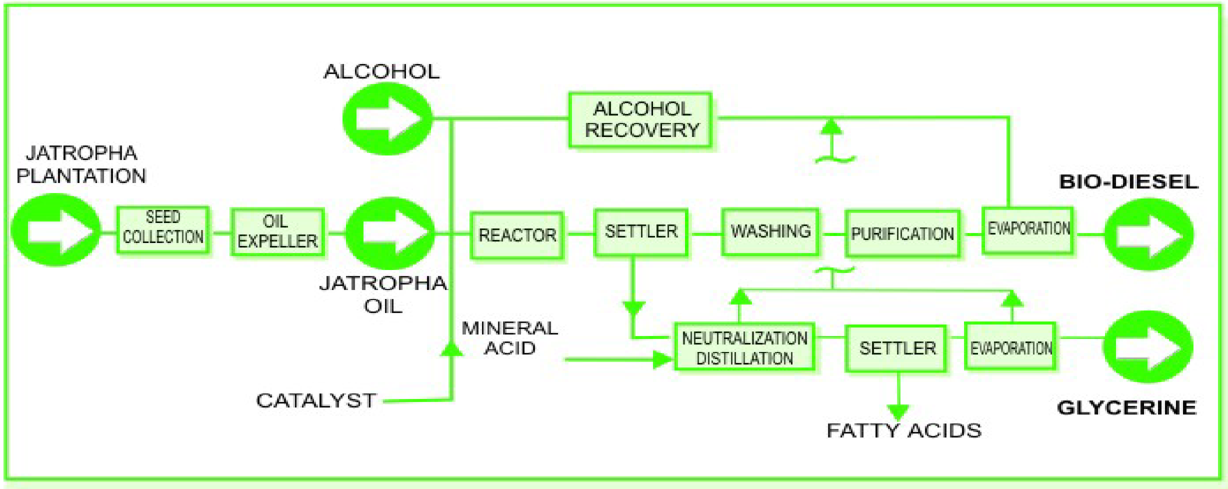


Figure 2 shows the process flow diagram for the manufacture of biodiesel.

Figure 2. Production of biodiesel using Jatropha feedstock



National biodiesel mission – Phase I demonstration project (2003-2007)

The Demonstration Project has the following objectives:

- To lay the foundation for a fast-growing and self-sustaining people and enterprise-driven programme of biodiesel production in the country.
- To produce enough seed for the production of biodiesel.
- To test, develop and demonstrate the viability of all the programme components and estimate the costs and varied benefits of all its forward and backward linkages.
- To inform and educate the potential participants of the programme.

The government will act as the prime mover. It will ensure that the necessary resources are arranged for each of the components, the stakeholders are fully involved in the project and that all components and activities of the national mission are properly planned and implemented.

The following are the aspects of the Phase I Demonstration Project:[24]

- Plantation area coverage;
- Nurseries development;
- Seed collection and oil extraction centres;
- Transesterification plant;
- Blending and marketing; and
- Financial requirement.

[24] Planning Commission (2003).

Plantation area coverage

This will involve 400,000 hectares of plantations in compact districts, each with an area of 50,000 to 60,000 hectares; it will also ensure that facilities are established for all the activities involved in forward and backward linkages. A total of eight compact areas are proposed: four in forest areas (in the States of Gujarat, Chhattisgarh, Tamil Nadu and Manipura); and another four in non-forest lands. These non-forest lands are around Allahabad (Uttar Pradesh), Ujjain (Madhya Pradesh), Nasik (Maharashtra) and in Andhra Pradesh. Non-forest land plantations would include marginal lands of farmers, fencing of farmers fields, public lands along roads and highways, canals and railway tracks. These plantations will be established by NGOs, self-help and user groups, cooperatives and the public and private sectors. The Ministry of Forests and Environment (MoEF) and the National Oilseed and Vegetable Oil Development (NOVOD) Board will serve as responsible agencies for the cultivation in the forest and non-forest areas, respectively by providing the necessary information and financial assistance.

Nurseries development

The government plan will also establish nurseries to supply plants to the beneficiary to ensure success of plantations and quick returns. The nurseries will also result in seed production at the end of the first year. A nursery will produce 2 million plants a year. Hence, over a period of three years it will produce 6 million plants, sufficient to cover 2,000 hectares. About 1,500 nurseries will be required for the non-forest planting areas and about 1,000 nurseries for forest areas.

Establishment of seed procurement and oil extraction centres

Assuming an oilseed yield of 3.75 t/ha/year, a cultivation area of 2,000 hectares will produce 7,500 t/year of jatropha oilseeds, all of which can be assigned one seed collection and oil extraction centre. An expeller with a seed-crushing capacity of 1 ton/hr is well-suited to extract oil from 7,500 tons of oilseeds a year. The cost of such an expeller is Rs. 300,000. An integrated procurement and oil extraction centre will employ about eight persons throughout the year.

Transesterification plant

The plan for the demonstration project calls for the installation of an 80,000 t/year biodiesel plant. The cost of the plant is estimated to be Rs. 700-750 million. On the other hand, with the current state of technology, a skid-mounted plant having a capacity of 9,000 t/year can be easily installed and quickly readied for operation mode. A 9,000 t/year plant can be served by four 7,500 t/year seed-collection and oil extraction centres.

Blending and marketing

Oil companies and other private sector firms, under the guidance of the Ministry of Petroleum, will take the lead in developing the blending and marketing of biodiesel.

Financial requirement of the demonstration project

The financial requirement of the demonstration project has been estimated at Rs. 14,960 million as shown in Table 11. This includes a government contribution of Rs. 13,840 million consisting of Rs. 12,000 million for nursery, plantation and protection, which has to be provided by the government as a promotional measure as well as the administrative expenses of Rs. 680 million and R&D expenses of an equal amount. For setting up seed collection and oil extraction units, the funds could be a mix of entrepreneurs' own contribution of Rs. 160 million (margin money), a subsidy from the government of Rs. 480 million and a loan of Rs. 960 million from the National Bank of Agricultural and Rural Development (NABARD) in the ratio of 10:30:60. The transesterification unit will be a commercial venture involving relatively large sum of money, estimated at Rs. 750 million. Oil companies guided by the Ministry of Petroleum are expected to encourage the private sector to set up such plants with financing from financial institutions; but the funds for R&D would be contributed by the government, oil companies, automobile manufacturers associations and petroleum companies.

Table 11. Financial requirement for demonstration project (millions of rupees)

Component	2003	2004	2005	2006	2007	Total
Nursery	960	1 920	1 920	0	0	4 800
Plantation	1 040	2 080	2 080	0	0	5 200
Protection	0	400	800	800	0	2 000
Seed expeller centres @ Rs. 8 million / centre	0	48	176	320	1 056	1 600
Sub-total	2 000	4 448	4 976	1 120	1 056	13 600
Component	**2003**	**2004**	**2005**	**2006**	**2007**	**Total**
Administrative expenditure @ 5 per cent	100	224	248	56	52.8	680.8
R and D @ 5 per cent	100	224	248	56	52.8	680.8
Grand total	2 200	4 896	5 472	1 232	1 161.6	14 961.6

Source: Planning Commission (2003).

National biodiesel mission – Phase 2 (2007-2012)

Phase II of the National Mission will aim to produce sufficient vegetable oil-based biodiesel to achieve 20 per cent blending. It plans to accomplish this through accelerating the momentum achieved in the demonstration project, converting plantation into a mass movement all over the country. It will begin in 2007 and completed during the XI Plan (2007-2012). The success of the demonstration project is expected to galvanize all the stakeholders and participants to mobilize resources with the government as facilitator.

Issues confronting biodiesel programme

One of the main problems in getting the biodiesel programme rolling is the difficulty linked to initiating large-scale cultivation of Jatropha. Farmers do not yet consider Jatropha cultivation remunerative enough. For instance, sugarcane plantations yield 70 t/ha and fetch the farmer Rs. 70,000/ha at a sugarcane price of Rs. 1,000/t. In comparison, if the Jatropha farmer gets Rs. 5,000 per ton of oilseeds and if the yield is 3.75 t/ha, his income is only Rs. 18,750 per hectare.

The other main issue is the lack of seed collection and oil extraction infrastructure. In the absence of this infrastructure and available oilseeds, it will be difficult to persuade entrepreneurs to install transesterification plants. Finally, there is the problem of glycerol utilization. The by-product glycerol is about 12 per cent of the biodiesel produced and is of about 88 per cent purity. If alternative means are not quickly found for utilizing glycerol, then its price will plummet due to excess supply.

***Problems cited by farmers in Jatropha cultivation*[25]**

The following problems have been cited by farmers regarding Jatropha cultivation:

1. Lack of confidence in farmers due to the delay in notifying, publicizing and explaining the government biodiesel policy.
2. No minimum support price.
3. In the absence of long-term purchase contracts, there are no buy-back arrangements or purchase centres for Jatropha plantations.
4. Lack of availability certified seeds of higher yield containing higher oil content.
5. No announcement of incentives/subsidy and other benefits proposed to be provided to farmers.

Solutions to farmers' problems

The government needs to take confidence-building measures and clearly formulate its policy and explain to farmers that their role is vitally important in the success of the biodiesel programme. Financial assistance should be given to NGOs in developing a large-scale awareness/training program for farmers. The government should arrange tours for reputable NGOs and progressive farmers to other countries/States to enable them to witness the success of biodiesel production first-hand.

The government should establish a minimum support price for Jatropha just as it did for sugarcane and farmers assured of timely government payments. The government should also guarantee a buy-back programme for limited periods when prices reach distress levels. Lastly, the government should supply high-quality certified seeds to farmers, either free of charge or at subsidized rates.

[25] Dhanda, K. S. (2004).

Easy loan facilities should be provided to unemployed rural youths for the establishment of oil expellers and oil extraction plants and collection centres at minimum interest rates and without collateral security.

Disposal of glycerol

Glycerol is the by-product of vegetable oil transesterification. The amount of glycerol produced is about 12 per cent of the weight of the biodiesel formed. The worldwide consumption of glycerol (1995 data) is as follows:

Table 12. Use of glycerol worldwide

	Application	Amount, tons
1	Cosmetic, soap, pharmaceuticals	202 000
2	Alkyd resins	43 800
3	Food and drinks	57 700
4	Polyglycerols	89 000
5	Tobacco	25 500
6	Cellulose films	35 500
7	Esters	93 400
8	Paper	7 300
9	Nitrates	2 900
10	Resale	103 700
11	Others	69 500
	Total	733 000

Source: Kale, V. 2004

Current production of biodiesel is about 2,500,000 tons and is soon expected to reach 3,000,000 tons. At 12 per cent, 360,000 tons of additional glycerol would be available, almost half the present requirement. New applications like biosurfactants and biopolymers are expected to use some of the new supply, but if the oversupply still remains, the price of glycerol could experience a sharp fall.

Biodiesel development in India

The following is an overview of the work being carried out on biodiesel development in India:[26]

- Development of high oil-yielding varieties of Jatropha by the Department of Biotechnology, the Aditya Biotech Research Cente (Raipur), the Indira Gandhi Agriculture University (Raipur) and the Bhabha Atomic Research Centre (Trombay).

- Plantation of Jatropha and Pongammia Pinnata (Karanja) by:

    - The National Afforestation and Eco-development Board (NAEB) under the guidance of the Ministry of Environment and Forests;
    - The National Oilseed and Vegetable Oil Development (NOVOD) Board under the guidance of the Ministry of Agriculture;
    - The Central Salt and Marine Chemicals Research Institute (Bhavnagar);

[26]Mandal, R. (2004).

- A number of NGOs such as Uthan (Allahabad), Sutra (Karnataka); the Institute of Agriculture and Environment (Jind, Haryana); the Bharatiya Agro Industries Foundation (BAIF) Development (Pune, Maharastra); Pan Horti Consultants (Coimbatore); Classic Jatropha Oil (Coimbatore); and Renulakshmi Agro Industries (Coimbatore), etc.

- Pilot plants on transesterification set up by Indian Oil Corporation (R&D), Faridabad; the Indian Institute of Technology (IIT), Delhi; the Punjab Agricultural University (PAU), Ludhiana; the Indian Institute of Chemicals Technology (IICT), Hyderabad; the Indian Institute of Petroleum (IIP), Dehradun; the Indian Institute of Science (IIS), Bangalore; and Southern Railways, Chennai.

- Trial runs on variety of transport modes using 5 per cent biodiesel blends, including:

  - Railways (a locomotive used biodiesel on a regularly scheduled train ride – the Shatabdi Express – from Amritsar to Delhi on 31 December 2002);
  - Tractors tested by Mahindra & Mahindra Co.;
  - Mercedes cars tested on Daimler Chrysler;
  - Public transport buses tested by Haryana Roadways and Bombay Electric Supply and Transport (BEST); and
  - In addition, trial marketing of 5 per cent diesel blends through some retail outlets is being conducted by the oil company Bharat Petroleum Corporation Limited (BPCL).

- Draft biodiesel policies are already being framed by the State Governments of Andhra Pradesh, Tamil Nadu, Chattisgarh and Uttar Pradesh.

- Awareness-raising seminars/conferences organized by NGOs and business groups such as Winrock International India; the Confederation of Indian Industries (CII); Uthan, Centre for Bharatiya Marketing Development (CBMD); and the Panchatatva Garima Foundation.

The current status of commercial biodiesel production in India

Commercial biodiesel production has not yet started in India. However, two companies have already secured financing and are well on the way to setting up transesterification plants:

1. Naturol Bioenergy Limited[27] (NBL), a joint venture with Energea Gmbh (Austria) and Fe Clean Energy (United States) plans on building a 300 t/day (about 90,000 t/year) plant in Kakinada, Andhra Pradesh. Energea is a leading technology supplier in biodiesel and has built several plants in Europe. Fe Clean, a private equity fund dedicated to clean energy projects would finance the project. The cost of the project, which is close to financial closure, is estimated at Rs. 1,400 million. According to NBL's Managing Director, the Industrial Development Bank of India (IDBI) has agreed to fund Rs 330 million after completing due diligence of the project. Other bodies include Andhra Bank, the State Bank of India, the National Bank for Agriculture and Rural Development and Infrastructure Development and Finance Company have shown interest for debt financing of the project. NBL is at an

[27] The Hindu Business Line (2005).

advanced stage of discussions with other companies for equity participation. The company had also requested IDBI to lead the consortium of financial institutions for financial closure of the project. Construction is expected to begin in 2005 and biodiesel production will start in 2006 or 2007.

NBL has been allocated 120,000 hectares for Jatropha cultivation. Since it might take a few years for the crop to bear fruit, NBL may, in the meantime, be obliged to procure the oilseeds from other sources.

2. Southern Online Biotechnologies[28] plans on installing a 30 t/day (9,000 t/year) biodiesel plant also in Andhra Pradesh. The project is seeking approval from the CDM Executive Board. Details on the project are given in the next section. The project claims a carbon emission reduction of 26,792 tons of CO_2 equivalent a year, and at an estimated price of $4 per ton of CO_2 reduction, the annual CDM revenue is expected to be about $108,000.

   Feedstock will be Pogammia Pinnata/Jatropha grown on 1,000 hectares of wasteland. This cultivation will yield 6,000 tons of vegetable oil. About 9,500 tons of vegetable oil is required for 9,000 tons of biodiesel, and the difference will be made up by animal fat.

   The cost of the project is estimated at Rs. 171 million, which will be raised through issuing shares. Biodiesel production is expected to start in 2006. Implementation of the project will be entrusted to Chemical Construction International Ltd. (CCIL), a New Delhi-based engineering and technology company. CCIL has an exclusive technical collaboration with Lurgi Life Sciences of Germany, a leader in fatty acids, glycerol and biodiesel technologies

The following two projects are in the very early stages of planning: A new plant of 5 t/day capacity is slated for construction by Alagarh Industries[29] in Sivakasi (Tamil Nadu) and D1 Oils India[30] is planning to build a 24 t/day plant.

---

[28] Biodiesel production and switching fossil fuels from petrol-diesel to biodiesel in transport sector - 30 TPD Biodiesel CDM Project in Andhra Pradesh, India. The project design document available at: http://cdm.unfccc.int/UserManagement/FileStorage/FS_686206579

[29] NDTV.com press release, "Biodiesel cleared for commercial production". The press release can be accessed at: http://www.ndtv.com/environment/Ecoinitiatives.asp?id=56232&callid=1

[30] D1 Oils – Growing Energy Solutions. Can be accessed at http://www.d1plc.com.

CDM biodiesel project in Andhra Pradesh

Southern Online Biotechnologies[31] aims to set up a biodiesel manufacturing plant in Samsthan Nayanapur Village, about 50 km from Hyderabad in the southern India, State of Andhra Pradesh. The plant will have a capacity of 30 t/day or 9,000 t/year. This is the first biodiesel project from India seeking approval from the CDM Executive Board. The project has already secured host country approval from the Ministry of Environment and Forests, which is the Designated National Authority (DNA) for India.

Feedstock

The project will use vegetable oil from Pongamia Pinnata/Jatropha oilseed grown on 1,000 hectares of wasteland around the project site as feedstock. Project proponents will provide 600,000 seedlings free of charge to local farmers for planting. Pongamia Pinnata will take five years to bear fruit. When in full bloom, the trees will yield 15,000 kg/ha of oilseed and up to 3,000 persons will be employed in seed collection. The oilseeds will provide about 6,000 t/year vegetable oil out of the 10,000 t/year required for the normal output of 9,000 tons of biodiesel per year. The remainder will be obtained from animal fat. The transesterification plant will employ 100 persons when fully operational and 60 people in the installation and commissioning phases.

Technology implementation

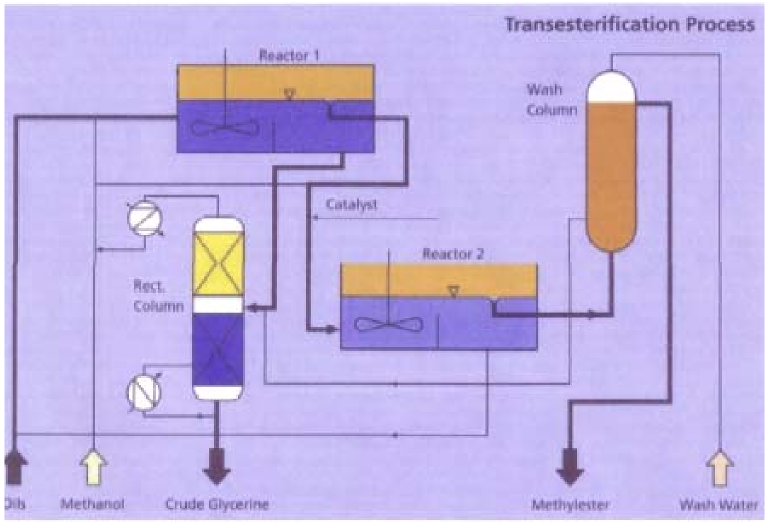
CCIL is in charge of implementing the project. Earlier, under Lurgi's technical supervision, CCIL implemented several fatty acids and glycerol processing plants in India. In this way, Lurgi's biodiesel technology flows to India through CCIL. No direct technology transfer agreement exists between the project proponents and Lurgi.

Technology description

The technology of biodiesel manufacturing involves pretreatment of raw oils, acid oils/fats, esterification/transesterification using methanol/ethanol and chemical catalysts and then finally washing and drying to obtain the biodiesel. A block diagram showing the proposed process is shown below.

[31] Please refer to footnote 28.

Figure 3. Process block diagramme for transesterification



Project operation and crediting period

The project will operate at 70 per cent capacity during the first year and at 100 per cent from year two onwards. The carbon emission reduction crediting periods are organized into three seven-year intervals, for a total of 21 years.

Project cost and financing

The capital cost to be raised through issuance of shares is estimated at Rs. 171 million.

Project status

The transesterification plant construction and commissioning is expected to be completed in late 2005. Availability of feedstock is the biggest factor affecting the start of operations. Since it will take five years for the Pongamia Pinnata trees to grow and produce seeds, the initial oil feedstock has to be procured from Jatropha or animal fats. In the case of feed from animal fats, additional pre-treatment is necessary to neutralize the free fatty acids present in fats, otherwise these acids will react with the alkaline catalyst and adversely affect the transesterification process. Approval from the CDM Executive Board for certified emission reductions is expected soon.

Carbon dioxide emission reduction

An annual estimate of emission reductions, in tons of CO_2 equivalent due to the project is furnished below for the first seven years of the crediting period:

Year	2005	2006	2007	2008	2009	2010	2011
Emission Reduction, (ton CO_{2eq})	20 842	26 792	26 792	26 792	26 792	26 792	26 792

Trade in biofuels

Paragraph 31(iii) of the Doha Ministerial Declaration encourages negotiations on "the reduction or, as appropriate, elimination of tariff or non-tariff barriers to environmental goods and services" (EGS). Biofuels derived from sustainable agricultural practices have many attributes that qualify them as EGS. They are easily transported and stored, and thus tradable; they are environmentally preferable; and with lower production costs, they compete favourably with petrol and petroleum diesel. They will be important in the successful implementation of economic development strategies. Modern energy is essential for economic advancement and poverty alleviation - key elements of the Millennium Development Goals - particularly when oil prices are hovering around $55 per barrel.

It is becoming increasingly evident that ethanol and biodiesel are going to play crucial roles in India's energy plans. In spite of the government's plans to produce these biofuels domestically, India may have to rely on foreign imports to meet some of their demands. To establish biofuel trade, the infrastructure for biofuel transport, store, blend and distribute biofuel must be created from scratch. The following are some of the key issues related to the trade in ethanol and biodiesel in India.

Trade in ethanol

The data in Table 6 show that the amount of ethanol available (in the column "balance") will potentially be able to meet the demand for 5 per cent blending after satisfying the requirements for potable and industrial use, even in 2016-2017. It is important to note, however, that India is currently the world's largest consumer of sugar. The average per capita consumption of sugar is estimated at 18.3 kg/year in the year 2002-2003[32]. Based on this existing trend, this is estimated to increase to 23-24 kg/year by year 2010. At an annual population growth rate of 1.6 per cent per annum, India's population is expected to be 1,160 million by 2010 and will need an estimated 24.3 million tons of sugar. To achieve this, sugarcane needs to be cultivated on an area of about 5.5 million hectares, with an average yield of 65 t/ha. As the increase in area of the sugarcane from the present 4.36 to 5.5 million hectares may not be possible due to other competing crops, it becomes necessary to improve the productivity and yield of sugarcane and sugar recovery. Thus, the sugar industry will be heavily burdened to meet the demand for sugar, let alone the demand for ethanol.

Considering the uncertainty in sugar production due to the dependence of the sugarcane crop on the monsoon, ethanol demand for 5 per cent blending might not always be met. For instance, the 2003-2004 drought meant that only 196 million of the 363 million ethanol litres required for 5 per cent blending in the nine mandated States was available (see section on "Difficulties in the Ethanol Industry"). Even under the conditions of Table 6, meeting the demand for 20 per cent ethanol blending will probably not be possible from domestic production alone. India will most likely become a net importer of ethanol if it is blended with gasoline at 20 per cent or even 10 per cent.

Brazil is the world's largest producer of ethanol from sugarcane; 55 and 45 per cent of the sugarcane processed by the country's agroindustry is for ethanol and sugar, respectively. Brazil's annual ethanol production is about 16,000 million litres; the country's biggest

[32]Please see Sugar Report, footnote 8.

exporter of ethanol at about 2,000 million litres per year. Other countries with ethanol export capacity are Jamaica and Costa Rica. China is a big sugar producer, but its ethanol production is meant for domestic consumption.

Table 13. Ethanol exports from major exporters in million litres							
Year	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Brazil	120	413	230	323	755	707	2,265
Jamaica	6	68	131	122	120	N/A	N/A
Costa Rica	58	56	32	82	29	36	N/A
Nicaragua	14	22	22	15	17	13	18
Mexico	N/A	19	53	22	7	7	N/A
Cuba	N/A	0.002	7	18	N/A	N/A	N/A

Source: United Nations commodity trade database, http://unstats.un.org/unsd

Table 13 shows the dominance of Brazil in the ethanol export market. The ethanol data retrieved from the United Nations commodity trade database was classified as commodity 220710 – ethyl alcohol, un-denatured, at least 80 per cent by volume. Commodity code 220710 most closely describes the ethanol for blending with petrol.

Brazil ethanol export to India in 2002 was 9.54 million litres valued at $1,349 million ($0.14/litre) and 447 million litres in 2004 valued at $86 million ($0.19/litre). Thus, when India's domestic production of ethanol dropped in 2003-2004 due to low sugarcane output, the country was able to import a substantial amount from Brazil.

Table 14 gives the molasses exports from leading exporters. Note that Brazil, because of its high distillation capacity (over 16,000 million litres of ethanol annually), does not export much molasses. The biggest exporters are Thailand at 1.3 million tons per year in 2003 and Mexico at 0.26 million tons. Thailand is aggressively stepping up distillation capacity with eight new ethanol plants[33] to be installed by 2004. Ethanol production would then go to up to 495 million litres a year out of which 165 million litres would be exported.

Table 14. Molasses exports from major exporters in million tons						
Year	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**
Thailand	0.617	1.010	1.413	N/A	1.326	N/A
Mexico	0.384	0.327	0.365	0.357	0.257	N/A
India	0.130	0.428	0.221	0.208	0.099	N/A
Cuba	0.131	0.161	0.032	N/A	N/A	N/A
Brazil			0.000	0.115	0.130	0.056

Source: United Nations commodity trade database, http://unstats.un.org/unsd

Trade in ethanol can thus play an important part in helping countries meet their ethanol requirements. While a country like India can stimulate domestic production by offering incentives to domestic producers, the trade policies do not have to be protectionist, but rather can spur domestic growth.

[33] All India Distillers Association. "Thailand grants licenses for eight companies to build ethanol plants". Available at http://www.aidaindia.org/aida/may-sep/indexmay_sep.htm

Trade in biodiesel

No data is currently available on trade in biodiesel. The big biodiesel manufacturing countries like Germany, France and Italy are utilizing their production for domestic consumption. Trade data is available for the following oilseeds:[34]

HS96	Description
120300	Copra
120400	Linseed
120500	Rape or colza seeds
120600	Sunflower seeds
120730	Castor oilseeds

However, this data refers to the manufacturing of edible vegetable oil, not biodiesel. Table 1 shows that in 2011-2012, 3.35 Mt of biodiesel will be required to meet 5 per cent blending standards nationally. Given that commercial production of biodiesel has not yet started, India might find it difficult to produce biodiesel for 5 per cent blending let alone 20 per cent by the year 2011-2012. Biodiesel imports could be used to bridge the gap between demand and domestic supply. As an alternative to biodiesel import, oilseeds or vegetable oil could be imported as feedstock for biodiesel manufacture.

[34] UNCTAD Secretariat, June 2005.

Conclusions

The two biofuels discussed in this paper, ethanol and biodiesel, will play an extremely important role in meeting India's energy needs. The current manufacturing cost of ethanol and biodiesel in India is about Rs. 21/litre ($0.46/litre), about the same as petrol and diesel. This puts biofuels in a favourable position, especially as the cost of petroleum is expected to continue its upward trend. Biofuels offer several significant benefits including:

- Reduced emission of pollutants such as carbon monoxide, unburnt hydrocarbons, particulate matter, polycyclic aromatic hydrocarbons (PAH) and nitrated PAH. Biofuels contain virtually no sulphur.
- Reduced emission of the greenhouse gas carbon dioxide, which contributes to global warming. For every ton of petrol or diesel substituted by ethanol or biodiesel, the net emitted carbon dioxide is reduced by about 3 tons.
- Increased employment. Every $11,000 invested in the ethanol industry produces a job, as compared to $220,000 in the petroleum industry. By 2007, the first phase of the National Biodiesel Mission will generate an estimated 127.6 million person days to plant, 36.8 million person days to collect seeds and 3,680 person years for running the seed collection and oil-extraction centres.
- Energy security and decreased dependence on oil imports by diversifying energy supply.
- 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 biofuels in rural areas is closely linked to poverty reduction as greater access to energy services can:
    - improve access to pumped drinking water;
    - reduce the time spent by women and children on basic survival activities (gathering firewood, fetching water, cooking, etc);
    - allow lighting for increased security and the night time use of educational media in school and home study; and
    - reduce indoor pollution caused by firewood use, together with a reduction in deforestation.
- Increased nutrients to the soil and decreased soil erosion and land degradation resulting from the cultivation of biofuel feedstock crops.
- Good fuel properties. The octane number of ethanol is 120, much higher than that of petrol, which is between 87 and 98. The cetane number of biodiesel is at least 51.

Ethanol is produced in India by the fermentation of molasses, which is a by-product of sugar manufacturing. Currently, India and Brazil are the world's largest sugar producers, each at about 21 million tons a year. India has 4.36 million hectares of land under sugarcane cultivation, with a cane output of about 310 million tons per year. The normal annual ethanol output is 1,900 million litres and the distillation capacity is 2,900 million litres per year. India is the fourth largest ethanol producer after Brazil, the United States and China. India's petrol demand is expected to be 10.07 million tons in 2006-2007, rising to 12.85 million tons in 2011-2012. At 5 per cent ethanol in petrol, the demand for ethanol blending would be 640 million litres in 2006-2007 and 810 million litres in 2011-2012. This demand may potentially be satisfied with current capacity after meeting the requirements for potable alcohol and ethanol needed in chemicals manufacture. The Government of India made 5 per cent ethanol blending in petrol mandatory in nine sugarcane growing states, effective 1 January 2003.

India is not as efficient an ethanol producer compared to Brazil and the United States. For instance, the cost of ethanol production in Brazil is $0.20-$0.30/litre, substantially less than the $0.40/litre in India. Sugarcane yield can be improved by incorporating more efficient agricultural practices like inter-cropping with other crops, biopest control, use of biofertilizer, integrated weed management and the deployment of mechanized farming. The use of energy-efficient ethanol dehydration methods like pressure-swing adsorption and membrane separation can also reduce production costs.

The government needs to reform restrictive policies to loosen constraints on ethanol production. For instance, the ban on cross-state movement of molasses should be removed. Ethanol distilleries should be allowed to use sugarcane juice instead of just molasses for ethanol manufacture. When sugar prices are depressed, this would permit sugarcane farmers to divert some of the sugarcane to ethanol production, thus bringing extra income to the farmers. In addition, state and central government policies should be harmonized. State governments stand to gain windfall revenue from excise tax on potable ethanol and would hence prefer a substantial portion of the ethanol production to be earmarked for potable use. However, the central government is charged with energy policy and the procurement of ethanol for blending. Also the wide fluctuations in the price of molasses, which is the main determining factor in the cost of ethanol, should be brought under control. In order to protect itself from the volatilities of molasses prices, the alcohol-based industry is demanding that futures trading be allowed for the commodity. This would take away the spikes in the prices, as well as smooth the price graph to more realistic levels.

India is now the world’s largest sugar consumer, and this has put added pressure on the ethanol industry. Thus, when sugar production dropped to 15 million tons in 2003-2004, only 196 million litres of the required 363 million litres of ethanol could be produced, causing a temporary derailment of the 5 per cent petrol blending programme. Alternate feedstock crops are needed. As agricultural research has amply demonstrated, sweet sorghum and tropical sugar beet could be grown as cost-effective feedstock crops instead of sugarcane. Furthermore, exciting new biotechnology involving enzymatic saccharification and fermentation has made it possible to use readily available cellulosic material such as wood and crop residue for ethanol production. This breakthrough technology is about to be commercialized on a large scale.

If there is a shortfall in ethanol supply due to a poor sugarcane crop year or an increased demand because of a 10 or 20 per cent ethanol blending requirement, ethanol imports can fill in the supply gap. In 2004, India imported 447 million litres from Brazil. Trade in ethanol can thus play an important part in helping countries meet their ethanol requirements. While a country like India can stimulate domestic production by offering incentives to domestic producers, the trade policies do not have to be protectionist, but rather can spur domestic growth.

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. The chosen biodiesel technology is the transesterification of vegetable oil. The cornerstone of the biodiesel programme is the government’s ambitious National Biodiesel Mission 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 raw material for biodiesel. Extensive research has shown that Jatropha Curcas offers the following advantages: it requires little water and fertilizer to cultivate, not browsed by cattle or sheep, pest resistant, easy propagation, low gestation period, high-seed yield and oil content and its capacity to produce high protein manure. The National Biodiesel Mission will be implemented in two stages:

1) A demonstration project carried out between 2003-2007 to cultivate 400,000 hectares of land, yielding about 3.75 tons oilseed per hectare per annum. The project will also demonstrate the viability of seed collection and oil extraction, as well as construct a transesterification plant.
2) A commercialization period during 2007-2012 will further cultivate Jatropha and install more transesterification plants to position India to meet 20 per cent of its diesel needs through biodiesel.

The work done up to now in biodiesel development includes: development of high oil-yielding varieties of Jatropha; plantation of Jatropha by government-sponsored agencies; setting up of pilot plants on transesterification; successful trial runs on locomotives and road vehicles using 5 per cent biodiesel blend; and organizing seminars to expand awareness of the biodiesel programme.

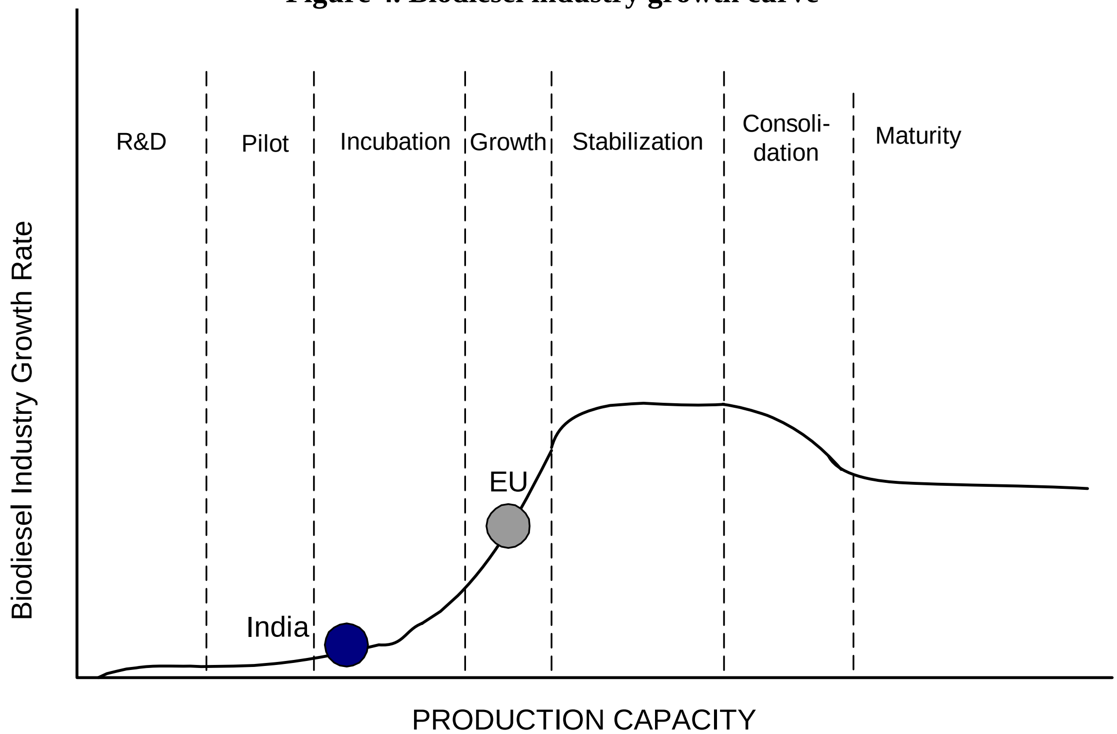
So far no commercial transesterification plants have been installed. However two plant projects have secured financial backing and are on their way to implementation. Naturol Bioenergy Limited, a joint venture between Energea Gmbh and Fe Clean Energy, plans to set up a 300 t/day (90,000 t/year) biodiesel plant near Kakinada, Andhra Pradesh. Southern Online Biotechnologies is setting up a 30 t/day plant also in Andhra Pradesh. Both plants are expected to come onstream in 2006.

The main problem in getting the biodiesel programme rolling has been the difficulty in initiating the large-scale cultivation of Jatropha. Farmers do not consider Jatropha cultivation is rewarding enough. To alleviate this problem, confidence-building measures need to be taken. The government should clearly formulate its policy and explain to the farmers that their role is vitally importance to the success of the biodiesel programme. The government should establish a minimum support price for Jatropha oilseeds to assure farmers of timely payments.

The other main issue is the lack of infrastructure in seed collection and oil extraction. In the absence of infrastructure and available oilseeds, it will be difficult to persuade entrepreneurs to invest in transesterification plants. Finally, there is the problem of glycerol utilization. The by-product glycerol is about 12 per cent of the biodiesel produced, and is of about 88 per cent purity. If no alternative means are quickly devised for utilizing glycerol, its price will plummet due to excess supply.

Figure 4 illustrates the position of India and the European Union on the biodiesel industry growth curve. India has just finished the pilot stage and is entering the incubation stage. The EU is well into the growth phase. For instance, the UK is setting up two plants totalling 350,000 t/year capacity in 2005 alone, and a few more are planned in the near future. Of course the hectic growth pace in Europe is fuelled by the European Commission mandate that biofuels comprise 2 per cent of the fuel consumption by 2005 and 5.75 per cent by 2010.

Figure 4. Biodiesel industry growth curve



Diesel consumption in India is estimated at 66.91 million tons in 2011-2012. Given this figure, the biodiesel required for 20 per cent blending would be 13.38 million tons. Obtaining biodiesel in this amount is quite a daunting task and involves about 14 million hectares of land under Jatropha cultivation. To put it in perspective, the land currently under sugarcane cultivation is 4.36 million hectares. India may have to import biodiesel or vegetable oil feedstock or even oilseeds.

In conclusion, the biofuels industry is poised to make important contributions to meeting India's energy needs by supplying clean domestic fuel. The ethanol industry is mature, but with efficiency improvements, the use of alternate crops and the deployment of new technologies like enzymatic fermentation of cellulosic material, it can easily supply the ethanol requirements for 5 per cent or even 10 per cent ethanol blending. As for biodiesel, R&D work on high oil-yielding Jatropha seeds is complete and pilot projects for plantations and transesterification plants are under way. The industry is in the incubation stage, but 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. In the meantime imports could help, as could income generated from the sale of certified emission reductions from biodiesel projects approved by the CDM executive board.

References

All India Distillers Association. "*Thailand grants licences for eight companies to build ethanol plants*". Available at http://www.aidaindia.org/aida/may-sep/indexmay_sep.htm.

Bhandari R. C. (1995). "*Molasses Utilization – Problems and Prospects*".

Biodiesel production and switching fossil fuels from petrol-diesel to biodiesel in transport sector - 30 TPD Biodiesel CDM Project in Andhra Pradesh, India. Project Design Document available at http://cdm.unfccc.int/UserManagement/FileStorage/FS_686206579.

D1 Oils – "*Growing Energy Solutions*". Available at http://www.d1plc.com.

Dhanda, K. S. (2004), "*Farmers' Experiences, problems, and suggestions on Jatropha plantation and cultivation*", International Conference on Biofuels, New Delhi, 16-17 September.

European Union of Alcohol Producers (2005). "Special Report Biofuels", *The Economist*, 14 May 2005.

Garafalo, R. (2004), "*Biodiesel in Europe and Worldwide: Overview and Development Perspectives*", Conference on "Renewable Resources, Renewable Energy: A Global Challenge," Trieste, Italy, 10-12 June 2004.

Goel M. (2004). "Zeolite membrane dehydration system – New energy efficient ethanol dehydration technology", International Conference on Biofuels, New Delhi, 16-17 September.

Gokhale D. (2004). "*Tropical Sugar Beet (TSB), a revolutionary alternative source for sugar, ethanol and alcohol*," International Conference on Biofuels, New Delhi, 16-17 September.

The Hindu Business Line (2005). "*Naturol BioEnergy set to achieve financial closure by March*", 21 January. Available at: http://www.blonnet.com/2005/01/22/stories/2005012202450200.htm.

Indian Express Press Report (1998). "*Price Swings in Molasses Cause Shakeout*," 27 April.

Kale, V. (2004). "*Glycerine and its Derivatives*", International Conference on Biofuels, New Delhi, 16-17 September.

Mandal, R. (2004). "*Indian Scenario & Policy Issue for Successful Implementation of Biodiesel Program*", International Conference on Biofuels, New Delhi, 16-17 September.

Ministry of Food and Agriculture, Government of India (2003). Sugar Report.

Ministry of Petroleum and Natural Gas, Government of India (2004). Statement by Minister Mani Shankar Aiyar to the Lok Sabha, 21 December.

Mittelbach, M. and C. Remschmidt (2004). "*Biodiesel, the comprehensive handbook*", pg. 24, Martin Mittelbach Publisher, Graz, Austria.

National Renewable Energy Laboratory, U.S. Department of Energy (2001). "*Bioethanol – Moving into the Marketplace*".

Nigam, R. B. and P. K. Agrawal (2004), "*Ethanol Manufacture from Cane Juice and Molasses*," International Conference on Biofuels in India, New Delhi, 16-17 September.

NDTV.com press release, "*Bio-diesel cleared for commercial production*." Available at. http://www.ndtv.com/environment/Ecoinitiatives.asp?id=56232&callid=1.

Planning Commission, Government of India. Report of the Working Group, Tenth Plan.

Planning Commission, Government of India (2003). Report of the Committee on Development of BioFuel, 16 April.

Pramanik, T. and S. Tripathi (2005). "*Biodiesel: clean fuel of the future*", Hydrocarbon Processing, Vol. 84 No. 2, p.50.

Riso National Laboratory (2004). "*New and Emerging Technologies*", Riso Energy Report 2. Edited by Hans Larsen Jens Kossman, and Leif Sønderberg Petersen, Denmark.

Seetharama N. (2004). "*Sweet sorghum as biofuel: prospects and challenges*". International Conference on Biofuels, New Delhi, 16-17 September.

Singh, J. P. (2004). "*Prospects of reducing cultivation cost of sugarcane*", International Conference on Biofuels, New Delhi, 16-17 September.

UNCTAD (2005). "*Biofuels – Advantages and Trade Barriers*." Paper Prepared by Suani Teixeira Coelho, 4 February. UNCTAD/DITC/TED/2005/1, Geneva.

Uppal J. (2004). "*Emerging Employment Opportunities in Biofuels Sector*", International Conference on Biofuels in India, New Delhi, 16-17 September.