Liquid Biofuels for Transportation: India country study on potential and implications for sustainable agriculture and energy

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Preface

Worldwide interest and activity in biofuels has grown dramatically in the last few years. Governments, private investors, environmentalists are among those who have begun to push for stronger support for biofuels as a way to meet a range of economic, social and environmental goals.

In order to assess the broad ramifications of the rapid and large-scale development of biofuels globally, the Federal Ministry of Consumer Protection, Food and Agriculture (BMVEL) has commissioned the (German Technical Cooperation) GTZ to comprehensively survey the issue of “fluid biofuels for transportation” guided by the principle of sustainable agriculture, energy and transport and to bring the results of the analysis in the international debate. As part of this undertaking, regional studies have been conducted in India, Brazil, China and Tanzania. In addition, experiences and knowledge from Germany, Europe and the US have been collated.

In India, the interest in biofuels has grown dramatically during the last few years. The chief rationale for biofuels in India is energy security. Better environmental performance, greening of wastelands and creation of new employment opportunities - are seen as some of the other advantages of biofuels. The two biofuels that are currently the focus of attention are (i) bio-ethanol and (ii) biodiesel.

The study “Biofuels for Transportation: Indian Potential and Implications for Sustainable Agriculture and Energy in the 21st century” aims at providing an overview of the biofuel development in India. It investigates the potential for biofuel development in the country and examines important socio-economic and environmental sustainability issues in the context of the large-scale biofuel programme currently being contemplated in the country.

The Indian study team consisted of researchers from three institutions – The Energy & Resources Institute (TERI), New Delhi, the Institute for Social & Economic Change (ISEC), Bangalore and ICRISAT, Hyderabad.

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- Indian Tobacco Company – International Business Division
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- Central Salt and Marine Chemicals Research Institutes
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- Department of Rain shadow Development
- Department of Forest, Government of Andhra Pradesh

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List of Abbreviations

APM	–	Administered Pricing Mechanism
ASTM	–	American Society of Testing and Materials
BOD	–	Biochemical Oxygen Demand
BoT	–	Balance of Trade
BSP	–	Bio-safety Protocol
CDM	–	Clean Development Mechanism
CO	–	Carbon Monoxide
COD	–	Chemical Oxygen Demand
CPCB	–	Central Pollution Control Board
CSMCRI	–	Central Salt & Marine Chemicals Research Institute
DDG	–	Decentralized Distributed Generation
FFA	–	Free Fatty Acid
GDP	–	Gross Domestic Product
GHG	–	Green House Gas
GoI	–	Government of India
HSD	–	High Speed Diesel
INR	–	Indian National Rupees
IOC	–	Indian Oil Corporation

IPP	–	Import Parity Principle
IPP	–	Intellectual Property Rights
JFM	–	Joint Forest Management
KSRTC	–	Karnataka State Road Transport Corporation
LD	–	Lethal Dose
MNES	–	Ministry of Non-conventional Energy Sources
MoRD	–	Ministry of Rural Development
MT	–	Million Tonnes
NABARD	–	National Bank for Agriculture and Rural Development
NDDB	–	National Dairy Development Board
NMB	–	National Mission for Biodiesel
NOVOD	–	National Oil and Vegetable Seed Development
(NO)x	–	Nitrogen Oxides
NTGCF	–	National Tree Growers Cooperative Federation
PAH	–	Poly Aromatic Hydrocarbons
PM	–	Particulate Matter
RIDF	–	Rural Infrastructure Development Fund
SHG	–	Self Help Groups
SuTRA	–	Sustainable Transformation of Rural Areas
SVO	–	Straight Vegetable Oil
TBO	–	Tree Born Oil Seeds
TBT	–	Technical Barriers of Trade
USDA	–	United States Department of Agriculture
VAT	–	Value Added Tax
VESP	–	Village Energy Security Programme

Conversion

Currency Conversion

US $ 1	INR 45
Euro 1	INR 54

Unit Conversion Table

1 tonne	1000 kilograms
1 ha	10000 sq. metres
1 acre	4047 sq. metres
1 kilolitre	1000 litres
1 cubic metre	1000 litres
1 crore	10 million
1 Lakh	0.1 million
1 tonne	1000 kilograms

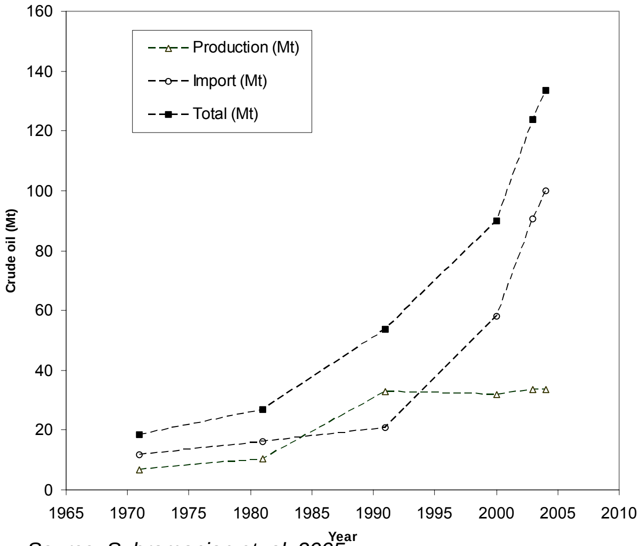
1 Introduction

1.1 Rationale for biofuels in India

Energy security, socio-economic and environmental benefits are often sited as the main reasons for the Government of India support for biofuels.

India ranks sixth in the world in terms of energy demand accounting for 3.5% of world commercial energy demand in 2001. The domestic production of crude oil has stagnated, while the demand has been rising at a rapid rate, resulting in increased crude oil imports (Figure 1.1). During 2004-05, the country imported 95.86 million tonnes (MT) of crude oil valued at US$ 26 billion and the expected imports for 2005–06 of 98.26 MT valued at US $41 billion. The Indian economy is expected to grow at a rate of over 6% per annum and the petroleum imports are projected to rise to 166 MT by 2019 and 622 MT by 2047 [TERI, 2002]. There is a growing need for energy security as any disturbance in the supply of petroleum fuels or increase in petroleum prices can have negative impact on the growth of Indian economy. Indigenously produced biofuels are being considered as one of the options to partially substitute petroleum fuels and reduce dependence on imported oil.

Fig. 1.1: Crude oil imports vs. production



Source: Subramanian et. al, 2005

In addition, the promotion of biofuels in India is supported by the benefits offered in terms of:

- Generation of new employment opportunities in raising, reaping and processing of biofuel crops [Mandal and Mitrha, 2004].
- Addition to the renewable energy options for decentralised distributed generation (DDG) of electricity and for motive power applications (water pumping, milling, etc.) in energy deficient rural India [MNES, 2004].
- Greening of wastelands and regeneration of degraded forest-lands, thereby helping in eco-restoration and preventing further land degradation [Mandal, 2004].
- Better environmental performance through reduction in vehicular pollution and Green House Gas emissions. It is well established that the use of biofuels in vehicles results in reduction of SO2, particulate matter, CO, etc. In addition, a sustainable biofuel system results in no net addition of CO2 into atmosphere [Subramanian, et.al, 2005].

Biofuels have generated considerable interest among the government, research community, industry and general public. The development of biofuels in the India can be tracked by the key milestones outlined in Box 1.1.

Box 1.1: Biofuel Development in India - Important Milestones

- Use of Biofuels- Ethanol ("Power Alcohol") in World War II
- Large number of committees and studies undertaken since 1975
- Trials on cars and other vehicle undertaken in 1979-80 by Indian Oil Corporation (IOC) & Indian Institute of Petroleum (IIP) with 10 & 20% ethanol blend
- Trials undertaken in Delhi in1990-92 on around 92 Cars
- Pilot Project involving trials in 3 Oil Depots (2 Maharashtra & 1 UP) to cover around 350 petrol stations in 2001- 2002
- Statement of Minister of Petroleum in Parliament in Dec 2001 for the rationale/benefits of Ethanol / Biofuels and intention to blend
- SJ Chopra's Committee Report concluding that Ethanol was the best Oxygenate for blending with petrol - March 2002 placed in the Parliament
- Notification of September, 2002 for mandatory blending of 5% Ethanol in 9 States and 4 UTs from Jan 1, 2003 & history of its implementation
- Autofuel Policy's (March 2003) reference to Biofuels
- Budget for 2002-03 Rs.0.75 per litre rebate on Petrol blended with ethanol that was brought down to Rs.0.30 per litre in a few months. This incentive was not renewed from FY 2004-05 onwards
- Report of the Committee on Development of Biofuel by Planning Commission –April 2003
- A National Mission on Bio-diesel (NMB) is proposed to be constituted with the Ministry of Rural Development as the nodal ministry. Under the proposed demonstration phase of the NMB, Government of India plans to raise jatropha plantations on 0.4 million ha. of wastelands. Important policy decisions with respect to the demonstration phase of NMB are expected soon-2003.
- Reference to Tariff Commission in 2003 by Minister Petroleum & Natural Gas (MOP&NG) to determine price of Ethanol.
- Announcement of Biodiesel Purchase Policy in October 2005.

Currently, India's biofuel programme is primarily based on Bio-ethanol derived from sugarcane molasses and biodiesel derived from non-edible oil seeds, e.g. Jatropha and Pongamia. Since 2002, the Government of India has taken two important policy initiatives for the promotion of biofuels. Ministry of Petroleum and Natural Gas has mandated 5% ethanol blending from January 2003 in nine states and five union territories[1].

A National Mission on Biodiesel (NMB) is planned to be constituted with the Ministry of Rural Development as the nodal ministry. Under the proposed demonstration phase of the NMB, Government of India plans to raise Jatropha plantations on 0.4 million ha of wastelands [Planning Commission, 2003]. Important policy decisions with respect to the demonstration phase of NMB are expected soon.

1.2 Scope of the study and report outline

The study aims at assessing the broad ramifications of the rapid and large-scale development of biofuels in India. Besides informing stakeholders, the objective of the study is to identify opportunities

[1] *Since 2004, there have been some changes in the Government of India's notification on mandatory blending of ethanol with petrol. For further information on this, refer to Section 2.9.1*

and constraints of biofuel development, in order to minimize the costs and maximize the benefits of the biofuel development. The scope of the study covers:

- Analysis of the current situation in India with respect to: availability of biofuel resources, processing technology, end-use applications, government policies, markets for biofuels (Chapter 2).
- Potential of biofuels in India, considering: land availability, technology advancements, future demand-supply scenario for transportation fuels, and infrastructure and investments requirements (Chapter 3).
- Discussion and analysis on the sustainability issues in biofuel development, with respect to, food security, social and economic sustainability and environmental sustainability (Chapter 4).
- Biodiesel value chain and discussion on biofuel production and utilization models (Chapter 5).
- Analysis on the national and international implications of large-scale biofuel development in India, on petroleum imports, international trade, foreign exchange balance, global environment etc. (Chapter 6).
- Broad conclusions and future outlook for policy options, institutional models, technology choices, keeping in view the sustainability criteria (Chapter 7).

It is hoped that the report will contribute towards the ongoing debate on biofuel development in the country as well as the global project aimed at informing policy makers and the public in both the North and South about the opportunities and risks of biofuels.

1.3 Methodology

The methodology developed for this study is driven largely by the objective of assessing and analysing the local experiences, the relevant market and conditions for the sustainable production, use and marketing of biofuels in the transport sector. With emphasis on appreciating the local experiences, the study was based on:

- Literature survey of research papers and reports, news articles, government documents, and web-based information on biofuel sector in India.
- Review of a number of representative cases across the entire value-chain of biofuel production. The information gleaned has been interspersed as instances throughout the report.
- Discussions with key stakeholders, including those from the farming community, research organizations, industry and policy makers at central and state level.

A list of the meetings and field visits is provided in Annexure I.

1.4 Limitations and constraints

The study team would not like to claim completeness in terms of coverage of all the activities taking place in the country on biofuels. With only about two months at their disposal, the study team was highly constrained by the limited time available to review the activities underway in this sector. Due to paucity of time, the report lays special emphasis on the biodiesel component, which has recently come into limelight because of Government of India’s concerted efforts in its development. The presentation of the draft report at TERI’s International Conference “Biofuels – 2012 Vision to Reality” at Delhi on 17th October 2005 provided the study team an opportunity to get a feedback from all the stakeholders on the report helping them incorporate important aspects / issues that had been overlooked during the conduct of the study.

2 Current Situation

This chapter provides an overview and analysis of the current status of biofuels in India with respect to availability of resources, processing technology, end-use applications, markets for biofuels and policy framework.

2.1 Biofuel options

The three biofuel options currently being considered in the country are: straight vegetable oils (SVOs), biodiesel and bio-ethanol.

2.1.1 Straight vegetable oil (SVO)

SVOs, referred to as pure plant oils (PPO) in Europe, are derived from both edible and non-edible oilseeds. Edible oils derived from rapeseed, sunflower and soybean, are being used as feedstock for producing biodiesel in USA and Europe. In India, as edible oils are in short supply, non-edible tree borne oilseeds (TBOs) of Pongamia pinnata, Jatropha curcas, Azadirachta Indica (Neem), are being considered as the source of SVO and biodiesel.

Research on the use of SVOs in diesel engines shows that there are problems associated with their high viscosity and high flash point. The high viscosity interferes with the fuel-injection process in the engine, leading to poor atomisation of fuel and inefficient combustion [Barnwal et. al, 2005]1. Heavy smoke emissions and carbon deposition in the combustion chamber have been reported.

In recent years, Sustainable Transformation of Rural Areas (SuTRA) and Samagra Vikas have operated small stationary diesel engines (5 to125 hp) on Pongamia oil for power generation and water pumping. The experience of engine performance was limited as the run hours did not exceed 1500 hours on single engine. Therefore, it is difficult to assess the feasibility of using SVOs as fuel in small stationary engines (refer Box 2.1).

Box 2.1: Use of SVOs in engines: SuTRA

SuTRA was a Global Environment Facility (GEF) project with the objective of demonstrating the possibility of biofuel packages for meeting the energy needs of rural households and agriculture. One of the technology options selected was the direct use of pongamia, neem and cottonseed oil to generate power in DG sets (cumulative capacity 230 kVA) for drinking water and irrigation. The demonstration was carried out in ten villages and hamlets of Tumkur district (Karnataka) during 1998 to 2001.

Discussions on the performance of engines using pongamia SVO with the project staff and local people revealed that Operation and maintenance (O&M) costs with SVO were higher compared to diesel. But no scientific data was available to arrive at the exact O&M requirements.

Source: TERI report on evaluation of SuTRA, 2003

Vehicle engines are more sophisticated than small stationary diesel engines and vehicle manufacturers do not approve of the use of SVOs. However, one of the largest public transport service providers in the country – Karnataka State Road Transport Corporation (KSRTC) – is going ahead with trials on 10% SVO blend in buses (Box 2.2 for details). KSRTC has monitored the performance of two vehicles during the trial runs and encouraged by the results have plans to operate the entire fleet of Doddaballapur depot (82 buses) near Bangalore on

[1] *In large engines (> 1 MW), preheating of the oil has helped in managing problems associated with the higher viscosity of SVOs. A 3 x 8 MW power plant by Wartsila has been operating on SVOs in Italy since 2003 [Niklas, 2004].*

this blend by the end of this year. It has plans to extend the use of blends to 10 more depots in near future.

Box 2.2: SVO as transport fuel: KSRTC experience

KSRTC, with a fleet of 4000 buses, is a major public transport corporation under the Government of Karnataka. It started trials on the use of pongamia oil in its buses about 3 years ago. After initial testing on old buses, experimental trials on 10% oil blend in 2 new buses were taken up in 2004. The performance of these buses was compared with 2 new buses running on diesel on the same route. Initially, problems were faced in achieving proper mixing of pongamia oil with diesel, which was solved by adding an enzyme-based additive[2] with simultaneous agitation at 200 rpm. The cost of the additive is INR 2200/litre and 1 litre of additive is added in 6000 litres of fuel.

According to KSRTC, an overall efficiency (mileage) improvement of 12.5% in comparison with diesel has been observed. Though maintenance costs are slightly higher as fuel filters are now replaced after every 8,000 km, compared to 10,000 km on diesel operation.

In addition, the current market price of pongamia oil is INR 28/litre compared to price of diesel at INR 37/litre. Even with the additional cost of INR 3.67/litre for the enzyme-based additive, as well as costs for more frequent replacement of fuel filters, KSRTC has estimated an overall saving of INR 3/litre by using the blend over diesel.

Source: Discussions with KSRTC officials

However, several engine and fuel experts, during their interactions with the study team, were of the opinion that KSRTC should carry out more detailed and rigorous investigation on engine performance and maintenance requirements to support their claims.

2.1.2 Biodiesel

The problems associated with SVOs can be overcome by converting them into alkyl esters of fatty acids (biodiesel) through a process known as trans-esterification. Biodiesel has properties very similar to those of diesel (Table 2.1)

Table 2.1: Properties of biodiesel from different feedstock and fossil diesel

Fuel	Kinematic viscosity (mm2/s)	Cetane No.	Lower heating value (MJ/kg)	Cloud point (°C)	Pour point (°C)	Flash point (°C)	Density (Kg/l)
Soybean biodiesel	4.5	45	33.5	1	-7	178	0.885
Sunflower biodiesel	4.6	49	33.5	1	-	183	0.860
Diesel	3.06	50	43.8	-	-16	76	0.855

Source: Barnwal et. al, 2005

Biodiesel is a relatively new fuel in the Indian context. At present its availability is limited to small quantities being used for conducting pilot trials on vehicles and lab-scale experiments. Daimler Chrysler carried out trials with 100% Jatropha biodiesel on two Mercedes-Benz C220 CDI cars during 2004. An Indian research institute, Central Salt and Marine Chemicals Research Institute (CSMCRI),

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[2] *The trade-name of the additive is "Soltron" fuel additive. This Bio- Engineered liquid fuel additive is a ready to use additive formulated for dispersion of heavy hydrocarbons, carbon, water, sludge and prevention of sludge formation. Treatment improves atomisation and combustion. It contains enzymes that literally change the structure of the interface between the fuel and water and also increase the oxygen absorption ability of the fuel to assure clean burning.*

supplied 1,200 litres of Jatropha biodiesel for the trials. No major engine modifications were carried out and one of the vehicles successfully covered 6,000 km without any problems. The average mileage during the trip was 13.5 km/litre, which is comparable to that with fossil diesel [CSMCRI, 2004].

Another important trial was conducted by Indian railways on a diesel locomotive (16 cylinder Alco DLW, rated at 3100 HP) using 5,000 litres of imported soybean biodiesel blends (B10, B20, B50, B100) during April-May 2004 [Saxena, 2004]. The state road transport corporations of Haryana, Gujarat, Andhra Pradesh and Indian vehicle manufacturers - Tata Motors, and Mahindra & Mahindra are also carrying out trials with biodiesel blends.

2.1.3 Bio-ethanol

Ethanol is produced by fermentation of carbohydrates present in biomass. In India, molasses – a by-product of sugar industry, is the main feedstock for ethanol. Use of bio-ethanol in blends up to 20% with gasoline in vehicles is well established [Planning Commission, 2003]. As mentioned above, the Government of India made the blending of 5% ethanol with gasoline mandatory in selected states of the country with effect from 1st January 2003.

2.2 Biofuel resources

2.2.1 Tree borne oil seeds

India has more than 300 different species of trees, which produce oil-bearing seeds [Subramanian et. al, 2005). Around 75 plant species, which have 30% or more fixed oil in their seeds/kernel, have been identified and listed [Azam et.al, 2005]. The promising non-edible sources are: Jatropha curcas (Ratan Jyot), Pongamia pinnata (Karanja), Melia azadirachta (Neem), and Shorea robusta (Sal).

Traditionally, collection and selling of tree-based oilseeds (TBOs) was generally carried out by poor people for use as fuel for lighting. Presently there is an extended use of these oils in soaps, varnishes, lubricants, candles, cosmetics, etc. However, the current utilization of non-edible oilseeds is very low (Table 2.2).

Table 2.2: Non-edible oil sources in India

Oil source	Botanical name	Potential quantity (tonnes/year)	Current utilization (tonnes/year)	Percentage of utilization
Rice-bran	Oryza sativa	474,000	101,000	21
Sal	Shorea robusta	720,000	23,000	3
Neem	Melia azadirachta	400,000	20,000	5
Karanja	Pongamia pinnata	135,000	81,000	6

Source: Subramanian et. al, 2005

For the large-scale biodiesel programme Jatropha and Pongamia have been found to be suitable as both the species grow well in rainfed semi-arid areas and are not browsed by livestock [Planning

Commission, 2003]. While Jatropha is a native species of South America, Pongamia is of Indian origin. A comparison of various characteristic features of these plants is presented in Table 2.3.

Table 2.3: Jatropha vis-à-vis Pongamia

Characteristics	Jatropha	Pongamia
Ecosystem	Arid to semi-arid	Semi-arid to sub-humid
Rainfall	Low to medium (200 -1000 mm)	Medium to high (500 -2500 mm)
Soil	Well drained soils	Tolerant to water logging, saline and alkaline soils
Nitrogen fixation	No Nitrogen fixation	Fixes Nitrogen
Plant suitability	Wastelands, degraded lands, live fence for arable lands, green capping of bunds, shallow soils	Field boundary, nala bank stabilization, wastelands, tank foreshore
Plant habit	Mostly bush, can be trained as small tree	Tree can be managed as bush by repeated pruning
Leaves	Not palatable by livestock	Not palatable by livestock, used as green leaf mulch
Gestation period	Short, starts yielding during 3rd year, attains maturity at 6th year	Long, starts yielding after 4th to 7th year. Yield increases with increase in canopy.
Harvest	Fruits to be plucked	Fruits to be collected
Oil content	27-38% in seed	27-39% in kernel
Protein	38%	30-40%
Oil cake use	As manure (4.4% N, 2.09% P, 1.68% K)	As manure (4.0% N, 1.0% P, 1.0% K)
Fire wood	Not useful	Good as firewood, high calorific value: 4,600 k cal/kg
Toxicity	Toxic	Non-toxic

Details of Jatropha plantations undertaken recently are presented in Table 2.4.

Table 2.4: List of some recent Jatropha plantations

Name of the Agency	Plantation details	Remarks
National Oilseeds & Vegetable Oils Development Board (NOVOD)	7,500 ha	Model plantations in 21 states
Uttaranchal Biofuel Board	10,000 ha	Year of plantation: 2005
Chhattisgarh	80 million seedlings	Year of plantation: 2005
CSMCRI-Daimler-Chrysler project	20 ha in Gujarat + 20 ha in Orissa	Year of plantation: 2003, onwards
IOC-Indian Railways	1,10,000 saplings at Surendra Nagar, Gujarat	

Besides income from by-products, the economic viability of biodiesel will depend largely on the seed yields, which show large variations (Table 2.5). These variations in the seed yield data for Jatropha and Pongamia can be attributed to the differences in the quality of germ-plasm, plantation practices and edapho-climatic conditions. In addition, due to absence of data from block plantations, several yield estimates are based on extrapolation of yields obtained from individual plants or small demonstration plots.

Table 2.5: Seed yields from Jatropha and Pongamia

Reference	Type of data	Reported yield on maturity
Jatropha		
Agro-forestry Federation, Nashik [Patil and Singh, 2003]	Primary data from block plantations	1.0 -1.2 tonne/ ha
Planning Commission, 2003	Estimates for poor soil (Kutch) Estimates for average soil	1.6 – 2.5 tonne/ha * 3.3 – 5.0 tonne/ha
Becker and Francis	Estimates for poor soils with low nutrient content	1.5 – 2.0 tonne/ha
TERI [2005]	Estimates for rain-fed and irrigated conditions	3.0 – 5.0 tonne/ha
Pongamia		
Patil et. al, 2003	Field study (Nasik, Maharashtra)	9 to 90 kg of seeds/tree
Ilorkar and Banginwar, 2003	Field study: Vidarbha (Maharashtra)	4 to 6 kg of seeds/tree

** Seed yield for planting density of 1666 plants and 2500 plants per ha. Respectively*

Some of the agencies promoting Jatropha in India and elsewhere are projecting much higher yields. A few examples are;

- Chhattisgarh Biofuel Development Authority: 10 - 12 tonne/ha [CBDA, 2005]
- D1 Oils Plc.: 10-12 tonne/ha as targeted output [Quinn, 2005]

Such high yields are yet to be demonstrated in block plantations in India and hence these claims should be viewed cautiously.

2.2.2 Resource for bioethanol

In India, sugar-cane molasses is the feedstock for ethanol production. Maharashtra, Tamil Nadu, Uttar Pradesh, Punjab, Karnataka, Andhra Pradesh, Bihar, Haryana and Gujarat are the main states engaged in sugar-cane production. During 2002-03, the total area under sugar-cane production was 4,361,000 ha [Singh, 2004]. The area under sugarcane has shown an increase of 2.5 times since 1950-51, however, in the recent years, the area and the yield has stagnated as shown in the Table 2.6.

Table 2.6: Area under sugarcane production

Year	Area (thousand hectare)	Yield (tonnes/ha)
1950-51	1,707	32.10

1960-61	2,415	45.50
1970-71	2,615	48.30
1980-81	2,667	57.80
1990-91	3,686	65.40
1995-96	4,147	67.80
2002-03	4,361	64.60
		Source: Singh J P, 2004

During 2001-02, the total production of ethanol from molasses was 1.77 billion litres - out of which about 70% was used for potable or industrial purposes - leaving a balance of 0.53 billion litres for use as fuel [Planning Commission, 2003].

Ethanol production in the country is constrained because of its dependence on a single source – sugarcane molasses. An increase in ethanol production is possible by utilizing secondary cane juice. The other option is to promote alternate crops, like sweet sorghum, for ethanol production[2]. Sweet sorghum requires less water and fertilizer inputs (around 35-40% of that required for sugarcane) [Rao, 2004]. Due to short cycle of 3.5 – 4 months, in irrigated areas up to two cycles are possible in a year. Although, ethanol from sweet sorghum is estimated to be about 10% cheaper compared to molasses based ethanol [Rao, 2004], commercial production of ethanol from this crop is yet to start in the country.

At present, research is being carried out to develop technologies to produce ethanol from cellulose materials, e.g. rice straw, bagasse, which may emerge as more sustainable feedstock for ethanol production in the longer term.

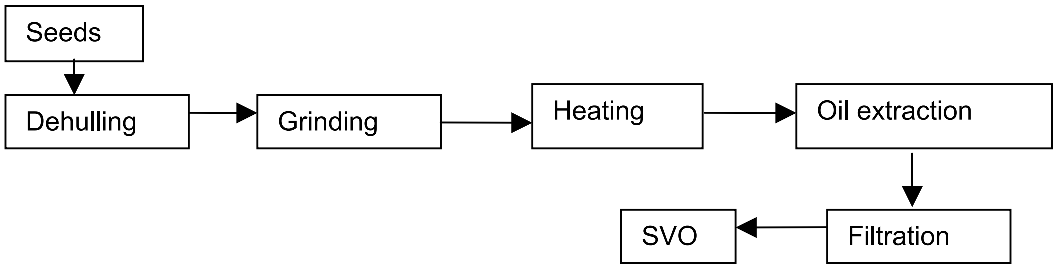
[2] *In India, use of food grains for production of ethanol is not viable because of the issues related to food security.*

2.3 Technologies for biofuels production

2.3.1 Straight Vegetable Oil

Sequence of operations employed for the production of SVOs is shown in Figure 2.1.

Fig. 2.1: Production process for SVO



For Pongamia oil, after filtration, de-gumming operation is recommended to remove seed particles, phosphatides, carbohydrates, proteins and metals. Of the various technologies used for oil extraction (Table 2.7), mechanical oil extraction is the most common for extracting non-edible oils. The typical recovery efficiency of good expellers is 80-85% of oil content in the seed.

Table 2.7: Oil extraction technologies

Extraction technology	Capacity
Screw or hydraulic press	5 -30 kg/batch
Ghanis[3] (animal-driven or motorized)	Up to few hundred kg/day
Expellers	50 -3000 kg/h
Solvent extraction	200 -4000 tonnes/day
	Source: TERI 2005

2.3.2 Biodiesel

The process of biodiesel manufacture involves pre-treatment of crude vegetable oil followed by the process of trans-esterification using methanol or ethanol. Biodiesel is separated from glycerol and it is then washed and dried to obtain the final product. Glycerol is a by-product of the process. Technology for the preparation of biodiesel from low free fatty acid (FFA) content and high quality oils is well known. The challenge in India is to handle multi feed stocks with high FFA[4] (Jatropha and Pongamia have high FFA compared to several edible oils) [Prasad, 2005].

Several Indian R & D institutions are working on small-scale (up to few thousand lpd capacities) trans-esterification technology. CSMCRI, Bhavnagar has developed acid and base catalysis process to

[3] *Ghanis are the traditional devices used in India for oil extraction. It consists of wooden or metal pestle, which is driven in a large metal or wooden mortar.*

[4] *Non-edible oils of Jatropha and Pongamia are having high free fatty acids compared to edible oils*

produce high quality biodiesel[5]. Acid catalysis is preferable as a pre-treatment option for vegetable oil having high free fatty acid content [Mehta, 2004]. The process can be used for capacities ranging from 100 lpd to 2000 lpd. One batch operation takes 8 hours for completion. The typical cost of 500 lpd capacity plant is estimated at INR 6 million, including the civil cost.

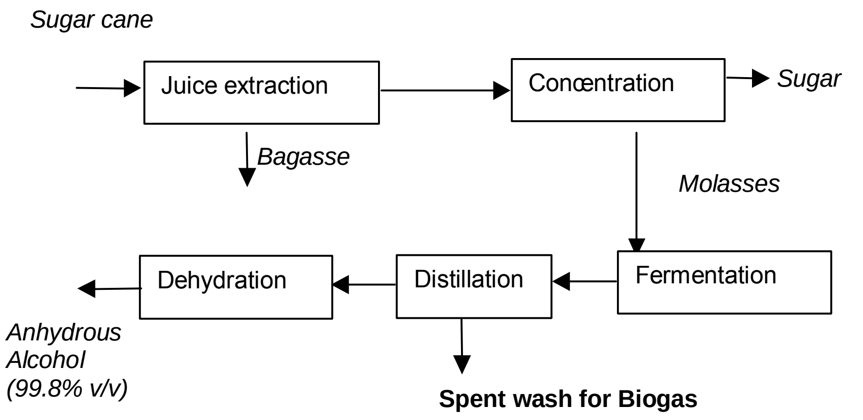
Indian Institute of Chemical Technology, Hyderabad, has developed a batch process with the traditional catalysts both for low and high FFA vegetable oils [Prasad, 2005]. The technology developed by Indian Oil Corporation (IOC) has been transferred to M/s Venus Ethoxyethers. Under a World Bank Development Marketplace supported project, being implemented in Orissa by CTx GreEn and Gram Vikas, very small capacity (5-25 lpd) trans-esterification plants, suitable for operation in remote villages are being developed. Apart from these institutions, Delhi College of Engineering, Punjab Agriculture University, Indian Institute of Petroleum are some of the other institutes working on biodiesel production technology.

2.3.3 Bio-ethanol

Although at present most of the Indian bio-ethanol is produced from sugar cane molasses, technologies are also available for the conversion of sugar-cane juice, sweet sorghum and other grain-based feedstock to ethanol. The main steps in the ethanol production from sugarcane are shown in Figure 2.2.

Praj Industries Limited, Pune, is the leading supplier of fuel ethanol production technology in India. The company has technologies that utilize multiple feedstock (cane molasses/ beet molasses/ cane juice as well as starchy raw materials). Their ECOFINE distillation technology is designed to produce alcohol conforming to ASTM standards**.**

Fig. 2.2: Ethanol production from sugarcane



[5] *CSMCRI has applied for a US patent and the institute is in the advanced stage of negotiations for setting up of commercial plants based on the technology*

2.4 By-products in the biofuel system

2.4.1 Oil extraction

During oil expelling, about 65-70% of the seed kernel is obtained as de-oiled cake. De-oiled cake from non-edible oil seeds is a good organic manure (refer Table 2.3). It is extensively traded at prices ranging from INR 2.0/kg to INR 6.50/kg. During the interactions with the oil-expelling units in Tumkur district of Karnataka, it was learnt that the de-oiled cake from the mills is exported to Kerala for use as manure in rubber plantations.

2.4.2 Trans-esterification

Glycerol is a by-product of trans-esterification process. Depending on the purity, the glycerol prices range from INR 15/kg to INR 40/kg. This glycerol is used in cosmetics and soap manufacturing. Pharmaceutical grade glycerol can fetch up to INR 100/kg.

CSMCRI in its technology package for biodiesel from Jatropha has also developed processes for production of soap and potash fertilizer as by-products of the trans-esterification process.

2.4.3 Bio-ethanol

Bagasse is the main by-product from the cane-crushing process. It is used as a fuel for steam generation and electricity production. The mill-wet bagasse contains about 50% moisture and has a calorific value of 9.5 MJ/kg [Prakash et. al, 1998]. Several sugar mills are able to export excess electricity to the grid, resulting in additional revenue to the industry. Surplus bagasse is also used for paper making and for compost making.

Effluent from the distillation process is known as spent-wash. It has a high bio-chemical oxygen demand (BOD) and chemical oxygen demand (COD), and is a very good source of biogas. Approximately 35 litre of biogas is generated per litre of spent wash [Prakash et. al, 1998]. This biogas, containing about 60% methane and having an approximate calorific value of 23 MJ/m^3, is used as fuel in boilers.

Other uses of byproducts, which have been undertaken overtime are:

a. Production of yeast from molasses
b. Mushroom cultivation on bagasse
c. Briquetting of bagasse for use as fuel
d. Use of sugarcane bagasse and molasses as animal feed.

2.5 Structure of processing industry

2.5.1 Oil extraction

Indian oil extraction industry consists of cottage industries or *ghanis* in villages, small-scale oil expellers (50 – 3,000 kg/h) and large-scale units based on solvent extraction technology, mostly devoted to production of edible oils. During 2002-03, 4.92 million tonnes (MT) of oil was produced in

India [Barnwal et.al. 2005]. According to an estimate, the oil extraction industry in India is operating at only 30-40% of its installed capacity [Tandon, 2004]. The excess capacity could be used for the extraction of non-edible oils too without any additional investments. NGOs like Samagra Vikas are in favour of a decentralized system of oil extraction. The main advantage with this decentralized system is the provision of recycling of de-oiled seed cakes to the local farms and value addition within the local economy itself[6].

2.5.2 Biodiesel

Currently biodiesel is being produced only on a small-scale in pilot plants. For instance, the pilot plant at CSMCRI, Bhavnagar has produced around 9,000 litres of biodiesel during last one and a half years. One of the first commercial biodiesel plants is being planned by Southern Online Biotechnologies (P) Ltd., in Andhra Pradesh. The project is proposed with an initial capacity of 30 tonnes of biodiesel per day, which is expandable to 100 tonnes per day. The technology for the unit will be provided by Lurgi Life Science Engineering, Germany, along with their local partner, Chemical Constructions International Private Limited, New Delhi. The plant includes both oil expelling and trans-esterification units. Unlike Europe, the preference in India is on decentralised production of biodiesel through small capacity plants.

2.5.3 Bio-ethanol

In the absence of a well knit policy in the past for purchasing and blending ethanol, not many distilleries have been producing ethanol. Only three distilleries attached to sugar mills had war years' experience, and were able to gear themselves up to supply ethanol immediately. India currently has 122 bio-ethanol plants having a total installed capacity of 1.2 million kilolitres/ annum [ethanolIndia, 2005]. Maharashtra has the largest number of plants (71 units), followed by Uttar Pradesh (14), Gujarat (12), Andhra Pradesh (6) and Tamil Nadu (4). Fifty-five of the units are stand-alone plants not attached to sugar factories.

2.6 Biofuel markets

2.6.1 Markets for tree borne oil seeds (TBOs) and oils

Traditional markets exist for trading of tree borne oil seeds and oils. Some of the places where such markets exist are: Dahod (Gujarat), Udaipur, Banswara (Rajasthan), Tumkur, Kolar (Karnataka), Raipur (Chhattisgarh), Coimbatore (Tamil Nadu), etc. The present production of oil from TBOs is estimated at 60,000 tonnes per annum [Tandon, 2004]. A field survey by Samagra Vikas in Tumkur and Kolar districts of Karnataka and Gudiyatham of Tamil Nadu found that every year around 27,000 tonnes of TBOs are processed to produce about 6,400 tonnes of oil (Table 2.8).

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[6] *Decentralised production system is discussed in Chapter 5*

Table 2.8: TBO Production in Tumkur & Kolar districts of Karnataka and Gudiyatham (TN)

Variety	Total seed procurement in tonnes	Seed prices (Rs/kg)	Oil in tonnes	Oil selling price (Rs/kg)	Seed Cake in tonnes	De-oiled Cake rate (Rs/kg)
Pongamia	24,470	8.43	6,117	25.88	18,532	4.71
Neem	2,536	3.84	273	30.03	2,407	4.72
Mahua	37	10.00	8.5	26.00	30.5	3.75

Source: Samagra Vikas, 2004

In another study in the area, it was found that there are several layers of operations in this trade (refer Table 2.9 below). The seed collector or the farmer gets only INR 3-4 /kg. By eliminating the middle-men there is good potential to improve the farm gate prices of these seeds. The increase in the prices can enhance seed collection levels, which at present is only about 60%.

Table 2.9: Price levels of Pongamia oil seeds at various stages of trading

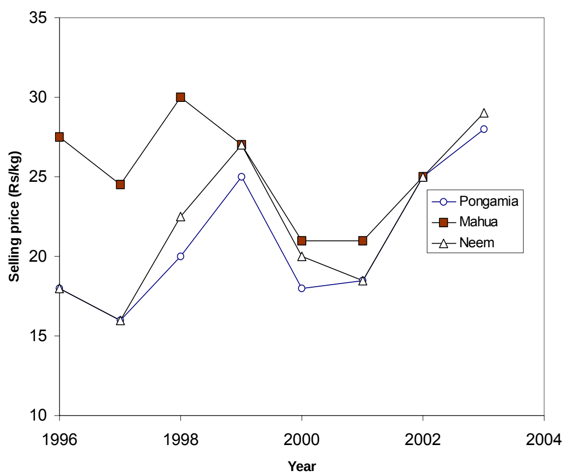
Year 2002-2003	(In Rs/100 kg)	
	Minimum	Maximum
Village markets	300	400
Primary wholesale markets	400	500
Wholesale markets	500	700
Regulated markets	600	900
Export markets	600	900
Import markets	600	800

Source: Raju K.V. 2003 (on-going study in Kolar district of Karnataka)

Major benefits from Pongamia oil are accruing to traders-cum-oil extractors who buy seeds in the lean season, and process them as and when the market demand rises.

The price movement (during 1996-2003) for oil derived from three varieties of TBOs is shown in Figure 2.3.

Fig. 2.3: Selling price of oil derived from main TBOs



Source: Tandon, 2004

2.6.2 Markets for biodiesel as transportation fuel

Commercial biodiesel production is yet to start in the country. Current usage is limited to conducting trials on vehicles and lab experiments. The current market price of biodiesel varies from INR 55 -110 per litre. The cost of Jatropha biodiesel is particularly high (INR 80-110/litre) as Jatropha seeds are in high demand for raising new plantations.

2.6.3 Market for bio-ethanol as transport fuel

During the period March 2003 to September 2004, 0.37 billion liters of fuel ethanol was purchased by the oil industry [ethanol India, 2005] as a part of the 5% ethanol blending programme. During 2004 due to drought conditions, sugar cane production came down and the ethanol producers were not able to meet the demand of oil companies. During 2005, better sugar cane crop is expected and the ethanol procurement is expected to start in the next few months. The fuel ethanol prices have gone up from INR 15.50 per litre in 2003 to around INR 19.50 per litre in 2005.

2.7 Cost/price competitiveness of biofuels against fossil fuels

In April 2002, the Government abolished the Administered Pricing Mechanism (APM) for petroleum products making petrol and diesel prices market determined. As per the new arrangement, the prices of petrol and diesel were to be based on Import Parity Principle (IPP), linking retail petrol and diesel prices to national landed prices (as if imported). Though initially pricing of petrol and diesel was as per IPP, its implementation suffered a set back when global crude oil prices started rising and the government tried to insulate the Indian consumer from the volatility of international crude oil prices. As a consequence, while the Indian basket of crude oil has increased by almost 100% during the period 01.04.2003 to 01.08.2005, the retail prices of petrol and diesel were increased only by 21% and 29% respectively during this period (Table 2.10). The profitability of the Indian oil companies has been severely strained due to these artificially low retail prices of petroleum products.

Table 2.10 Increase in the prices of petrol and diesel

Date	Price of Indian basket of crude (US$/barrel)	Petrol* (INR/litre)	Diesel* (INR./litre)
01.04.2003	27.09	33.49	22.12
01.04.2004	31.86	33.70	21.74
01.04.2005	50.16	37.99	28.22
01.07.2005	54.23	40.49	28.45
01.08.2005	54.14	40.49	28.45

** Retail prices in Delhi* *Source : Economic Times, New Delhi, August 12, 2005*

A large part of the retail prices of petrol and diesel is made up of taxes and duties as shown in the Table 2.11, 53% of the prices of petrol and 28.50% of the prices of diesel are due to taxes, duties, cess, etc. If ethanol and bio diesel are to be used as transportation fuel, after blending with petrol and diesel, these would be purchased in bulk by oil companies for blending. In this scenario, the prices of ethanol and biodiesel should match the import parity price or the ex-storage point price for petrol and diesel, which currently is in the range of INR 18 – 20 per litre.

Table 2.11: Petrol/Diesel price build up in Delhi

Sl. No.	Elements of pricing	Value (Petrol) (INR)	Value (Diesel) (INR)
1	Ex-storage point price (from depots, terminals)	17.969	19.672
2	Freight and other charges, etc.	00.143	00.134
3	Sales Tax, Surcharge on ST, Excise Duty, Cess and other statutory levies, etc.	21.530	08.135
4	Dealer commission	00.848	00.509
5	Total retail selling price per litre	40.490	28.450

Source : Economic Times, New Delhi, August 12, 2005

The ethanol prices are already in this range. Recently, against a tender for purchase of ethanol by oil companies, the ethanol manufacturers have offered a price of INR 19.55 per litre. It is expected that the prices of molasses (raw material for ethanol production), which had gone up to INR 5,000 per tonne in 2004, would stabilise around INR 2,500 per tonne during 2005 and then it would be possible for ethanol manufacturers to supply ethanol at around INR 19 per litre[7]. The availability of fuel ethanol is expected to increase in the coming years as the alcohol beverage manufacturers, which presently consume 40-45% of the molasses, are shifting towards grain-based alcohol. Thus a larger quantity of molasses would be available for fuel ethanol production in coming years.

In the case of biodiesel, where full-fledged manufacturing industry is yet to be established, the market price of biodiesel currently ranges between INR 55-110 per litre. The present production comes from a few operational pilot plants and therefore, current market prices are artificially high. The prices of biodiesel are expected to come down after a few years. as harvest from the new plantations would become available. The projected prices of biodiesel in various studies ranges from INR 16 – 50 per litre. The cost of production of biodiesel will depend to a very large extent on the prices of oil seeds and that of by-products.

As described in Box 2.2, the current selling prices of SVOs in Karnataka is INR 28 per litre (without any taxes and levies), which is much lower compared to the local market prices of diesel (about INR 37 per litre). If the diesel prices rise further, or continue to remain at the same levels, unorganised trade in SVOs is expected to increase in rural areas, where large quantities of diesel is required to diesel operated irrigation pump sets and tractors.

[7] *Personal communication with Praj officials.*

It is clear that at the current high-level prices of oil, biofuels are emerging as a cost competitive option. Additional advantages such as eco-friendly features of biofuels, reduced dependence on imported oil supplies increased employment opportunities makes the development of biofuels highly desirable in the country. Lower taxes and duties on biofuels can further improve the cost competitiveness of biofuels against fossil fuels.

2.8 Key actors

There are a large number of institutions, which are playing a part in the biofuel development in the country. They can be classified under different categories e.g. R&D institutions, facilitating agencies, government agencies, private industry linked with biofuel production, vehicle manufactures, transport companies, etc. Some of the prominent organizations doing work on biodiesel are listed in Table 2.12 below. Table 2.13 lists key actors in the area of bioethanol.

Table 2.12 Organizations working in Biodiesel sector

Research	Facilitation (NGO)	Policy & Implementation	Biodiesel production	Field trials
International Crop Research Institute for Semi-Arid Tropics (ICRISAT) National Bureau of Plant Genetic Resources (NBPGR) The Energy and Resources Institute (TERI) Centre for Research in Dry land Agriculture (CRIDA) University of Agricultural Science Central Salt & Marine Chemicals Research Institute (CSMCRI) **Processing Technology** Central Salt and Marine Chemicals Research Institute (CSMCRI) Indian Institute of Chemical Technology (IICT) Indian Institute of Petroleum (IIP) Indian Institute of Technology (IIT) (New Delhi, Mumbai) Delhi College of Engineering (DCE) Punjab Agricultural University (PAU) Indian Oil Corporation (IOC) R&D Lab Engines IIT (New Delhi, Mumbai) Socio-economic & Policy Institute for Social & Economic Change (ISEC) TERI	Samagra Vikas Gram Vikas Winrock International TERI Sustainable Transformations Pvt. Ltd. (SuTRA) Bharatiya Agro Industry Foundation (BAIF) Rural Community Assistance Corporation (RCAC)	Central Planning Commission Ministry of Environment & Forests (MoEF) Ministry of Rural Development (MoRD) Ministry of Non-conventional Energy Sources (MNES) Department of Bio-Technology (DBT) Petroleum Conservation Research Association (PCRA) Ministry of Petroleum & Natural Gas (MoPNG) National Bank for Agriculture & Rural Development (NABARD) National Oilseeds and Vegetable Oil Development Board (NOVOD) Central Pollution Control Board (CPCB) State Uttaranchal Biofuel Board Chhattisgarh Biofuel Board Deptt. Of Rain Shadow Areas Dev. AP Deptt. of Forest, AP Integrated Tribal Development Authority, AP	Southern Online Biotechnologies, Hyderabad D1 Oil Mohan Bio-oils Natural Bioenergy Ltd	Karnataka State Road Transport Corporation (KSRTC) Andhra Pradesh State Road Transport Corporation (APSTRC) Haryana Roadways Gujarat State Road Transport Corporation (GSRTC) Indian Railways Daimler Chrysler Tata Motors Mahindra & Mahindra Escorts Pvt Ltd

Table 2.13 Organizations working in Bio-ethanol sector

Research and Development	Facilitation (NGO)	Policy & Implementation	Manufacturing plant suppliers and Associations of production units	Companies involved in blending
Indian Agriculture Research Institute (IARI) The Energy and Resources Institute (TERI) Sugarcane Research Institute **Processing Technology** Praj Industries	Winrock International	Central Planning Commission Ministry of Environment & Forests (MoEF) Ministry of Agriculture (MoA) Petroleum Conservation Research Association (PCRA) Ministry of Petroleum & Natural Gas (MoPNG) Central Pollution Control Board (CPCB)	Alfa Laval India Praj Industries Indian Sugar Mills Association All India Distillers Association Ethanol Manufacturers Association	Indian Oil Corporation Ltd. Hindustan Petroleum Corporation Ltd. Bharat Petroleum Corporation Ltd. IBP Ltd.

2.9 Policy Environment

2.9.1 Bio-ethanol

Government of India through a notification[8] on Ethanol blending programme (EBP), made 5% ethanol doping in petrol mandatory in 9 states and four union territories[9], with effect from 01 January 2003. As per the notification, the oil companies have the responsibility to buy ethanol and blend it with petrol. As an incentive to the oil companies, an exemption in the excise duty was offered. During 2003-04, against the requirement of 363 million litres, the oil companies could only purchase 196 million litres. Difficulties in ethanol procurement were reported in the states of Maharashtra, Goa, Gujarat, Andhra Pradesh and Karnataka. The regular supply of ethanol got affected due to drought conditions, which affected the sugarcane crop thereby restricting the availability of molasses.

On 27th October 2004, the government came out with a new notification, as per which the oil companies are obliged to blend 5% ethanol in designated states and UTs, only if the following conditions are fulfilled:

- If the price of sourcing indigenous ethanol for supply of ethanol blended petrol is comparable to the price of the indigenous ethanol for alternative use.
- The indigenous delivery price of ethanol offered for the ethanol-blended programme at a particular location is comparable to the import parity price of petrol at that location.
- The indigenous ethanol industry is able to maintain the availability of ethanol for ethanol blending programme at such prices.

As some of these conditions have not been met, oil companies are not procuring ethanol since last year and the ethanol programme has come to a halt. Against the recent call for tenders for supply of ethanol, the minimum basic price quoted for ethanol was INR 19.69/litre, which is higher compared to the import parity price of INR 19.55/litre for petrol [ethanol India, 2005].

2.9.2 Biodiesel

2.9.2.1 Committee on Development of Biofuel

The Planning Commission, Government of India, had set up a Committee on Development of Biofuel in 2002. The committee submitted its report in April, 2003. The main recommendations of the report include launching of a National Mission on Biodiesel with special focus on plantation of Jatropha. The proposed National Mission is envisaged for

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[8] *The Gazette Of India: Extraordinary [Part I- Sec. I], Ministry of Petroleum And Natural Gas Resolution New Delhi, 3rd September 2002 No. P-45018/28/2000-C. C*

[9] *The areas which have been notified are the States of Goa, Gujarat, Haryana, Karnataka, Maharashtra, Punjab, Uttar Pradesh, Uttarachal, Andhra Pradesh(all districts except Chittoor and Nellore), Tamil Nadu (only districts Coimbatore, Dindigul, Erode, Kanyakumari, Nilgiri, Ramanathpuram, Tirunelveli, Tuticorin, and Virudhunagar), and the Union Territories of Chandigarh, Dadra & Nagar Havili and Daman & Diu.*

implementation in two phases i.e. Phase I as demonstration project and Phase II for self-expansion of biodiesel programme.

The Planning Commission made a presentation to Prime Minister on the report on 11.7.2003, wherein it was decided that the Ministry of Rural Development (MoRD) will act as a nodal ministry for processing the recommendations of the report. The demonstration project in Phase I, would be taken up initially over a period of 5 years and would include six micro missions:

- Micro-mission on plantation on forestlands
- Micro-mission on plantation on non-forest wastelands
- Micro-mission on plantations on other lands (degraded and wastelands)
- Micro-mission on procurement of seed and oil extraction.
- Micro-mission on trans-esterification, blending and trade.
- Micro-mission on Research and Development.

Under these micro-missions, promotion of jatropha cultivation in forest and non-forest areas (200,000 ha forest land and 200,000 ha non-forest land) especially in wastelands is proposed to be carried out. The State Forest Departments, under the overall supervision of the Union Ministry of Environment & Forest, would implement the project in forest area. Similarly, for implementing the project in non-forest areas in the States, State Departments of Rural Development, Panchayati Raj and Agriculture would be involved.

Department of Land Resources, MoRD, in consultation with the states is in the process of preparing a proposal for approval of the programme by Planning Commission and other authorities. One of the main issues being discussed is the quantum of central government funding for the project. While some of the states are insisting on 100% grant-in-aid for Jatropha plantations, the other proposals include a combination of grants and low interest loans to the state for the plantation programme.

2.9.2.2 Biodiesel purchase policy

The Ministry of Petroleum and Natural Gas announced biodiesel purchase policy on October 9, 2005. As per the policy, which will come into force from January 1, 2006, the public sector oil marketing companies will be purchasing biodiesel (B100) at Rs.25/litre for blending with diesel. The purchase of biodiesel will be carried out through 20 purchase centres. The biodiesel should meet the norms set by the Bureau of Indian Standards[3]. Initially, 5 percent biodiesel will be blended with diesel, the extent of blending would be increased to 20 percent in phases.

3 The Bureau of Industrial Standards (BIS) specification BIS 1460 for High Speed Diesel covers specifications for 5% bio-diesel blended diesel also. BIS has also come out with the specification for pure biodiesel (B 100), vide PCD3 (2242)C-dated 26.7.2004, which is an Indian adaptation of American ASTM D 6751.

2.9.2.3 State level policies and activities

State governments will have a key role in the implementation of the biofuel programme. Many state governments have already drafted policies on the promotion of biodiesel related activities.

In the policy note prepared by Tamil Nadu government for 2005–06, it is stated that as a part of alternate cropping strategy, cultivation of Jatropha, sugar beet and sweet sorghum are being aimed at on contract farming basis through approved industrial entrepreneurs for the production of ethanol and biodiesel.

Government of Andhra Pradesh has already prepared a draft policy paper on biodiesel and plans to cover 40,000 acres of area under Jatropha plantation during the current year. The government has made a special concession for promoting drip irrigation for Jatropha in the form of a subsidy to the extent of 90% subject to a maximum of INR 50,000 per farmer. Provision for free seedling material to all BPL (below poverty line) families and a grant to cover the plantation cost and the provision of free seedling material for other farmers (other than BPL) interested in Jatropha cultivation and offering an assured source of irrigation are the two strategies being followed by the government. Further, a sum of INR 9.85 million has been released to R & D institutions for taking up biofuel related research activities. The government has also promised a reduction in value added tax (VAT) to the biodiesel industries coming up in the state.

Information collected during the study shows that the state governments of Uttaranchal and Chattisgarh have already taken some concrete measures, referred in Table 2.14 below, towards the initiation of the biofuel programme.

Table 2.14: Uttaranchal and Chhattisgarh policies on Jatropha plantation

State	Actions taken
Uttaranchal	A new organization " Uttaranchal Biofuel Board" has been created to coordinate biofuel activities. Plantation of Jatropha is being taken up on un-irrigated degraded forest-land Plantation during 2004-05: 360 Hectares. Plantation during 2005-06:10,000 Hectares. Plantation planned till 2012: 200,000 Hectares State Government has entered in to an agreement with a private sector company to establish the production capacity for processing of 600,000 tonnes of Jatropha Seeds to Bio Diesel.
Chhattisgarh	State has set up a biofuel development authority with effect from 26th January, 2005 under the Chattisgarh Renewable Energy Development Agency. A total of 80 million Jatropha seedlings had been planted during 2005 by different departments, and the target for 2006 is 160 million Jatropha seedlings. Most of these plantations are on government wasteland and fallow land. In addition, it is proposed to establish a pilot demonstration plantation in 300 acres of land of farmers in each district.
	Source: Personal communications with the officials from the two states

2.9.2.4 Financial Support

Credit facilities in biodiesel area are mainly available for plantation of biodiesel plants, raising nurseries, establishments of seed collection and oil expelling centres and biodiesel manufacturing units. Credit institutions are already extending support for these activities.

National Bank for Agriculture and Rural Development

National Bank for Agriculture and Rural Development (NABARD), as an apex body with regard to policy, planning and operations in the field of rural and agricultural credit is actively involved in extending credit support for biodiesel programme in rural areas along with other financial institutions. Raising biodiesel plants/tree borne oilseeds in wastelands has been identified as a thrust area by NABARD. It is extending (Renganathan and Kannabiran, 2005) the following support:

- 100% refinance to the banks at a concessional rate of interest rate (maximum of 6.25% per annum) for wasteland development.
- Refinance support for biodiesel expeller units.
- Co-finance biodiesel manufacturing plants along with other banks.
- Prepared a model scheme to popularise Jatropha in wastelands and biodiesel production.
- As part of its environmental promotional assistance scheme, NABARD is assisting NGOs and other research organizations to spread awareness about non-conventional energy sources including biofuels through demonstration of alternatives and technologies.

Recently, NABARD has started supporting the state governments' initiative to promote biodiesel programme. Under its Rural Infrastructure Development Fund (RIDF), NABARD has provided assistance to the government of Andhra Pradesh for implementation of the Andhra Pradesh Minor Irrigation Programme. In this programme, installation of drip system for cultivation of biodiesel plants is subsidized up to 90% (subject to maximum of INR 50,000 per farmer) in ten rain shadow districts of the state. It has sanctioned, as part of RIDF, a loan of INR 305,2 million for raising Pongamia plantation in 15,000 ha of degraded lands covering 15 districts of Andhra Pradesh. The forest department will be implementing the project directly by involving the Vana Samrakshana Samiti members. As part of capacity building, workshops for the bank officers were also conducted.

National Oilseeds and Vegetable Oils Development

National Oilseeds and Vegetable Oils Development (NOVOD) Board is implementing a back-ended credit linked subsidy programme for promotion of tree borne oilseeds. Under this scheme 30% subsidy is provided for establishment of seed procurement centre, installation of an oil expeller, multipurpose pre-processing and processing facility, nursery raising and commercial plantation. Banks in coordination with NOVOD have provisions to implement this scheme.

2.9.3 National Autofuel Policy

The National Auto Fuel Policy, which was approved by the Cabinet on 10th March 2003, gives a roadmap for achieving various vehicular emission norms over a period of time and the corresponding fuel quality up-gradation requirements. The policy does not recommend any particular fuel/ technology for achieving the desired emission norms. But considering the practical implementation of the policy, without putting heavy burden on country's economy, needs domestic production of alternative fuel. The policy recommends that commercialisation of biofuel vehicles as one of the main ways to achieve energy security and avoid environmental issues in the transport sector. The policy recommends that technologies for producing ethanol / biofuels from different renewable energy sources and vehicles to utilize these biofuels would be encouraged in the country by providing R&D and other support through fiscal and financial measures. The committee, of course, could not recommend mandatory use of biofuels because of their limited availability in the country.

2.10 Legal Framework

The India Power Alcohol Act, 1948, the only legislation we had in India to promote the use of Power Alcohol[10], was recently repealed to make it more market driven, without diluting the very objective and spirit of the legislation for which it was enacted to make it a broader perspective.

In general, as far as the biofuels programme is concerned, there has not been any legal push till date. However, the existing legal framework in India has adequate scope to incorporate legal aspects associated with biofuels.

At the outset, it is of utmost importance to define the terms; 'biofuels', 'biodiesel' and 'bio-ethanol' in the Indian context as these definitions will have a direct relations with 'The Weights and Measures Act', 1976 and also 'The Motor Spirit and High Speed Diesel Order', 1998. This would therefore clearly lay down the scope and extension of various fuels under the term biofuels.

Any mismanagement in the blending process would have a direct impact upon the engine of the vehicle using the particular fuel. The Motor Sprit and High Speed Diesel (Regulation of Supply and Distribution and Prevention of Malpractice's) Order 1998 regulates the supply and distribution of motor spirit and high-speed diesel and lays down strict standards against adulteration. This is a notification made under Section 3 of the Essential Commodities Act for the purpose of tackling adulteration and malpractice in supply and preparation.

[10] *Section 3 (c) of the Indian Power Alcohol Act, 1948 says: "Power alcohol means ethyl alcohol containing not less than 99.5 per cent by volume of ethanol measured at 60 % F corresponding to 77.4 over proof strength."*

Also there exists a direct concern that these toxic oils can be used for adulteration in edible oil by illiterate farmers and people involved in oil extraction. The ‘Prevention of Food Adulteration Act’, 1954 protects consumers against adulterated foodstuffs.

The supply of these fuels must meet all the set standards in the supply of these fuels. With regard to the quality of the product, the ‘Bureau of Indian Standards (BIS) Act’, 1986 provides for standardization, marking and quality certification of goods. The product has to be notified under the BIS Act to ensure the quality of the product and to conform to such specifications for use as fuel in Vehicles.

Jatropha, being a toxic seed and the fact that oil extracted could result in allergic conditions to the workers, it is essential that proper knowledge about the safe handling of biofuels is made available to any person or corporation dealing with these fuels. The ‘Manufacture, Storage and Import of Hazardous Chemical Rules’, 1989 and ‘The (Amendment) Rules’, 2000, govern the manufacture, use and the storage of chemicals.

2.11 Summary

In India, the large-scale development of biofuels, including SVO, biodiesel and bio-ethanol, is still in its infancy. While SVO and bio-ethanol are commercially available, biodiesel is available only in small quantities. SVOs and biodiesel are being considered both for stationary and transport applications, bio-ethanol is being considered only as a transport fuel.

The main feedstock for production of bio-ethanol is sugarcane molasses; sweet sorghum is being considered as another feedstock to increase the production of bio-ethanol. For SVO and biodiesel, non-edible TBOs - Jatropha and Pongamia - have emerged as the favourite options, primarily because of their ability to grow on wastelands. The proposed National Mission on Biodiesel is primarily based on growing Jatropha on wastelands. The country has indigenous technology for oil expelling, small-scale trans-esterification and bio-ethanol production. Currently price of biofuels are not competitive to fossil fuels. But increase in the crude oil prices and technological advancements being made on the biofuel production can make these green fuels to economically vie with fossil fuels in the near future.

Though there is considerable interest amongst various stakeholders on biofuels, absence of a comprehensive policy on biofuels has impeded the progress. National Biodiesel Mission, though proposed in 2003, has still not got approval of the Government. Despite these setbacks, several state governments, private industry and some NGOs are going ahead with their projects on biodiesel. Bio-ethanol blending with petrol, which was made mandatory in 2003 in certain areas of the country, is currently on hold because of shortage of ethanol and a policy modification in 2004. Efforts are being made to find alternative crops e.g. sweet sorghum for enhancing bio-ethanol production. Research is also being conducted in developing a process to utilise agriculture residues for bio-ethanol production. It seems that till alternative feedstock are made available, the future production and use of ethanol for blending with petrol is not likely to register a significant change.

In India, there is no comprehensive legal framework for the use and promotion of the biofuels. In order to make use of biofuels as a viable and a sustainable fuel source for the greater good of the country, it is essential to have a legal framework that promotes, sustains, and takes care of the factors and actors involved in the program.

3 Biofuel Potential

This chapter examines the potential for biofuel development in the country vis-à-vis availability of land resource for biofuel plantations, cultivation techniques, advanced processing in extraction and trans-esterification stages. The economics of biofuel production is also covered.

3.1 Potential for Biodiesel

Biodiesel is emerging as an important biofuel option in India. There is a scope to increase biodiesel production by tapping existing resources of TBOs in the country as well as by taking up new plantations.

3.1.1 Availability of land

The availability of land is an important requirement for the large-scale national biofuel programme. The present strategy of the Central Government is to utilize wastelands for biodiesel plantations so as not to affect the food security of the country. However, several private industries and state governments are exploring the possibility of utilising agriculture land as well for biodiesel production.

3.1.1.1 Biodiesel plantation on wastelands

Biodiesel plantation on wastelands mainly depends on two factors; availability of wastelands and suitability of different agro-ecological regions for biodiesel plantations.

a) Wasteland availability

The 1995 report of the high level Mohan Dharia Committee on wastelands development analysed the land use statistics available for 305 million ha (mha) out of the 329 mha land area of the country, and noted that there was much confusion regarding the extent of wastelands (Table 3.1).

In the committee's view confusion arose from differing definitions of wastelands used by various agencies; also because these agencies failed to distinguish between lands which had gone out of productive use because of extreme degradation and lands which were still in use although these too were degraded to some extent.

As per the recent Wastelands Atlas of India [NRSA, 2000] of 392 million hectare (mha) area of the country about 63.85 mha of the area can be classified as wasteland (including 14.06 mha of degraded notified forest lands).

However, it would not be correct to assume that entire 63.8 mha of wasteland would be available for raising biofuel plantations under the National Biodiesel Programme. No estimate has so far indicated the number of people who live in the different categories of wastelands or how they use them, and its relevance for sustainability.

Table 3.1: Various estimates of wastelands

Source	Area (mha)	Estimated/ scientific
National Commission on Agriculture (NCA-1976)	175.00	E
Directorate of Economics and Statistics, Department of Agriculture and Cooperation	38.40	E
Ministry of Agriculture (1982)	175.00	E
Department of Environment and Forests (B.B. Vohra)	95.00	E
National Wasteland Development Board (Ministry of Environment and Forests, 1985)	123.00	E
National Bureau of Soil Survey and Land Use Planning, ICAR-1994	187.00	E
Society for Promotion of Wasteland Development (SPWD-1984)	129.58	E
National Remote Sensing Agency (NRSA-1995)	75.50	S
Dr. N.C. Saxena (Secy. RD-WD)	125.00	E

In addition to uncultivated wastelands which have been historically part of the farmers' holding, especially in *ryotwari*[1] semi-arid areas [Saxena, 2001], about 5.6 mha of wastelands has been allotted to many poor families under various programmes over the last 20 years (Ministry of Rural Development, Government of India, Annual Report 2000-2001). Besides, there are no records available with any government/local agencies on the extent of encroachments. Thus, substantial culturable waste area has been privatised, at times as a conscious policy outcome, although such lands may still be lying uncultivated.

Though productive use of wasteland is considered as an important component of the agriculture strategy in the mid term appraisal of the tenth plan, wasteland ownership becomes an important issue. The Approach Paper to the Mid Term Appraisal notes that in both forest and government owned wastelands, it is difficult to involve local communities unless land ownership is given to them. While the government may be able to promote plantation of TBOs on government or community land, for the privately owned wastelands it would not be possible unless the farmer's are offered assured returns or convinced of the financial viability of the raising biodiesel plantations.

[1] The ryotwari system was a system of revenue collection introduced by the British in which the government didn't act through any intermediary or zamindar, but maintained direct contact with the "ryot" or the president

Therefore, there is a need to exercise caution before one makes any assumptions about the potential of existing wastelands for raising biodiesel plantations.

b) Regional suitability

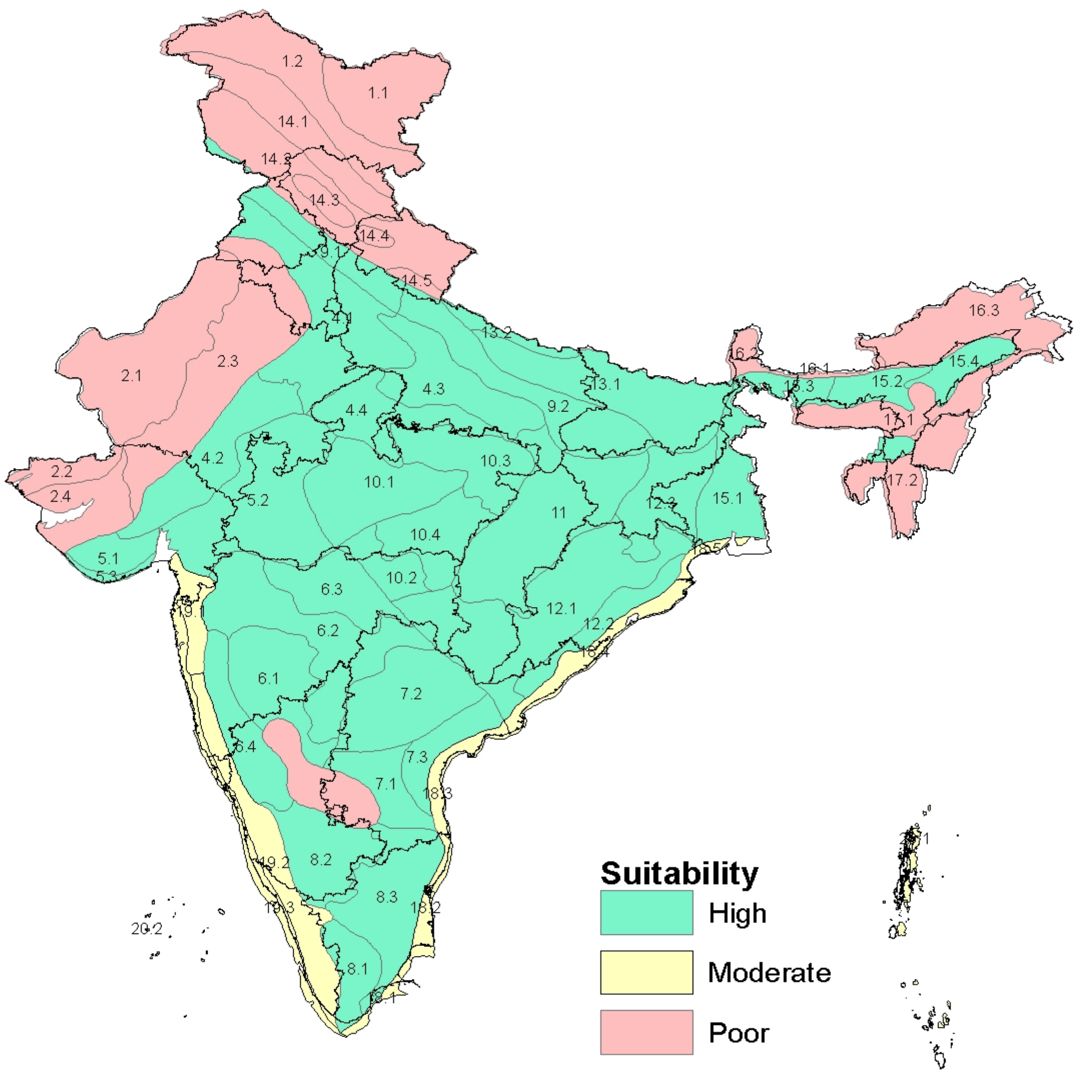
For identifying suitable regions for biodiesel plantations (jatropha and pongamia), agro-ecological regional approach evolved by National Bureau of Soil Survey and Land Use Planning (NBSS&LUP) is adopted [Sehgal et al, 1996]. The approach uses soil, climate and physiographic parameters for delineating areas into agro-ecological regions and sub-regions (Annexure 2). Using these parameters, an attempt was made to classify area suitable for jatropha and pongamia in three classes namely high, moderate and poor. These areas are marked in the map of India in Figures 3.1 (pongamia) and Figure 3.2 (jatropha).

Both jatropha and pongamia being hardy establish well in a variety of soil and climatic conditions.

Coastal areas were classified as moderately suitable for both species. They can be grouped in high as they grow well but there are other tree species, which are more profitable like 3 Cs (coconut, cashew and casuarina). It is highly unlikely that jatropha and pongamia will compete with these species. Arid and humid areas were classified as poor because both jatropha and pongamia will grow but seed setting and yield will be poor[4]. In arid areas there are limited options but humid areas have other options like bamboo, which performs well in these areas. Therefore, it is the semi-arid and sub-humid tropical areas, which are considered as highly suitable for plantations of jatropha and pongamia. Within semi-arid tropics, jatropha is preferable in semi-arid (dry) while pongamia in semi-arid (wet).

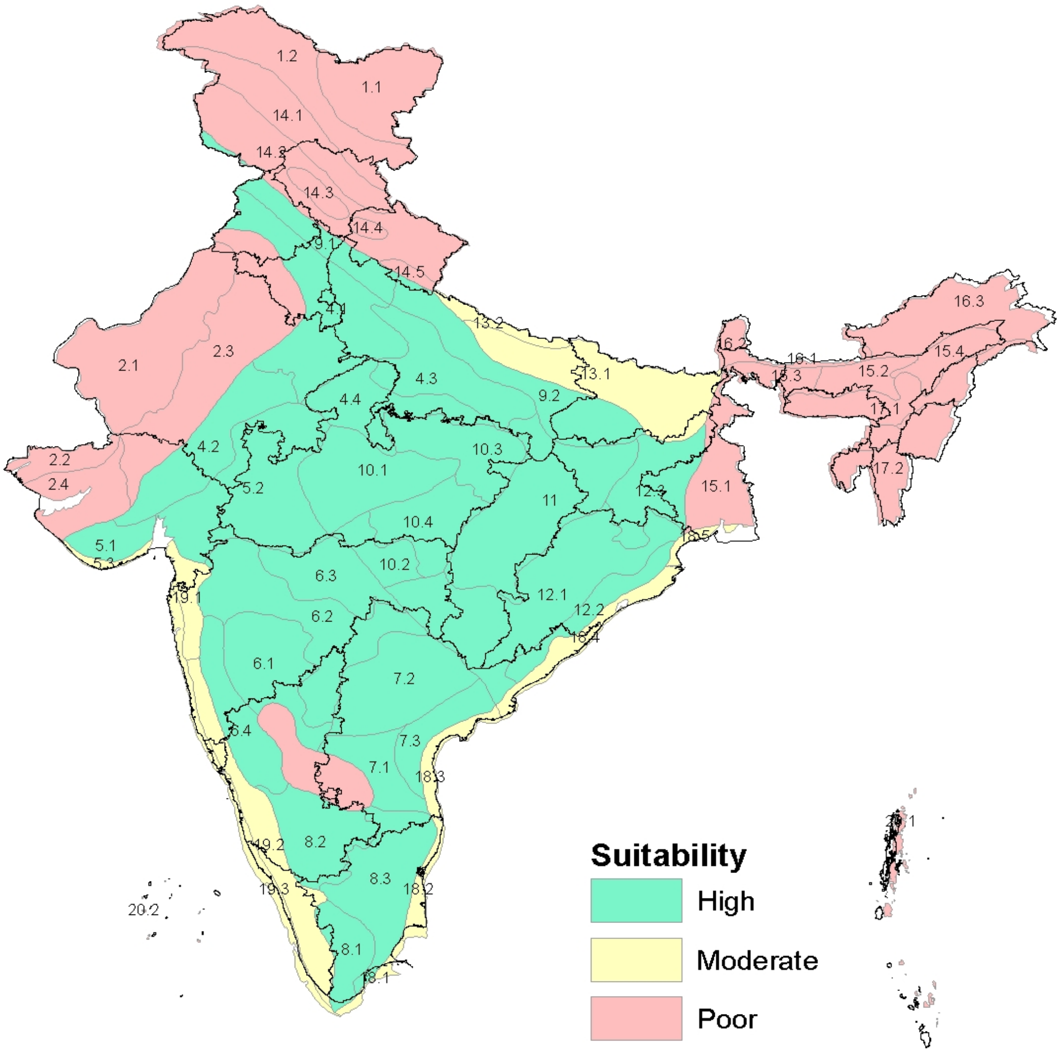
[4] *Areas based on the ratio of precipitation (P) and potential evapo-transpiration (PET), having a value of 0.03-0.2 are classified as arid, 0.2 to 0.5 semi-arid and 0.5 to 0.75 as sub-humid (Bruins et. al., 1986).*

Fig. 3.1: Suitability map for Pongamia



Area delineated using AESR map of NBSS&LUP, Nagpur (Sehgal et. al., 1996)

Fig. 3.2: Suitability map for Jatropha



Area delineated using AESR map of NBSS&LUP, Nagpur (Sehgal et. al., 1996)

3.1.1.2 Biodiesel plantation on agricultural land

a) Fallow lands

In dry land areas, substantial area is left fallow. In a study in red and black soil areas on Nalgonda and Ranga Reddy districts of Andhra Pradesh under watershed programme, it was observed about 30% of the watershed was left fallow [Osman, unpublished, 2004]. The Planning Commission has estimated that 10% of the total fallow land (24 million ha.) can be brought under jatropha plantation [Planning Commission, 2003].

b) Agro-forestry

Agro-forestry on farmlands can be used for promoting biofuel plantation without affecting crop production. The model of boundary plantation with Poplars in Punjab, Haryana and Western UP is highly popular and can be expanded to biofuel plantations as well. Pongamia in S. India and jatropha in several states is traditionally being grown as protective hedge around agriculture fields. The Planning Commission has estimated that 3.0 mha of land can be brought under biofuel plants by planting them as protective hedge around agriculture fields [Planning Commission, 2003].

c) Crop diversification

Diversification of agriculture should receive very high priority in North India, particularly Punjab and Haryana as intensive cultivation with wheat-paddy rotation has led to deterioration of soil health and depletion of underground water resources. An expert committee constituted by the Government of India to look into possible alternatives for crop diversification recommended that at least 20% of the area presently under rice and wheat should be replaced by competitive alternate crop/cropping systems/farm enterprises. Under crop diversification, oilseeds both edible and non-edible, could be considered as these crops require low inputs and less water compared to rice and wheat. However, optimum level of diversification can be achieved only if farms are offered practical, viable and economically attractive alternate land use options.

The Planning Commission, Government of India, based on the above mentioned factors, estimates that with appropriate extension and availability of planting stocks, it would be possible to cover 13.4 mha of land with *Jatropha Curcas* so as to meet the 5% blending requirement by the year of 2012. The category wise information on this estimate is given in the table 3.2 below.

Table 3.2: Planning Commissions estimates on potential area for Jatropha plantation

Type of land	Total area (Million hectares)	Area estimated for Jatropha plantation (Million hectares)	Assumptions
Forest Cover	69	3	14 Million hectares of forests are under the scheme of Joint Forest Management out of which 20% would be easily available for Jatropha plantation
Agriculture land	142	3	It is assumed that farmers will like to put a hedge around 30 million hectares for protection of their crops
Agro-forestry		2	Considerable land is held by absentee landlords who will be attracted to Jatropha plantation as it does not require looking after
Cultivable fallow lands	24	2.4	10% of the total area is expected to come under Jatropha plantation
Wastelands under Integrated Watershed Development and other poverty alleviation programmes of Ministry of Rural Development		2	
Public lands along Railway tracks, roads and canals		1	
Total area that can be brought under Jatropha plantation = 13.4 mha			
Source: Planning Commission, 2003			

For the demonstration phase of the National Mission on Biodiesel, jatropha plantations are planned on 0.4 million ha. State governments of Chhattisgarh, Uttaranchal, Andhra Pradesh, etc. have already started the process of identification of wastelands.

3.1.2 Availability of planting stocks

Jatropha can be propagated both by seed and by cuttings. But as the demonstration phase of the National Biodiesel Programme proposes to establish 400,000 hectares of jatropha plantations, the choice of planting stock will necessarily be seed, because cuttings would not be available in such huge quantities. For planting one hectare of land at a spacing of 2m x 2m (i.e., 2,500 plants per hectare), 5 kgs of seed is required. A total of 2,000 tonnes of seed would be required for raising plantation on 400,000 hectares. Since the programme is proposed to be implemented over three years, around 666 tonnes of seed would be required every year. Additionally, planting stocks will be required for entrepreneurs, private farmers and the jatropha programmes of several state governments. Though the quantity of the seeds may not be a problem, the price could be high. At present, jatropha seeds are being sold at a premium price ranging from INR 12-60/kg[2], this might increase further once the programme is launched.

It would also be essential to ensure that the seeds used are of high purity and have a high germination rate. For this, selection of superior germplasm from the existing population and to get seeds with superior genetic quality should be a priority.

The forest departments of Andhra Pradesh and Karnataka have undertaken a massive production of seedlings in recent years for pongamia plantations, largely in response to meet the biofuel demand. Andhra Pradesh state alone has plans to distribute 33 million plants and Karnataka state has planned for another 20 million plants during the year 2005-06.

3.2 Potential for Bioethanol

As already discussed in the previous chapter, sugarcane molasses is the main source of bio-ethanol production in India. Although in terms of sugarcane production, India and Brazil are almost equally placed, in Brazil, out of the total cane available for crushing, 45% goes for sugar production and 55% for the production of ethanol directly from sugarcane juice (Box 3.1). In India, about 60% of cane is utilized for the production of sugar, about 30% for alternate sweeteners, namely gur and khandsari, and the balance 10% for seeds. Thus only molasses produced during sugar production is available for ethanol production. Till such time when suitable alternatives, like sweet sorghum, are widely grown, the country's bioethanol programme would depend on sugarcane production.

The area under sugarcane is presently less than 2% of total cultivable area in the country and about 3% of the irrigated area. As already shown in Table 2.6, although the area under sugarcane has increased by 2.5 times since 1950-51, in the recent years, the area and the yield has stagnated as shown in Table 2.6. In 2002-2003, 4.36 million hectares of cultivable land were under sugarcane. The sugarcane area declined in the year 2003-'04 to 3.9 million hectares and to 3.7 million hectares in 2004-'05, mainly due to drought and pest attacks (Shree Renuka Sugars Ltd. 2005).

[2] *The mean-monthly sales price of jatropha seeds at Dahod Agriculture Produce Market Centre (APMC) in 2002-2003 was INR 78.57 / quintal. (Euler, H et at , 2004)*

Box 3.1: Bio-ethanol - Comparison between India and Brazil

India and Brazil both depend on sugar cane for bio-ethanol production. India is the second largest producer of sugar in the world after Brazil. During the year 2002/03, Brazil produced 28.4 million tonnes of sugar, compared to 20.4 million tonnes produced by India. However, in bioethanol production, Brazil is way ahead of India with annual production of 14.8 million cubic meters during 2004 compared to Indian alcohol production of about 1 million cubic meters during the same year

There are several important differences between Brazil and Indian sugar and ethanol production systems:

- *Area under sugarcane production*: While India has 3.9 million hectares of land under sugarcane production; Brazil has 5.6 million hectares land under sugarcane production.
- *Raw material for ethanol production*: While in Brazil almost 55% of the total sugarcane production is directly used for producing bio-ethanol, in India due to large domestic demand for sugar all the sugarcane is used for sugar, gur and khandsari production and only molasses is used for ethanol production.
- *Large farms v/s small farms:* While in Brazil almost 80-85% of the sugarcane supply comes from large farms owned by sugar mills, in India, most of the sugarcane supply comes from small farmers. The yields per hectare are much higher in Brazil; in addition, the variations in the yearly yield are small and the sugar and ethanol production units enjoy a stable supply of raw material. In India, the yield of sugarcane per hectare is low, in addition, large cyclic variations in sugarcane production are observed. The sugarcane production typically follows a 5 to 7 year cycle. Higher sugarcane and sugar production results in a fall in sugar prices and non-payment of dues to farmers. This compels small farmers to switch to other crops thereby causing a shortage of sugarcane, causing an increase in sugarcane prices. Farmers then switch back to sugarcane.
- *Size and efficiency of sugar and ethanol production units*: While the Indian sugar industry has grown horizontally with large number of small sized sugar plants set up throughout the country as opposed to the consolidation of capacity in the rest of the important sugar producing countries, including Brazil. While the average size sugarcane crushing capacity in India is only 3,500 TCD, in Brazil it is 9,200 TCD. The smaller and often old sugar plants in India have much lower efficiencies compared to the new and large sugar plants in Brazil.

Sources:

Indian Sugar, Vol LIV, No.9, December 2004
Indian Sugar, Vol LV, No.4, July 2005
Lucon Oswaldo, Bioethanol: Lessons from the Brazilian experience. Proceedings of the conference "Biofuel 2012: Vision to Reality", October 17-18, 2005, Organized by The Energy and Resources Institute, New Delhi, India.
Web-site www.fas.usda.gov, accessed on November 8, 2005

Sugarcane is one of the most significant commercial/cash crops grown by farmers in India, and there is considerable scope for increasing the area under sugarcane considering the fact that it is more profitable compared to other crops. The Planning Commission has visualized a conservative increase in area under sugarcane by 0.6 million hectares during the 10th Plan period, but considering past trends, the area under cane is not likely to exceed 5 million hectares.

However, sugarcane cropping is generally admitted to be resource-intensive. Only those farmers who have ready access to cash or credit, irrigation and water supply, fertilizers and pesticides can farm sugarcane. The sugarcane plant requires steady irrigation for its growing period of 18 months to 2 years, so subsistence farmers are unable to farm sugarcane since sole reliance on monsoon supplies is inadequate. Payment for sugarcane also comes in lumps, but only after the harvest has been crushed at a sugar mill. Therefore, only those who can survive on such a system of deferred payments plant this crop.

3.3 Methods of enhancing production potential of Biodiesel

3.3.1 Plant breeding

The aforementioned non-edible oil plants have never really been grown under plantations of any scale and for this reason, little plant improvement work has been carried out. Overall plant breeding programmes for jatropha should be targeted on the following:

- Development of early bearing varieties to reduce the gestation period.
- Development of high yieldingvarieties in terms of both seed yield and oil content and composition.
- Development of day neutral varieties so that seed production takes place through out the year or varieties that produce in the “off season” to reduce collection cost
- Development of dwarf varieties that can reduce collection cost as well as management costs incurred on pruning
- Modification in male to female flower ratio in cyme[5] to improve the yield
- Development of varieties that are more tolerant to adverse conditions, such as frost, salinity, alkalinity, water logging etc., so as to increase the range of growth / cultivation of jatropha.

As per the literature, tissue culture protocols were standardized for Jatropha curcas and optimised for both seedlings as well as mature plant parts [Sujatha, 2003]. There is a scope for improving oil content by hybridisation with non-toxic variety containing up to 60% oil. But apprehension about tissue culture plants is their survival rate in harsh environment, particularly wastelands. At the same time, tissue culture combined with application of bio-fertilizers like Mycorrhiza can increase the yield and reduce the gestation period (Box 3.2). Mutation breeding for crop improvement is one of the techniques to improve the yield. Therefore it would be worthwhile to extend the mutation breeding technique for the genetic improvement of jatropha and other non-edible oil crops.

[5] Cyme is a botanical term for a compound flower. Botanically defined as "a usually broad and flattish determinate inflorescence, i.e., with its central or terminal flowers blooming earliest".

Box 3.2: TERI's research efforts on enhancing biofuel production

TERI is undertaking a project entitled "Biofuel Micro-Mission Network Project on Jatropha" with the support from Department of Biotechnology, Government of India. The project aims at screening various Jatropha collections across the country for its oil content and composition. In another project with NOVOD board, different pongamia collections are also screened. While the standard seedling method of Jatropha propagation takes two years for the plant to yield. The year-long clonal culture-raised plantations take a year for the first yield. In addition, TERI has developed an unconventional method where mycorrhiza application speeds up the process and the first yield arrives after seven months of cultivation. Field trials are being conducted in seven different agro climatic zones across the country.

3.3.2 Processing technology

a) Detoxification of seed cake

Detoxification of the jatropha seedcake can lead to the increased value addition as the seed cake can then be used as cattle feed. Several investigations have revealed that de-acidification and bleaching could reduce the content of toxic phorbol esters to 55% [Haas et. al, 2000]. Efficiency of the treatment also depends upon the type of toxic component present in the seedcake. But more research needs to be carried out to develop effective detoxification techniques.

b) Oil extraction

Although oil extraction can be done with or without seed coat, for jatropha, utilization of a mechanical dehulling system (to remove the seed coat) can increase oil yield by 10%. Choosing efficient extraction methods can increase the yield by more than 5%. While in cold pressing (<60°C), around 86 – 88% efficiency is achieved, hot pressing (110 – 120°C) can increase it to around 90%. On the other hand, the solvent extraction method enhances the efficiency up to 99%. A disadvantage with the solvent extraction is that the quantity of phospholipids in solvent extracted oil is twice as high as compared to pressed oil. This necessitates a further step of oil degumming before trans-esterification.

Oil extraction methods are also being developed based on fermentation hydrolysis. In this process, cell walls of the oil plant seeds are destroyed followed by the release of the oil present within the cells [Janulis et al., 2004]. The destroyed almoners are released into the water phase, while the oil is separated using classical separation methods. This new method not only produces higher quality of oil and cake but also requires much less energy and results in lower levels of environmental pollution. The efficiency so far obtained is 86% and more research is needed to develop an effective enzyme system.

c) Enzyme based trans-esterification process

During alkali catalysed trans-esterification, naturally occurring FFA and those produced due to the hydrolysis of triglycerides lead to soap formation, which lowers the yield of biodiesel and renders the separation of biodiesel glycerol and the water washing difficult. In this context, recent research developments towards enzyme based trans-esterification holds promise for the future. Enzyme based process makes the separation easier and can handle high FFA feedstocks thereby enhancing the overall yield. It was reported that a direct methanolysis using an immobilized lipase is possible on the continuous mode [Bruce et al., 2004]. Researchers at US Department of Agriculture (USDA) Eastern Regional Research Centre have conducted bench scale experiments on biodiesel production using a variety of commercial enzyme preparations. As the cost of enzyme is very high, the technology is not being commercialised widely today. But research efforts to reduce the cost of production of enzymes are expected to contribute significantly to more effective and environment friendly biodiesel production process.

d) Trans-esterification on super critical fluids

Enzyme-based trans-esterification taking place in super critical fluid have several advantages. In this process, no catalyst is required and the reactions are complete within a short time of 2-4 minutes, compared to around 45 minutes required in the conventional process. Besides, the recovery of biodiesel is higher [Gerpan et al., 2005].

e) Co-solvent Process

Processes are also developed based on inert co-solvents that generate oil rich one phase system. The reaction is 95% complete in 10 minutes at ambient temperatures. Acid treatment for FFA is complete within minutes rather than several hours. The process can handle high FFA feedstocks rather easily and the reaction is very fast. It is claimed that the process cost can be cut down very significantly and make the biodiesel competitive with fossil diesel [Gerpan et al., 2005].

3.4 Methods of enhancing production potential of Bioethanol

3.4.1 Improved agronomic practices

Cost of sugarcane cultivation in India is high mainly due to flood method of irrigation (FMI) resulting in poor water use and problem of weeds. Drip method of irrigation (DMI) is a viable technology in sugarcane cultivation, which reduces the costs of electricity, water use and labour needed for weeding to the extent of 50 percent over FMI. This results in reduction of total cost of sugarcane cultivation of upto 18 percent (Rs. 3,450/acre) which can be attributed to the fact that water saving is high in DMI as water is supplied directly at the root zone (Narayanamoorthy, 2005). Consequently, the requirement of labour is less for managing irrigation, electricity consumption and weed problem is also reduced.

3.4.2 Alternative feedstock

Research and development initiatives for promoting alternate crops for ethanol production are in place. Sweet sorghum appears to be a promising option as it requires less water and fertilizer inputs (around 35-40% of that required for sugarcane) and has a short growing cycle of 3.5 – 4 months.

3.5 Potential of biodiesel as a transport fuel

3.5.1 Future diesel requirements

During 2003-04, the diesel consumption in the country was around 38 MT, out of which about 60% was used for transportation and rest was used in industries and agricultural sector. Due to the rapid increase in the demand for diesel and other petroleum products India's dependence on oil import is expected to rise to 92% by the year of 2030 (World Energy Outlook, 2000). To reduce India's dependence on oil imports and at the same time cut down on the import bill, it is important to develop renewable options like biodiesel to substitute fossil diesel. Table 3.3 below estimates of future demand of diesel in the country and calculates the amount of biodiesel required at various percentages of blends.

Table 3.3: Diesel demand and future biodiesel requirements

	Diesel requirement	Biodiesel @ 5%	Biodiesel @ 10%	Biodiesel @ 20%
2005	46.97	2.3485	4.697	9.394
2006	49.56	2.478	4.956	9.912
2007	52.33	2.6165	5.233	10.466
2010	66.07	3.3035	6.607	13.214
2020	111.92	5.596	11.192	22.384
2030	202.84	10.142	20.284	40.568

Source: TERI, 2002

3.5.2 Biodiesel production potential

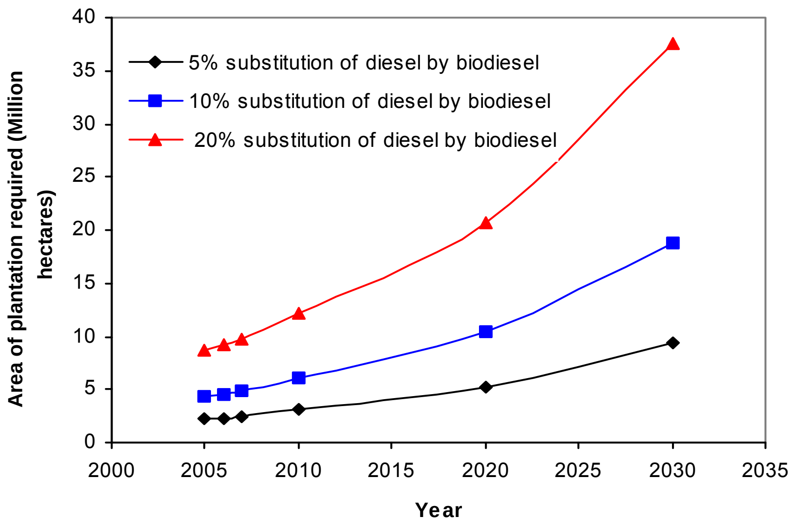
As mentioned in the section 3.1, while the total wasteland available in the country is 63.85 mha, it would be difficult to assess how much of this land would actually be available for planting biofuel plantations. Nevertheless, even if the entire 63.85 mha of wasteland is brought under jatropha plantation, and even considering a high yield of 5 tonnes per ha, only about 68.9 MT of biodiesel can be produced in the country (Table 3.4).

Table 3.4: Biodiesel production potential vis-à-vis different yield levels

Yield level (tonnes of seeds/ year)	Biodiesel production from 63.85 million hectares (MT)*
1	13.77
2	27.54
3	41.31
4	55.08
5	68.94
**Assumption: Biodiesel yield of 21.6% of the seed weight*	

Figure 3.3 depicts the area of plantation required for different blending requirements in different time frames. It can be seen that in order to meet the 20% blending requirements by 2030, 38 Million ha of wastelands have to be brought under biofuel plantation and yield has to be considerably increased to 5 tonnes/ha from the present yield level of 1 – 2 tonnes/ha. If the yield level is only 1 tonne per ha, bringing the entire 63.85 Million ha of wasteland under jatropha plantation would not be adequate to meet the target of 20% diesel replacement.

Fig 3.3: Land requirement for different blending percentages in different time frame*



**Yield is taken as 5 tonnes per hectare*

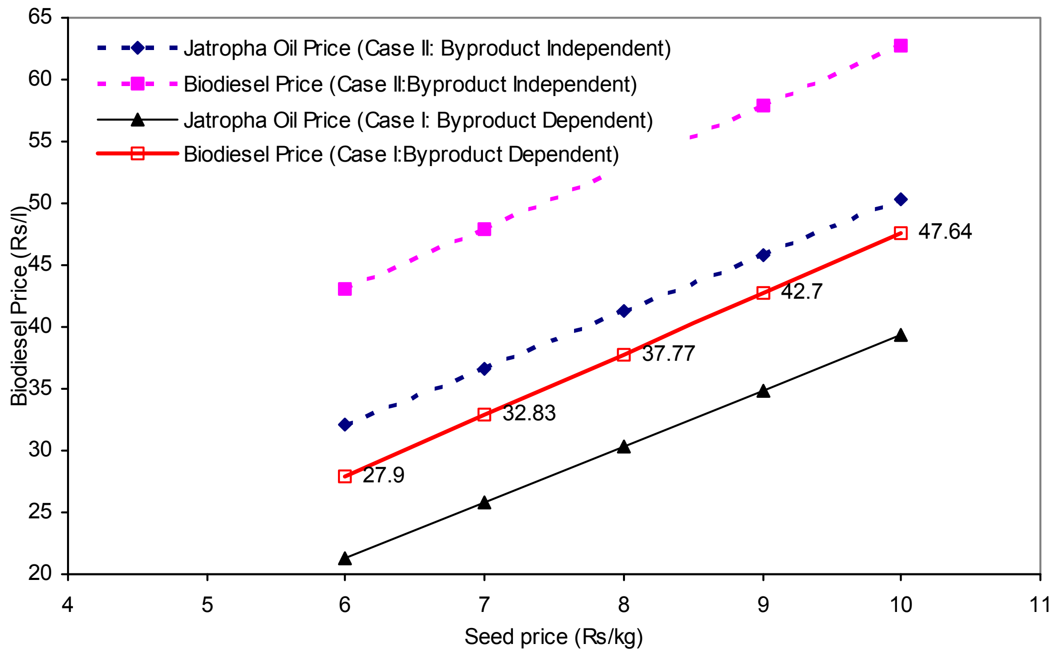
It is clear from the above discussion that biodiesel will not make any significant impact as transport fuel unless the present yields are increased substantially and larger areas of land are brought under biofuel cultivation. In this context, expansion of biofuel plantations in various edapho-climatic regions and the need for research innovations to improve the crop productivity in these regions are emerging as two main focal points that need to be addressed while implementing the biofuel programme.

3.5.3 Production cost of biodiesel: Variations with respect to seed prices and by-product value

Though biodiesel has several advantages in terms of better environmental performance and energy security of the country, economics of production is crucial for making the system sustainable. Two most important factors, which determine the production cost of biodiesel, are the procurement cost of the seeds and the selling price of by-products. Figure 3.4 depicts the significance of seed prices on the production cost of biodiesel.

In Case I, the by-product prices are assumed to be constant at INR 30/kg for glycerol and INR 4/kg for de-oiled case. In this case, when seed price ranging from INR 6 to 9/kg, the production cost of biodiesel will vary INR 28/litre to INR 48/litre. But future demand for by-products and steadiness in its prices are erratic. If biodiesel production goes up in the country, as anticipated, it is unlikely to see a constant demand and value for a huge quantum of by-products produced. Therefore, a by-product independent scenario assigning zero revenue from the by-products is presented in Figure 3.4 as Case II. It can be observed that in this case, the biodiesel production cost would increase by about 50%.

Fig 3.4: Sensitivity of Biodiesel production cost with respect to seed prices

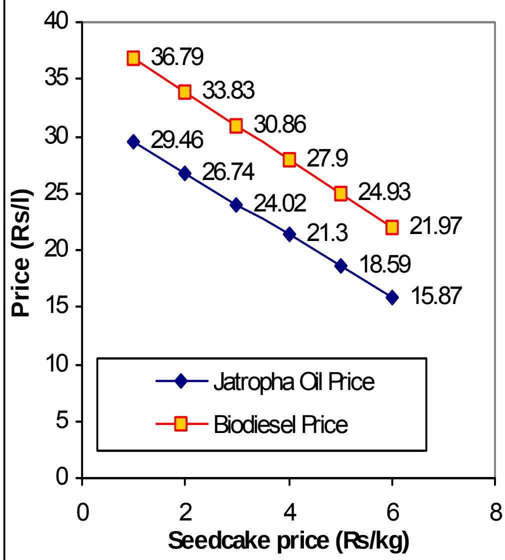


<u>Case I. By-product dependent</u>
Assumptions: Glycerol Price = INR 30/kg. Seedcake price = INR 4/kg; Oil yield = 24% of the seed weight (80% oil conversion); ; Amount of seed cake = 50% of the weight of seeds; Margin to the oil producer = 30%

<u>Case II. By-product independent (Value = 0)</u>
Assumptions: Oil yield = 24% of the seed weight (80% oil conversion); Margin to the seeds and oils = 30%;

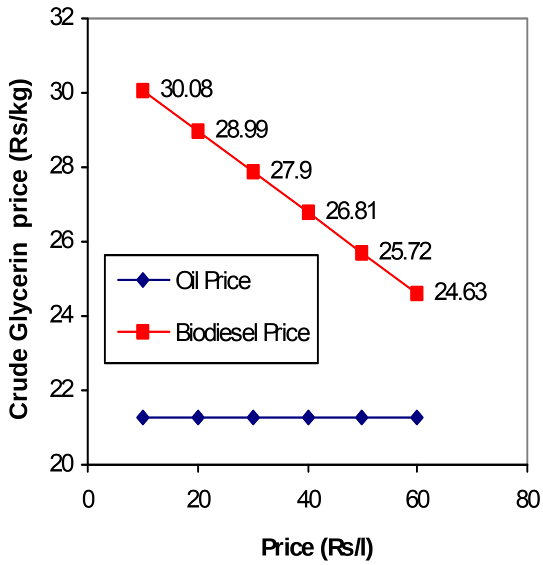
Figure 3.5 and 3.6 depict the variations in the biodiesel prices with the differences in the prices of by-products. It can be concluded that if one wants to make biodiesel production commercially viable, it is necessary to ensure a sustainable market for its by-products. In other words, biodiesel can only sustain synergistically along with the by-products.

Fig 3.5: Biodiesel price sensitivity to seed cake prices



Assumptions: Glycerol Price = INR 30/kg, Oil yield = 24% of the seed weight (80% oil conversion), Amount of seed cake = 50% of the weight of seeds, Margin to the oil producer = 30%, Seed price = INR

Fig 3.6: Biodiesel price sensitivity to glycerine prices



Assumptions: Glycerol Price = INR 30/kg, Oil yield = 24% of the seed weight (80% oil conversion), Amount of seed cake = 50% of the weight of seeds, Margin to the oil producer = 30%, Seed price = INR

3.5.4 Investment requirements for biodiesel production

The production of biodiesel includes nursery-raising, plantation in the initial stages followed by seed collection and seed procurement. The seeds are sent to the extraction plants where raw oil is extracted from the seeds and then sent to the trans-esterification plant where biodiesel is produced. The following table (Table 3.5) summarises the details of the costs estimated in the Detailed Project Report for National Mission on Biodiesel.

Table 3.5: Cost estimates for biodiesel production 22-tones/day capacity

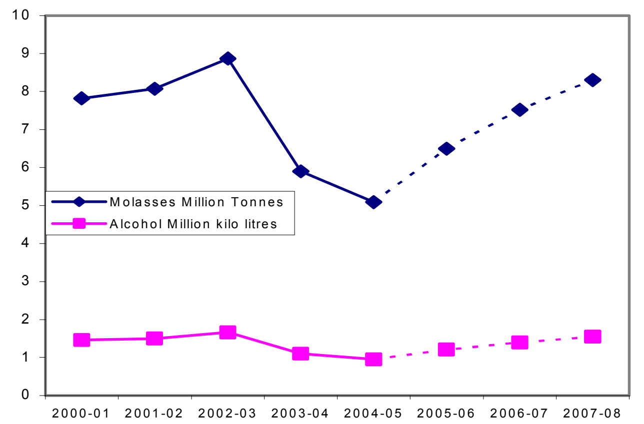
Total plantation costs for 20000 hectares	INR 524 millions
Capital costs for extraction plant (30 tonnes/day)	INR 213 millions
Seed storage cost	INR 44 millions
Raw oil storage cost	INR 0.35 millions
Biodiesel storage cost	INR 0.45 millions
Capital cost for trans-esterification plant (22tons/day)	INR 9 millions
Networking capital for plantation, extraction and trans-esterification stages	INR 797.8 millions
Total	INR 1,588.6 million
	Source: TERI, 2004

Thus, in all about INR 1.6 billion would be required for biodiesel production from 0.4 million hectares as proposed by the National Mission.

3.6 Potential of bioethanol as transport fuel

Maximum sugar and ethanol production was recorded in the year 2002-03. However, due to drought conditions, sugar-cane production and consequently the ethanol production dropped drastically during the period 2002-03 to 2004-05. As shown in Figure 3.7, molasses and ethanol production is estimated to rise and by the year 2007-08, production levels are expected to reach the levels attained during 2002-03 [Malhotra 2005].

Fig 3.7: Molasses and Alcohol Production in India



With gasoline demand expected to increase from 7.9 million tonnes in 2001-02 to 11.6 million tonnes in 2006-07, the requirement of ethanol at 5 per cent blending is expected to rise from 465 million liters to 682 million liters (GOI 2002). The current availability of molasses and alcohol is adequate to meet this requirement after addressing the needs of chemical industry and potable sectors (Table 3.6).

Table 3.6: Alcohol Production (in million liters)

Year	Molasses Prod.	Production of Alcohol	Industrial Use	Potable Use	Other Uses	Surplus Availability
1998-99	7.00	1411.8	534.4	5840	55.2	238.2
1999-00	8.02	1654.0	518.9	622.7	576	455.8
2000-01	8.33	1685.9	529.3	635.1	588	462.7
2001-02	8.77	1775.2	5398	647.8	59.9	527.7
2002-03	9.23	1869.7	550.5	660.7	61.0	597.5
2003-04	9.73	1969.2	578.0	693.7	70.0	627.5
2004-05	10.24	2074.5	606.9	728.3	73.5	665.8
2005-06	10.79	2187.0	619.0	746.5	77.2	742.3
2006-07	11.36	2300.4	631.4	765.2	81.0	822.8

Source: EthanolIndia

3.6.1 Production cost of bioethanol

As discussed in Chapter 2 (section 2. 7) the cost of production of bioethanol is directly related to the cost of sugarcane and molasses. If the cost of cane production can be brought down, it is likely to have direct impact on the price of molasses, thereby affecting the cost of ethanol production. As discussed, an important means of enhancing sugarcane production is to improve water use efficiency by using drip irrigation (Box 3.2).

Box 3.3: Effect of irrigation practices on sugarcane production cost

Disaggregate cost (break up) analysis indicates that @ 240 irrigations x 1 hour per irrigation x 5 Horse power (HP) of the pumpset, the requirement of total HP hours of water use for irrigating one acre of sugarcane is worked to be 1,200 under Drip-managed Irrigation (DMI) as against 2880 HP hours (@ 48 irrigation x 12 hr, irrigation x 5 HP of the pumpset) under Flood Managed Irrigation (FMI) and thereby water saving is accounted to be 58 percent (1680 HP hours) under DMI. This indicates that with the same amount of water used for irrigating one acre of sugarcane under FMI, about 2.40 acres of sugarcane can be irrigated using DMI. Water use per tonne of sugarcane (water use efficiency) is worked out to be 14.10 HP hours under DMI as against 52.40 HP hours under FMI and thereby gain over FMI is accounted to be 73 percent.

Electricity consumption on the other hand, is found to be as low as 900 Kwh under DMI as against 2,160 Kwh under FMI. While electricity use per tonne of sugarcane (electricity efficiency) is calculated as 39.30 Kwh under FMI, it is only 10.60 Kwh in case of DMI and thereby gain over FMI comes to 73 percent.

Added to the cost advantage, the productivity gain is also very high under DMI (85 tonnes/acre) when compared to FMI (55 tonnes/acre) accounting for about 55 percent (Narayanamoorthy, 2005). The benefit-cost ratio (BCR) at 15, 12 and 10 percent discount rates for drip-irrigated sugarcane are worked to be 1.97, 2.00 and 2.02, respectively.

3.7 Summary

There are many uncertainties about the production potential of biodiesel in the country. While on one hand the availability of wastelands for raising TBOs is a question mark, the present yield levels of 1-2 tonne per ha further constrain the production potential. Unless research innovations to improve the crop productivity are undertaken along with measures to tempt farmers to raise biofuelbiodiesel crops on private wastelands, biodiesel is not likely to make any significant impact as transport fuel. To develop biodiesel into an economically viable and significant option in India, biotechnological innovations to increase the seed yield are essential. The analysis presented in the chapter also shows that ensuring good prices for by-products is central to making biodiesel production an economically viable enterprise.

On the other hand, the main constraint as far as bioethanol is concerned is the dependence on molasses for bioethanol production. Improved agronomic practices for sugarcane cultivation, along with research on suitable alternatives would help provide this sector the required impetus.

4 Sustainability of Biofuel Development

With extensive debate on issues such as “food versus fuel” i.e. the possibility of energy-crop programmes competing with food crops and leading to shortages of food; and “net negative energy balance for biofuels”, i.e. energy consumption in biofuel production exceeding the energy output from biofuel, sustainability issues related with biofuels are far more complex vis-à-vis other renewable energy sources. The Chapter reviews the sustainability debate on Indian biofuel programme which has three main dimensions: food security, social and economic sustainability and environmental sustainability.

4.1 Food security vs. energy security

4.1.1 Food production: current scenario

India, with only 2.4% of the total land, 4% of the total water resource and 1% forest cover has to support about 16 % of the global population. The food grain production in the country has increased from an average of 187 MT during VIII Five Year Plan Period (1992-97) to 202 MT per annum during IX Plan period (1997 – 2002), despite the fact that the average area under food grain production had remained constant at around 122 million hectare (m ha). However, because of rapidly growing population, the average per capita availability of food grains declined from 174.9 kg per annum in the period 1989-1992 to 152.15 kg in the year 2001 (Table 4.1).

Table 4.1: Per capita food grain availability in India

Three-year Period ending in the year	Average Population million	Availability per Head per Annum of		
		Cereals (kg)	Pulses (kg)	Food grains (kg)
1992	850.70	162.83	12.1	174.9
1995	901.02	160.06	12.2	172.26
1998	953.04	162.08	12.0	174.08
2001	1008.14	151.80	11.6	163.40
Individual Year 2001	1027.0	142.55	9.6	152.15

Source: Economic Survey for years 1999-00 and 2000-01

Note: Availability is Gross Output less 12.5 per cent on account of seed, feed and wastage, and less net exports and net addition to public stocks. Output is for agricultural year from July-June: for example 1992 refers to 1991-92 and so on. Population figures for inter-censual years have been derived by applying the growth rate of 1.89 per cent per annum yielded by the 1991 and 2001 Census population totals. Population figure relates to the end of first quarter of the year against which shown.

4.1.2 Future food demand – supply scenario

Studies have shown that sizeable additions to population and higher economic growth would increase the demand for food in India. A recent study on cereal supply and demand for India in 2020 has indicated cereals shortages of different magnitudes under varying per capita income (PCI) growth rates and supply-related assumptions (Table 4.2).

Table 4.2: Projected cereals shortages for India in 2020

Supply scenario	Total net supply (MT)	Demand for food & feed		
		PCI		
		2%	3.7%	6%
Total demand (MT)		257	296	375
		Cereals shortage, MT		
Based on historical trend (1965-93)	321	64	25	-54
Increased nutrient & irrigation use	232	-25	-64	-143
Plus improved genetic/ technical efficiency	260	3	-36	-115

Source: Bhalla et.al. 1999

As per a report of Ministry of Statistics and Programme Implementation, the per capita income in India has been steadily growing over the last five years. The annual increase has been 6% in 2000-01, 7.7% in 2001-02, 6.8% in 2002-03, 10.2% in 2003-04 and 11.1% during 2004-05. From the above discussion, it is evident that India will be facing a challenging task of increasing its food production by over 50% in the next two decades. In such a scenario, any programme involving large-scale development of biofuels has to ensure that it does not compromise the nation's food security.

4.1.3 Food production- energy relationship

The rise in agricultural output would demand higher energy requirements for various farm operations. With increasing dependence of agricultural operations on fossil fuel for tillage, plant protection, harvesting and threshing, transportation, and electricity for irrigation, there is a direct link between energy security and food security (refer Box 4.1).

India has about 56% arable land, most of which is used only for about three months during the monsoon period. If enough energy for irrigation is available in the villages, the current production of about 200 MT of food grains and 100 MT of fruits and vegetables can easily be obtained from a much smaller area by multiple cropping. This would release a part of the land for raising TBOs [Shrinivasa, 2004].

Box 4.1: Power availability in farms

A study carried out in a dry-land village of Anantapur in Andhra Pradesh in 1988-89 and 2004-05 indicated that farm power availability increased by 28% over base year (1988-89). In terms of source of power, contribution from human and animal sources decreased by 34% and 68%, respectively. Use of mechanical power increased by 730%, implying that agriculture is now increasingly relying on mechanical power rather than animal and human.

Source: CRIDA, 2004

At the same time, about 125,000 villages in India are non-electrified; even in those that are electrified, electricity supply is poor, erratic and unreliable. In the absence/shortage of electricity a large number of farmers depend on diesel pump-sets for irrigation. Development of biofuels can help substitute a part of this energy requirement.

4.1.4 Implications of biofuel plantations

a) Tree Based Oils

Traditionally Pongamia and Jatropha have been planted along the field boundaries as live fences and are not known to significantly affect the crop productivity. The block plantations of Jatropha and Pongamia are proposed to be restricted to degraded notified forestland as well as marginal agricultural land which is mostly fallow (current or old) or cultivable wastelands. Unless these plantations spread to productive lands, it is too early to say that it will have any ramification on food availability.

In fact, waste and marginal agricultural lands need tree cover for protection against further degradation by water and wind erosion. The presence of tree cover is likely to improve the soil health through litter fall, recycling of nutrients from deeper layers and nitrogen fixation in case of legumes (Pongamia). In a study at Hyderabad, Jatropha had a leaf fall of 2,431 kg/ha/year, which returned 19 kg nitrogen to the soil [Rao and Korwar, 2003]. Besides soil fertility, addition of organic matter will improve the soil physical properties too. In the long term, due to soil improvements, wastelands under Jatropha/Pongamia plantations may be brought back into agriculture.

The oil extracted can be used for pumping irrigation water and for various farm operations using tractors and machinery. The availability of this new energy source can play a very important role in achieving the desired growth rate in food production. Self-reliance can be achieved at village level provided adequate area is earmarked for raising plantations and infrastructure is created for processing.

The seed cake is rich in NPK and micro-nutrients and serves as an excellent balanced organic fertilizer, thereby saving fertilizer and its subsidy. In a study, it was observed that use of Pongamia cake improved the maize grain yield by 87% over the farmers' practice (Wani, 2005). Recycling the seed cake rich in nutrients can further minimize the dependence on external input like fertilizer.

b) Sugarcane

The heavy requirement of water for sugarcane cultivation is one of the major question marks hanging over extension of areas to sugarcane development. With 310 of the 470 districts in the country categorized as overexploited vis-à-vis groundwater availability (GOI, 2002), judicious use of water resources is important from future food security perspective. Many argue that the allocation of vast quantities of a precious resource to a cash crop has had serious negative consequences for agriculture as a whole. The example of even well-endowed states like Maharashtra in western India is instructive. Sugarcane in Maharashtra state is the major cash crop, but it is actually grown in drought-prone areas. This has meant the development of expensive artificial irrigation projects. Sixty percent of the water from these projects is now used to irrigate 500,000 hectares of sugarcane-growing land (which amounts to 3% of the cropped area in the state), negatively impacting the other crops. In addition, water use for sugar cultivation also reduces water available for meeting social needs. Women in surrounding villages walk upto 15 kilometres to collect water drinking, cooking and domestic use (CABI/WWF, 2004).

Biofuel development also has implications on rural livelihoods, as it will provide new employment opportunities in rural areas, which can help in increasing local income and their ability to buy food and thus, achieve food security[1].

The issue of energy security v/s food security is complex and requires detailed analysis. For carrying out such an analysis, detailed data on economics of biofuel production in different regions of the country is needed, which is not available as of now.

4.2 Socio-economic aspects

This section is largely based on the study team's field observations made during the preparation of various case studies, across the country, during July-August 2005

4.2.1 Employment generation

One of the important objectives of the national mission on biodiesel in India is generation of employment in rural areas. It is estimated that one hectare of Jatropha plantation will generate 313 person days in the first year itself [TERI, 2004]. Another study [Becker and Francis, 2005] estimates around 200 person days of employment generation per hectare during the first year and about 50 person days in the subsequent years.

As far as sugarcane cultivation is concerned, about 50 million sugarcane farmers and a large number of agricultural labourers are involved in sugarcane cultivation and ancillary activities, constituting 7.5% of the rural population. Besides, the industry provides employment to about 2 million skilled/semi-skilled workers and others mostly from the rural areas. (Source: ISMA Website, 2005.)

Integrated Tribal Development Agency (ITDA), Adilabad has promoted a biofuel project at Powerguda, a remote tribal hamlet in Adilabad district of Andhra Pradesh. The project has resulted in increase in income to an average of INR 27,821 (2002-03) from INR 15,677 (1999-2000) per family. In 2003, the four self help groups (SHGs) of the project had INR 552,000 as total savings, which works out INR. 6,608 per household. This has released them from the clutches of money lenders and now, they are in a position to directly approach banks for loans.

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[1] *Food security and poverty are strongly co-related. Poverty is the main cause of food insecurity, and insecurity is also a significant cause of poverty (Panjab Singh, 2004). Thus apart from increasing the food grain production there is a need to focus on employment generation and livelihood security. Biofuel product ion provides an opportunity to generate new employment opportunities.*

Box 4.2: Promoting local level entrepreneurship in biofuel development: Experience of Samagra Vikas

Samagra Vikas, an NGO, has promoted oil-expelling units of around 500 kg/day capacity through local entrepreneurs. One such unit was established in Tumkur district. The experience generated through this pilot project indicates that such expelling units provide direct employment to 2 persons, involved in the operation of the oil-expeller and generate an income of INR 2,000 per month per person for 12 months. It also provides indirect employment to about 25 families involved in seed collection and seed supply. These families are supplying oil seeds directly to the oil-expelling unit at the rate of 200 kg per month per family. Taking the prevailing market price for Pongamia seeds in Tumkur market as INR 7/kg, each family can earn on an average around INR 1,400/month.

In Raichur district, Samagra Vikas is working with 75 village level cooperative societies for seed collection, and has promoted trial running of 5 jeeps and 5 diesel engines for irrigation purposes.

In parts of the selected districts of Karnataka, Pongamia oil is used by blending with the diesel in the proportion ranging from 10 to 30% for tractors, generators, and pump sets.

The Uttaranchal State government is focusing on Jatropha plantation on community land/waste lands and degraded forests by giving management of 2 hectares of land for raising Jatropha to each ‘Below Poverty Line’ (BPL)-family. According to the Uttaranchal government, since 2004, jatropha plantation has been taken up in about 10,500 hectares and in all about 5,000 BPL families have benefited.

The collection of non-edible oil seeds from existing trees in forests and common lands can provide additional employment opportunities for the rural poor. As mentioned in section 2.2, only a small part of the available resource is collected at present, and there is a scope for increasing collection. Further, employment opportunities exist for rural educated youth wanting to take up value addition to improve their income.

4.2.2 Creation of localised opportunities

Decentralized development of biofuels provides an opportunity for promoting local level entrepreneurship by offering opportunities for developing linkages from seed collection-process-use in the rural areas. The experience of Samagra Vikas described in Box 4.2 underlines such possibilities.

The potential for engaging women in raising nurseries and in collection of TBOs as part of biofuel initiative could lead to their enhanced participation in the village economy. This is indicated by some of the pilot projects in which active participation of women was encouraged.

In a pilot project implemented by Gram Vikas and CTx GreEn, and supported by the World Bank Development Market Place, two village level biodiesel plants have been established in Orissa. In this project women have been trained in biodiesel production process and have played a major role in the planning and implementation of the project. The biodiesel would be used for operation of water pump for village water supply system as well as power generation.

The Integrated Tribal Development Agency (ITDA) in Adilabad District of Andhra Pradesh has promoted the participation of women in its biofuel initiative. In the villages Powerguda and Kommuguda the work of managing the oil expeller, raising nursery and plantation activities were all done by the women's SHGs. In the year 2004 and 2005, the women's SHGs raised 20,000 seedlings of Pongamia and Jatropha. While half of the seedlings were sold to forest department @ 3 INR/seedling, the rest were planted on the field boundaries, farm bunds and community owned lands. These women are also members of the Forest Protection Committee - locally known as Vana Samarakshana Samithi, (VSS) - which is responsible of the management of forest area.

In Shimoga district of Karnataka, Samagra Vikas, with the help of the Forestry Department, have promoted nursery activities to raise 50,000 Pongamia plants and 30,000 neem plants which were planted and raised with the help of 175 women's self-help groups (SHGs). Such initiatives help provide women an opportunity to contribute towards household income as well as become active participant in village development activities.

4.2.3 Economic viability

Financial and economic analysis of biodiesel projects are part of several of the planning studies on biodiesel e.g. Detailed Project Report for the National Mission on Biodiesel [TERI, 2005] as well as the schemes prepared by state governments of Uttaranchal and Andhra Pradesh (Annexure 3).

Some private companies have worked out cost-benefits of Jatropha cultivation. They have indicated up to a net profit of INR 30,000 in the first year to INR 100,000 in the 5th year per hectare. On the other hand, the National Bank for Agriculture and Rural Development (NABARD), in its State Level Technical Committee Meeting (held on 15th May 2004), indicated an income from 1 ha of Jatropha plantation as INR 5,000 in the 3rd year and INR 25,000 from 8th year onwards (Table 4.3). The costs-benefits of jatropha plantation as worked out by the state government of Andhra Pradesh are given in Annexure 4.

Table 4.3: Estimations of NABARD on yield and income levels from Jatropha cultivation

Year	Seeds/ tree in kg	No of trees/ha	Quantity of seeds (in kg)	Cost Rs/kg	Total income
3	0.5	2000	1000	5	5000
4	1.0	2000	2000	5	10000
5	1.5	2000	3000	5	15000
6	2.0	2000	4000	5	20000
7	2.0	2000	4000	5	20000
8th year onwards	2.5	2000	5000	5	25000

The experience of farmers at Nashik and Andhra Pradesh shows that with the present levels of yields, growing of Jatropha on farmland may not be profitable. Some 5,000 acres of Jatropha plants promoted by local farmers cooperative during 1990s, was uprooted due to low yields and non-remunerative prices in Nashik district of Maharashtra state. In Khammam district of Andhra Pradesh, farmers uprooted Jatropha in some 200 acres when they did not get the promised buyback prices from a local company. Farmers, we were told, were offered only INR 2-3 per kg of seeds, against the promised INR 6-8 per kg. The experience of two farmers in Krishna district, who were interviewed by the project team is given in Box 4.3.

Box 4.3: Jatropha on good quality farmland: experience of farmers in Krishna district, Andhra Pradesh

Sri Mohan Rao, and K.V. Durgaprasad are among many enterprising farmers in Krishna District of Andhra Pradesh. Two years back, in 2003, KCP Sugar Mills-Vuyyur, distributed free of cost 5,000 plants per farmer to a few farmers. Each farmer planted 5,000 Jatropha plants in 2 hectares of land. The farmers were promised an income of INR 62,500 per hectare.

After 18 months, farmers collected about 100 kgs of seeds from five acres by incurring a labour cost of INR 10/kg of seed collected. In return they only got INR 6/kg as seed price, thereby incurring a net loss of INR 4/kg of seed collected. Although the farmers were satisfied with the plant growth, they were dissatisfied because of poor yield levels and financial returns. The problem was, the picking has to be carried out several times a year, as seed capsules do not mature at one time.

The disappointed farmers suggested that block plantations of Jatropha curcas on fertile lands should not be encouraged. They should be grown in wastelands, common lands, and as hedge plants and poor / landless should be allowed to collect the seeds, as in the case of minor forest produce.

Farmers are wary of the bad experiences like that of oil palm in coastal areas, Acacia mangium, and Annato (Bixa orellana) in Southern India. There is need to protect the interest of the farmers in initial years as the model is new and there are apprehensions which can be overcome by providing Minimum Support Price (MSP) which may be decided after assessing the cost of cultivation, gross and net returns. The procurement price of INR 6/kg offered by industries like M/S Natural Biodiesel in Andhra Pradesh is a welcome sign. In a feedback session organized at ICRISAT, the farmers from the rainfed areas of Medak, Kurnool and Cuddapah of Andhra Pradesh expressed their willingness to take up cultivation of Jatropha provided they were offered a buyback price of atleast INR 6/kg. On the other hand farmers from fertile and water abundant Krishna district in coastal Andhra Pradesh cited a minimum buy back price of INR 10/kg.

The price offered by the industry is going to play a major role in the acceptance of biofuel crops among the farming community. Poplar-based agro-forestry model or Eucalyptus-based farm forestry models became successful models of diversification just because the industries were able to provide remunerative prices to the farm based wood products. Taking the case of cost-benefit for the Pongamia oil production based on the discussions with oil extractors in Tiptur and Kolar districts of Karnataka, it is evident that if one takes into account the returns from seed cake sale, there is a considerable margin in oil extraction at present prices (Box 4.4).

Box 4.4: Cost-Benefits of Pongamia oil production in Karnataka

Discussions with oil extractors in Tiptur and Kolar indicated the following cost and benefits:

- Seasonal procurement cost of seeds INR 6,000/tonne
- Processing costs Rs 1,500/tonne
- As 4 tonnes of seeds give 1 tonne of oil, the production cost is INR 25,500/tonne
- In the process they get 75% or 3 tonnes of seed cake as output
- Total seed cake market price INR 16,500 for 3 tonnes @ INR 5,500/tonne
- The net production cost of the Pongamia oil is INR 25,500 - INR 16,500= INR 9,000/tonne

Against the net production cost of INR 9,000/tonne, the prevailing selling price of Pongamia oil is INR 28,000/tonne.

Source: Information collected from Samagra Vikas and during the field visit to Tiptur

At the same time, financial support and forward and backward linkages are essential to promote diversification and government needs to act as facilitator in the initial stages (Box 4.5). The Government of Andhra Pradesh, under Rain Shadow Area Development Programme, has shown an inclination to act as facilitator to protect the interest of the farmers. Under this programme around 500 Mandals of 10 districts are identified to develop 200 ha/year of Jatropha plantation in each Mandal. Thus, from 2005 the state has embarked on developing some 0.1 million ha of biofuel plantations every year for the next 10 years. This scheme provides a subsidy of INR 90,000 per ha (both for plant material and drip irrigation, or INR 30,000 for just plant material), to cultivate at the rate of 2,500 plants/ha. NABARD is supporting this programme by offering loans to interested farmers. In addition, the National Insurance Company provides Jatropha cultivators with crop insurance support.

Box 4.5: State support to biofuel development: Case of ITDA, AP

Integrated Tribal Development Agency in Andhra Pradesh have initiated block plantation schemes to provide assured returns to poorer sections of the society. The agency has tied up with local industries to provide technical know-how and marketing facilities. In the process, while the agency arranges for identifying the beneficiaries and identifies contiguous land, the industries provide plant material and help the farmer in land preparation, supervision, and establish buy-back arrangements. For example, assumptions are made on yield from 3rd year onwards for the next 30 years. The agency is planning (but not decided) on buy back rates of seeds and oil extraction process and oil selling rates. Largely the current focus is on Jatropha, though Pongamia is widely grown in the hilly areas of east coast and other plain areas of the state.

Source: D'Silva, 2004

In addition, there is a possibility of earning carbon credits for biodiesel project under the clean development mechanism. Under the Rain Shadow Programme in the state of Andhra Pradesh carbon sequestration through Jatropha plantations and green house gases emission reductions from bio diesel ensures carbon credits of INR 6 billion per year for 10 years. The returns from carbon credits assumed are not at the current market rates, but will be subjected to scrutiny at the time of exercise of the option. The possible revenues from the project could be escrowed by financial institutions/bankers for lending and direct project related revenue insurance to farmers for 0.6 million hectares.

4.3 Environmental aspects

A life cycle environmental impact assessment for biodiesel would cover analysis of all the environmental impacts occurring during the entire biodiesel production and utilization cycle. The seven stages of biodiesel production and utilization, which are considered, are:

- Plantation of Jatropha/ Pongamia
- Transportation of seeds to crusher
- Crude oil extraction
- Crude oil transportation
- Trans-esterification
- Biodiesel transport
- Biodiesel utilization

4.3.1 Energy and carbon balance

Life cycle energy balance analysis is one of the ways to quantify environmental impacts of biofuels. Such a calculation can lead to evaluation of energy yield ratio, which is defined as:

Energy yield ratio = Energy output (calorific value) / Total energy used for fuel production.

The total energy used for fuel production consists of:

- Energy consumption in agriculture, which includes direct energy consumption (petroleum products and electricity) and indirect energy impact (energy accumulated in fertilizers, chemicals, tractors and agricultural machinery);
- Energy consumption in oil seed processing (pre-treatment of oil seed and oil extraction) and conversion into biodiesel (trans-esterification reaction).

Energy yield ratio for various types of biodiesel in Europe is given in Table 4.4.

Table 4.4 Energy yield ratio for rapeseed esters in Europe

Country	Type of biodiesel	Energy yield ratio
Lithuania	Rapeseed oil methyl ester Rapeseed oil ethyl ester	1.43 – 2.28 1.62 – 2.66
European Union	Rapeseed oil methyl ester	1.9
France	Rapeseed oil methyl ester	1.9
		Source: Janulis, 2004

In all these cases the energy yield ratio is greater than 1, which shows that the biodiesel fuel energy is more than the total energy used for fuel production. The study further states that use of bio-fertilizers in place of chemical fertilizers can result in substantial increase in energy yield ratio.

Detailed analysis of energy used in biodiesel production and life cycle energy balance calculations are not available for Indian biodiesel. The life cycle energy balance is a function of agro-climatic conditions, agriculture and processing technology used. Therefore, there is a need to carry out a detailed energy analysis for Indian biodiesel for different feed-stocks and processing technologies.

All the biofuel crops fix carbon by photosynthesis via the carbon cycle. This carbon is emitted back into the atmosphere when the biofuels are burnt. Hence, there is no net addition of $CO2$ in the atmosphere due to burning of biofuels. If the biofuels are used to replace petroleum fuel, it would result in the net savings in $CO2$ emissions. It is estimated that 1 tonne of biodiesel produced or consumed, avoids emission of green house gases, equivalent to 3 tonnes of $CO2$ [Panigrahi and Reddy, 2004].

In case of sugarcane based bio-ethanol, the fuel life-cycle in Brazil estimates energy input/output ratios ranging between 8.3 and 10.2 (Lucon et al., 2005). Recent Australian life-cycle analysis work has revealed that 10% blends of bio-ethanol are considered green house gas neutral (CPCB, 2002). In case of sugarcane, avoided emissions of green house gases are 2.7 kg of $CO2$ equivalent per litre of anhydrous bio-ethanol. Thus bio-ethanol is definitely an efficient feedstock in terms of replacement of fossil fuels and carbondioxide emissions mitigation.

4.3.2 Nutrient recycling and impact of fertilizers

For getting the higher yields of oil-seeds from Jatropha/Pongamia plantations, some fertilizer inputs would be necessary. The application of fertilizer would depend upon the nutrient availability in the soil and the fertilizer inputs would vary from region to region.

Jatropha has been found to respond better to organic manure than to mineral fertilizer [Francis et al., 2005]. As mentioned in Chapter 2, de-oiled cake from non-edible oil seeds is a good organic fertilizer and is widely used in agriculture. The seed cake is rich in NPK and micro-nutrients and serves as an excellent balanced organic fertilizer, thereby saving of fertilizer and its subsidy. In a study undertaken by ICRISAT it was observed that use of Pongamia cake improved the maize grain yield by 87% over the farmers' practice [Wani, 2005]. Hence, a large part of the fertilizer requirement for biofuel plantations can come from the organic fertilizer derived from the de-oiled cake. To ensure that the de-oiled cake after oil expelling is given back to farmers, decentralized oil expelling needs to be promoted.

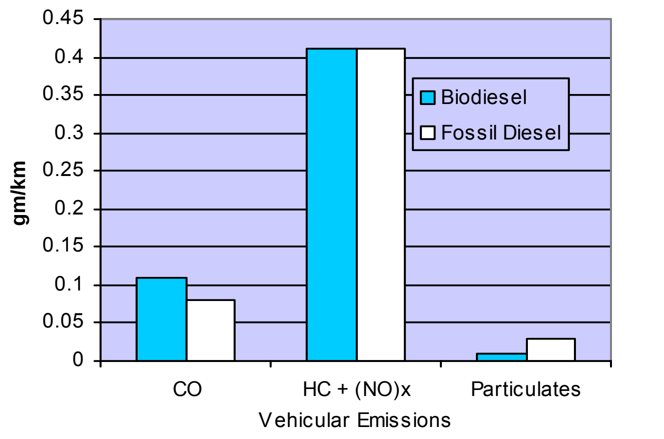
An alternative way of achieving higher yields in Jatropha is the application of mycorrhizal bio-fertilizer [TERI, 2005]. This group of bio-fertilizer is highly plant beneficial and offers a range of benefits like higher uptake particularly of phosphorus, nitrogen and other micronutrients along with rendering stress tolerance and disease resistance. Thus a combination of organic manure and bio-fertilizer can help reducing the dependence on chemical fertilizers for biodiesel crops.

Jatropha and Pongamia plantations on wastelands have the potential to improve the land and bring back these lands under agriculture production. Presence of tree cover is likely to improve the soil health through litter fall, recycling of nutrients from deeper layers and nitrogen fixation in case of legumes (Pongamia). Besides soil fertility, addition of organic matter will improve the soil physical properties too. Once the plants have established themselves and have fertilized the soil, their shade can be used for intercropping of shade-loving vegetables that can provide additional income to farmers [Francis and Becker, 2005]. In addition the tree cover protects the waste and marginal agricultural lands from further degradation by water and wind erosion. The Uttaranchal Biofuels Board has plans to promote water harvesting practices like creating water collection ponds along the contours and planting of aromatic grasses to improve moisture regime, in the waste lands to be brought under Jatropha plantations. These measures will further help in restoring the marginal land.

4.3.3 Air pollution

Central Pollution Control Board [CPCB, 2002] reported that the use of biodiesel in a conventional diesel engine results in substantial reduction of unburned hydrocarbons, carbon monoxide, and particulate matter. Emissions of nitrogen oxide increase by around 13%. Biodiesel decreases the solid carbon fraction of particulate matter (as the oxygen in the fuel enables more complete combustion into CO_2 and eliminates sulphur dioxide (as there is no sulphur in biodiesel). Emission tests for operation on neat (100%) biodiesel operation and on fossil diesel (B S II Altermann reference fossil diesel) were carried out at Automobile Research Association of India (ARAI) on Mercedes Benz cars during the CSMCRI – Daimler Chrysler project. The results show substantial reduction in particulate matter emissions as well as reduction in un-burnt hydrocarbons. However, a marginal increase in carbon monoxide and nitrogen dioxide were

Fig. 4.1: Emission comparison between biodiesel and fossil diesel



observed [Figure 4.1]. Further emission testing for biodiesel use in heavy machinery, stationary engines and cars is planned in the project.

Tests by the United States Environment Protection Agency (USEPA) with 100% biodiesel (produced from soybean oil) shows, reduction of particulate matter by 40%, un-burnt hydrocarbon by 68%, carbon monoxide by 44%, sulphates by 100%, poly-cyclic aromatic hydrocarbons (PAHs) by 80%, and the carcinogenic nitrated PAHs by 90% on an average [Becker and Francis, 2005].

Emission results of a test conducted by National Renewable Energy Laboratory (NREL), USA are given in the following table. The test was conducted on Taurus 1998 model with both E85 and gasoline RF-A (industry average gasoline). Table-4.5 shows the comparative emissions from ethanol and gasoline fuelled vehicle.

Table 4.5: Comparative Emissions (Ethanol Vs. Gasoline)

Emissions in g/mi	AFV-Ethanol	Gasoline
NHMC	0.10	0.10
CO	1.48	1.13
NOx	0.12	0.09
CO_2	396.4	439.7
		Source: CPCB, 2002

A recent Australian study with 10% blend of ethanol gives the following emission results:

- Decreased emissions of CO by 32%.
- Decreased emissions of HC by 12%.
- Decrease in non-regulated toxics: 1-3 butadiene decrease by 19%, benzene decrease by 27%, toluene decrease by 30% and xylene decrease by 27%.
- Increase in non-regulated toxics: acetaldehyde increase by 180% and formaldehyde increase by 25%.
- 1% increase in NOx

However, most sugarcane mills burn bagasse as fuel. While it is a renewable energy source, if proper pollution control equipment is not installed, the flyash in the air can impact the nearby communities. Burning of cane prior to harvest also causes air pollution and increases soil erosion (CABI /WWF, 2004).

4.3.4 Water and soil pollution

The studies carried out in Europe and USA on life cycle assessment of biodiesel using rapeseed oil and soybean oil indicate that water pollution is possible due to use of pesticides as well as fertilizers during growing of biofuel crops. In case of India, where the programme is based on growing non-edible oil plants on waste lands, the cultivation is likely to be less pesticide and fertilizer intensive. As mentioned earlier, it is expected that a large part of fertilizer requirements would be met through organic manure. There are no detailed studies on diseases and pest attacks on Pongamia and Jatropha, hence it is difficult to quantify the pesticide use for growing of these plants[2].

Biodiesel is readily biodegradable in the aquatic and soil environment as shown by experiments conducted at Idaho University [Peterson and Reece, 2002]. In the study, during a 28 day period, average CO2 evolution for the biodiesel reached 84% in aqueous systems, and average substrate disappearance amounted to 88% in the soil environment. Due to its biodegradable nature, biodiesel spill contaminated soil can be restored in 4 – 6 weeks to a degree that can support plant germination. However, the seed germination tests showed that biodiesel contaminated soil did have an effect on plant growth for the first three weeks due to the rapid growth of micro-organisms during the period of fuel degradation.

However, in case of bio-ethanol, high water use necessary for sugarcane cultivation is generally associated with significant runoff of polluted water. In some areas 70% of fertilisers applied are lost from farmland, undermining farmers' profits and harming ecosystems. Cane and beet processing also result in polluted effluent. When sugar mills are cleaned annually a tremendous amount of organic matter is released, usually straight into nearby streams. This reduces oxygen levels in the water, killing freshwater biodiversity; in 1995 sugar mill cleaning in Bolivia resulted in the death of millions of fish in local rivers (CABI /WWF 2004).

4.3.5 Toxicity

a) Toxicity of Jatropha Curcas seeds/oil/ fruits

Numerous feeding experiments with different animal species have demonstrated that Jatropha seed is highly toxic. Also, studies have demonstrated the toxicity of the oil, fruit and the pressed cake. The minimum lethal dose (LD50) of Jatropha seeds for different animal species is given in Table 4.6 below:

Table 4.6: Minimum lethal dose (LD50) of Jatropha seeds

Animal	Amount of seeds fed		Estimated curing intake (mg. total)	Days
	g/kg.	g. total		
Sheep	7.4	67	460	9
Goat	1.5	8	55	12
Calf	3.0	36	248	12

Source: G.M. Giibitz et al, 2005

Jatropha oil contains more than 2% Phorbol Esters. The acute oral LD50 of the oil was found to be 6ml/kg, body weight in rats. The tested animals, regardless of the species, showed inappetance, abdominal pain, diarrhoea, respiratory problems and imbalance. The isolated

[2] *In fact, traditionally Jatropha oil is itself used as a bio-degradable pesticide in some part of the country*

toxic fraction, when applied to the skin of the rabbits and rats produced a severe irritant reaction followed by necrosis. In mice, this fraction had a dermal toxic and lethal effect.

In humans, the effects of ingestion of seeds of Jatropha include marked nausea, gastro-intestinal irritation, abdominal pain, vomiting and diarrhoea. Archiote seeds of Mexico and watery extract of *Peltrophoroum africanum* are examples of antidotes for Jatropha.

b) Toxicity of biodiesel

Investigations conducted by University of Idaho on the subject, have shown that biodiesel is considerably less toxic than diesel fuel. But the study states that one should still avoid ingesting biodiesel or getting it on the skin. Although some adverse effects are noted with rats and rabbits, none died from either the biodiesel or diesel fuel.

4.3.6 Bio-diversity

Though India occupies only 2.4 % of the global area, its contribution to the world's biodiversity is approximately 8% of the total number of species [TERI, 1998]. Increased human and livestock population has resulted in enhanced demand for fuel, fodder, timber, and non-timber forest produce, increasing the pressure on existing natural resources causing irreplaceable loss of biological resources.

It is too early to predict the threat to biodiversity due to biodiesel development. In the demonstration phase of the biodiesel programme, 0.4 million hectares of land, spread over several hundred districts across states, is proposed for Jatropha plantations. As only 0.13% of the total land area of the country will be covered, the likelihood of any adverse effect on the biodiversity is minimal. Also, the plantations would be taken up on wastelands and does not involve destruction of forests. However, till now no study has been carried out on the impact of biofuel programme on biodiversity. It would be advisable to carry out a comprehensive study on this aspect particularly with respect to the Jatropha plantations.

Also, as the area under sugar cane has been more or less stagnant in the past few years, the threat to biodiversity has not been a concern. However, if concerted efforts are made to expand the area under sugarcane cultivation it could lead to loss of habitats.

In the meantime, several steps can be taken to ensure genetic diversity during the demonstration phase itself. Intercropping (with grasses, trees, crops) can help maintain genetic diversity in the Jatropha plantations. Similarly, Jatropha and Pongamia plantations on field boundaries can be promoted. More importantly, as mentioned in section 2.2, India has more than 300 different species of oil bearing trees, thus a multi-species biodiesel programme is possible, and steps can be initiated in identifying other promising species and initiating research so that they become viable alternatives.

4.4 Criteria for sustainability

In this section, sustainability of the biofuel development in India has been analysed. The sustainability criteria developed by Öko-Institute, Germany, [Fritsche et al., 2005] for assessing environmental, economic, and social aspects of biofuels in developing countries were applied for the ongoing and planned initiatives on biofuels in India. Individual criterion has been classified into highly relevant, relevant and not relevant in the Indian context. Some new criteria are also proposed.

Environmental Criteria	Observations
Conservation of natural ecosystems-excluding destruction, e.g. clearing of old-growth forests for cultivation of energy crops	Highly relevant to countries like Brazil and Malaysia, where tropical forests have been cleared for sugarcane and palm oil plantations. Relevant for India in the long-term, as large-scale Jatropha and Pongamia plantations on forest lands may start interfering with the natural ecosystem.
Preserving genetic diversity, including a minimum number of species as well as structural diversity within energy crop plantation	Highly relevant in the context of Indian biofuel programme, because of plans to grow mono-crop Jatropha over millions of hectares. India has more than 300 different species of oil-bearing trees, thus a multi-species biodiesel programme is possible, and should be preferred. Intercropping (with grasses, trees, crops) can also help in maintaining genetic diversity.
Sufficient re-circulation of nutrients into cultivated soils and woodlands	Highly relevant for sugarcane and sweet sorghum cultivation for bio-ethanol. In case of these crops the soil productivity can decline due to intensive cultivation. Inter-cropping, crop rotation, adoption of bio-fertilizers can help in re-circulation of nutrients in sugar cane cultivation [Singh, 2004] and should be part of the bio-ethanol strategy. Relevant for Jatropha and Pongamia cultivation. In general, these plantations help in restoration of wastelands. The application of de-oiled cake in Jatropha and Pongamia, which is excellent organic manure, can also help in re-circulation of nutrients. Thus, decentralized oil extraction, which makes it possible to supply the de-oiled cake back to farmers, should be preferred.
Avoiding negative impacts of fertilizer and pesticide use as well as of air pollutants	Highly relevant for sugarcane. It would also be relevant if intensive Jatropha farming were taken up. Not relevant for Jatropha and Pongamia plantations on wastelands under rain-fed conditions, as very little inputs (fertilizer and pesticides) would be used in this case.
Avoiding water pollution and critical irrigation needs in semi-dry and dry regions	Water pollution is highly relevant for bio-ethanol as water pollution is possible due to fertilizers and pesticides used in sugarcane cultivation. Management of water pollution is an important issue in distillery industry involved in making ethanol [Guha, 2004]. It is relevant for biodiesel production, as water pollution may be caused due to discharge of effluents during biodiesel production. Effluent treatment, water recycling, minimizing water use in the processing of bio-ethanol and biodiesel should be emphasized in the national strategy. Irrigation water requirement: This criterion is highly relevant for India as large parts of the country are water-stressed. Main criticism against sugar cane is its large water requirement [Singh, 2004]. In case of Jatropha, Pongamia cultivation in arid, semi-arid areas, one irrigation/month during summer months will be required during initial 2-3 years. This would put additional pressure on the areas' scarce water resources. Water harvesting, efficient irrigation techniques, should be part of the national strategy.
Avoiding Soil Erosion	Not relevant where plantations on waste lands would help avoiding soil erosion; relevant for sugar cane plantations.

Social criteria	Observation
Priority for food supply and food security for the export country's people	Not relevant in the immediate future. The cultivation of Jatropha and Pongamia is mostly restricted to degraded notified forestland as well as marginal agricultural land, which are mostly fallow (current or old) or cultivable wastelands. Would become relevant if plantations spread to arable lands competing for scarce water resources as in the case of sugarcane cultivation
Avoiding health impacts from energy crop cultivation	Highly relevant for Jatropha as Jatropha seed is highly toxic. The studies have demonstrated the toxicity of the oil, fruit and the pressed cake. There would be a need to create mass-awareness amongst the rural population in Jatropha growing areas as well as amongst the end-users utilizing the Jatropha oil/biodiesel.
Instead of displacement, integration of landless persons in energy cropping systems and subsequent local processing of the crops	Highly relevant. It should be one of the most important criteria while deciding upon a production model. The JFM model and the decentralized production and utilization model have the maximum potential to integrate landless persons in biodiesel systems. Contract farming and cooperatives are expected to remain restricted to farmers having land, though in both models, decentralized oil expelling can be integrated.
Preservation and development of jobs in rural areas	Highly relevant for India, given the extent of poverty in rural areas. The choice of the production model should be carried out keeping in view this criterion. JFM model has large potential for providing employment to poor sections of the society.
Inclusion of local people in the distribution of economic revenues from bio-energy	Highly relevant for India. The choice of the production model should be carried out keeping in view this criterion. JFM and cooperative models would ensure the inclusion of local people. Local utilization of biofuels should be preferred for the provision of electricity generation, water-pumping and motive power in rural areas. This can also generate additional employment opportunities in rural areas
Participation of local people in decision making	Highly relevant for India as already discussed above.
Economic criteria	**Observation**
Access to modern energy for all people, and covering of each individual's minimum needs for modern energy	Highly relevant given the large number of non-electrified villages in the country and large un-met demand for electricity and modern fuels in rural areas. The maximum impact can be generated through decentralized production and utilization approach.
Balancing possible export revenues to economic and social development of the exporting country	Not relevant in the short term. India has huge internal requirements of fuel for transportation as well as rural energy. As indicated, even a very large biofuel programme at best would meet only a fraction of these requirements, hence, India will not have surplus biodiesel for export.
Contribution of possible export revenues to economic and social development of the exporting country	Not relevant in the short term as discussed above.
Costs of expansion and development of infrastructure and logistics for energy crop cultivation, processing and exports	Highly relevant in light of Government of India's plans for large-scale production of biodiesel
Dependence on subsidies	Highly relevant. Subsidies would be required for establishing plantations, particularly for JFM and decentralized production models. However, all the projects should have sound business plans and should become commercially viable at some stage.

4.5 Summary

The issues related to food security, social and economic sustainability and environmental sustainability were discussed in this chapter. It was noted that as the focus of Indian biodiesel programme is on growing plantations over waste lands, no adverse impact on food security are anticipated in the near future. On the other hand, the Indian bio-ethanol programme, which depends primarily on sugarcane production, could be a source of concern as it would put pressure on the already scarce water resources of the country. As India faces a challenging task of increasing food production by over 50% in the next two decades, any large scale biofuel programme has to ensure that it does not compromise with the nation's food security.

The biofuel programme can contribute to social and economic development of rural India. Large-scale employment generation for poor is possible if plantations are taken up in forests and common lands. Local institutions like JFM Committees, SHGs and Panchayats can play a very important role in involving village communities in biofuel programmes. Locally produced biofuels can provide fuel for irrigation pump-sets and for electricity generation, this will improve access to modern energy services to rural population and help in improving productivity.

As there are uncertainties over the yields of oilseeds, for which sufficient field data is not yet available, the financial viability of the biodiesel is yet to be proven. The varied experience in yield levels and crop management practices has raised some apprehensions among farmers leading to a hesitation for taking up planting of biofuel crops.

Adoption of water conservation techniques, along with measures to check water pollution in sugarcane cultivation are important from the perspective of sustainable implementation of bio-ethanol programme in the country.

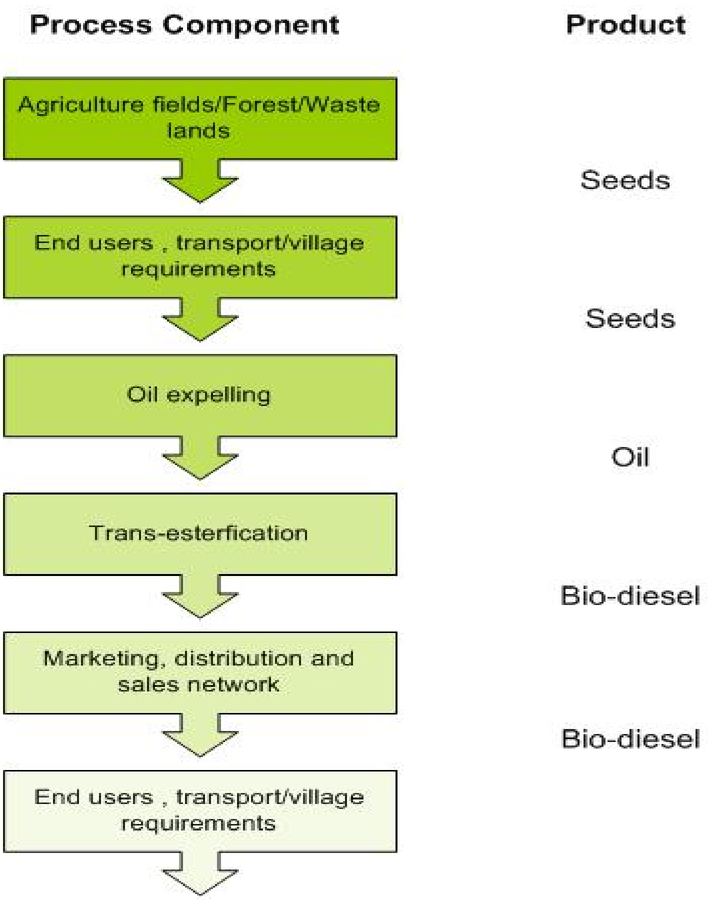
To date, very little work has been done on studying the environmental sustainability of biofuel development initiatives in India. The environmental impacts of biofuels, primarily energy consumption and emissions over complete production cycle and impact on bio-diversity have not been studied in detail. However, experiments in India on biodiesel use in vehicles have shown reduction in several important air pollutants.

Social, economic and environmental sustainability of biofuels in the country will depend to a large extent on the model selected for biofuel cultivation, production and utilisation. Possible models are the subject of discussion in the next chapter.

5 Biofuel production and utilization models

The last two chapters have dealt with the potential for biofuel in India and the likely impacts of a large-scale biofuel programme on agriculture, society and environment. Both the potential for biodiesel as well as impacts will depend to a large extent on the approach undertaken at various stages of the biodiesel value chain (Figure 5.1).

Fig 5.1: Value chain for Biodiesel



Rural India has a complex and varied historical background; it has different policy and tenural environments and diverse physical settings. Under these circumstances, promotion of biofuel through enhancement of rural livelihoods and rural ecosystems require working on a variety of lands and different forms of institutions. This chapter deals with different existing and proposed models of biodiesel production and utilization in the country.

5.1 Joint Forest Management (JFM) model

As described in Chapter 2 and 3, the Government of India's biodiesel initiative is focused on utilizing wastelands for biofuel plantations. Out of the 400,000 ha to be developed in the demonstration phase, 200,000 ha would be on degraded forest lands. For raising biofuel plantations on forests lands, the Joint Forest Management (JFM) approach is relevant. The approach is already being applied in Uttaranchal (Box 5.1)

The JFM concept is a partnership between the local community and the Forest Department in the conservation, management, and sustainable use of forest resources. One of the important components of the JFM programme is rehabilitation of degraded forests. Biofuel plantations can be promoted under the JFM programmes on degraded forestlands. In return for their contribution, the village community is entitled to a part of the net income obtained from the collection of forest produce, in this case, oilseeds.

Box 5.1: Approach adopted by Uttaranchal Biofuel Board

Uttaranchal Biofuel Board has developed a programme based on JFM concept for raising Jatropha plantations. Van Panchayats, JFM committees, SHGs, are the grass root implementing agencies for raising plantations on the wastelands and degraded forests. The project will be implemented through the Forest Department and the Divisional Forest Officers will facilitate and coordinate the programme. After the production of seeds starts, the grass root agencies will collect the seeds and bring them to the road head spot of Uttaranchal Forest Development Corporation (UFDC) which will purchase the seeds. The biodiesel production will be carried out by a private industry which will buy the produce from UFDC. In this programme the government is proposing a 100% grant, i.e. all the expenses (estimated at INR 30,000 /ha) related to the establishment and management of plantations in the first two years will be provided to the beneficiary families. The programme is targeted towards providing employment opportunities to the BPL (Below Poverty Line) families. The private investor will carry out all the investments in the processing plant.

Source : Uttaranchal Biofuel Board

In Table 2.2, it was shown that only a small fraction of the available TBO seeds are currently collected. JFM programmes can also be used for increasing collection. Owing to lack of attractive pricing for the seeds, unlike other minor forest produce (e.g., beedi leaf, gum, honey) local people do not attach much importance to the collection of these seeds. Field level discussions indicate that higher price levels at farm gate, would attract more people to seed collection. The existing tribal development agencies, Girijan cooperative societies, and self-help groups can be encouraged to improve seed collection and processing.

5.2 Industry-farmer partnership model

Apart from growing biofuel trees on forests and common lands, biofuel plants can also be grown on private agricultural lands. State governments like Andhra Pradesh and Tamil Nadu and private companies like Southern Online Biotechnologies, D1 oil are targeting farmers for cultivation of biofuel trees on agricultural land. Two of the possible approaches based on partnership between the industry and the farmer are presented in this section.

i) Contract farming

Contract farming is defined as a system for the production and supply of agricultural/horticultural produce under forward contracts between producers/suppliers and buyers. The essence of such an arrangement is the commitment of the producer/seller to provide an agricultural commodity of a certain type, at a time and price, and in the quantity required by a known and committed buyer.

There are several success stories in contract farming, these include Pepsi Foods Ltd. experience in Punjab with potato, tomato, groundnut and chilli growers, Ugar Sugar model for barley in north Karnataka, Appachi Cotton Company experience with integrated cotton cultivation, etc. [Spice, 2003]. In most of the cases mentioned above, the companies supplied the farmer quality farm inputs (based on R & D carried out by the companies), offered technical advice as well as organized loans to the farmers. In one particular case, farmers were organized as self help groups (SHGs) and the loan was channelled through the SHG. In another case crop insurance was also a part of contract farming package. Ugar Sugar Works has plans to extend the contract farming system to energy projects – for sourcing of Casurina and Eucalyptus for a 44 MW cogeneration plant. The company also thinks that this model can be extended to biodiesel production from Pongamia in the region [Spice, 2003]. This model can also work well for bioethanol production where sugar producing mills, that also produce bioethanol, can have direct contracts with farmers for the supply of sugarcane.

Main criticisms against contract farming are limited involvement of farmers, farmers having little influence on the fixing of price, lack of transparency, etc. Andhra Pradesh government has drawn a draft policy to promote contract farming (which takes care of some of these criticism) in which the state government will enter into a tripartite agreement with industry and farmers (refer Box 5.2).

Box 5.2: Government–Industry-Farmers partnership model (Andhra Pradesh)

The draft policy proposes a tripartite partnership between the government, industry and farmers. It has a provision for fixing of the minimum buy back price by the Government in consultation with the biodiesel industry, farmers and other key stakeholders. It proposes signing of two tripartite agreements between farmers/ registered farmer societies; state biodiesel board and biodiesel industry:

- The first tripartite agreement would be for buy back of Jatropha seeds.
- The second tripartite agreement is to ensure credit linkages and payments to farmers. Loan amount disbursed to farmers would be routed through the industry.

Jatropha growing farmers are required to have a bank account with the financial institutions that are signatory to the tripartite agreements. All payments (including the payment by industry for seeds) to the farmers would be directly credited to their accounts. Net payments will be made to the farmers through the bank after deducting the required pay back amount of the loan. The government would directly pay to the banks the difference in the interest component on the loan as a back ended subsidy.

Source: Draft policy paper on biodiesel project, September 2004, Government of AP.

ii) Market linked coordinated farming

The approach followed by ITC Bhadrachalam Paperboards Limited for sourcing raw material for its pulp and paper mill has evolved from the contract-farming model described above. ITC invested in R&D on developing high yielding, disease resistant clones for Eucalyptus. ITC now produces these saplings using modern nursery technology and these plants are sold to interested farmers. The company also provides technical guidance to the farmers for proper site selection and clone matching.

Unlike contract farming, there is no buy-back arrangement and farmers are free to sell their produce to any prospective buyer. ITC itself purchases the produce (eucalyptus wood) at the ruling market price. The important feature of the ITC approach is that it is entirely free from any kind of subsidies either from the government or from the industry. Interestingly, in case of ITCs plantations, 70% of their plantations are grown by large farmers (above 10 acres).

From the viewpoint of financial sustainability, industry-farmers partnership models score over other models. R& D has emerged as an area where the corporate private sector has a real and demonstrated comparative advantage (Saigal and Kashyap, 2002). This is another area where the biofuel programme can gain from the application of company-farmers partnership models.

5.3 Decentralized production and consumption model

The models described so far can be used for producing biodiesel in large quantities to be used as transportation fuel. NGOs like Gram Vikas in Orissa, Samgra Vikas in Karnataka (Box 4.2); projects like ITDA, Adilabad (Box 4.3) and the Village Energy Security Programme (VESP) of the Ministry of Non-conventional Energy (MNES) have promoted the concept of decentralized production of SVO/ biodiesel for meeting energy requirements in the villages.

The oil seed supply is sourced by increasing the collection of oil seeds from existing trees in the village as well as nearby forests (which is feasible in forest fringe villages) and planting of oil seed bearing trees on community waste lands and forest lands. The projects have provision of setting up of small expelling units or ghanis. Under GV-CTxGreen project, small (5-25 lpd) trans-esterification units have been set up at the village level. The SVO or biodiesel produced is used locally for electricity production, water pumping and motive power for agricultural operations and micro-enterprises. The de-oiled cake is used within the village system as organic manure.

This model has the potential to catalyze rural development in a large number of villages in India, which currently are facing shortages of electricity. The model also ensures that all the benefits remain within the village economy.

5.4 Cooperative/producer company model for biodiesel

Cooperatives have been working successfully in the case of milk production/ processing and sugar production in the country. India has witnessed successful ventures through semi-autonomous bodies like National Dairy Development Board and its affiliated state level federations (separately for milk and edible oil) and district level unions and village level producer cooperatives. These have time-tested and proven experiences across the country. These models have effectively taken care of both backward and forward linkages and have well-established linkages and practices, suitable to Indian conditions. They have advantage of having evolved locally, and applied nationally.

A three-tier cooperative model, covering the entire value chain of biodiesel production, has been proposed in the DPR for National Biodiesel Mission [TERI, 2005].

The model envisages formation of oil cooperative societies, which could cover a village, or a cluster of villages. A farmer growing oil seeds can become the member of the cooperative by buying a share in the society and agreeing to sell his oil seed produce exclusively to the society. The main function of the oil cooperative society would be to collect the seeds and sell the same to the expeller units located at the district level. The cooperative society can also be utilized for channelling inputs like finance, fertilizer, planting material, etc. to individual farmers.

The next level of cooperative would be at the district level. Cooperatives at the district level will have village level oil cooperative societies as their primary shareholders. The district level cooperatives will buy seeds from the village oil cooperative societies. The main functions of the district level cooperatives would be:

- Collection, storage, handling, and transport of the seeds
- Promotion of oil seeds in their area of operation
- Channelling inputs to the oil cooperative societies.

Federation of cooperatives will be formed at the state level. It would be a company that will have district level cooperatives as their primary shareholders. It would be responsible for the management of the expeller units, trans-esterification units, resource centres and the marketing of biodiesel (Box 5.3).

The advantage of the cooperative model is that it can ensure that the benefits are distributed amongst a large number of small farmers. There are already state level oil federations with district level unions (e.g., Orissa, Karnataka, Maharashtra, Andhra Pradesh, Madhya Pradesh). These were set up by the National Dairy Development Board and are functioning in several states. Both Jatropha and Pongamia may be added into their procurement and processing list. These oil federations can also take care of both procuring and processing both at decentralized and if need be, at centralized levels. They need to be oriented to provide backward linkages.

Box 5.3: National Tree Grower's Cooperative Federation

The Tree Growers Cooperative Pilot Project was set up in 1986, by the National Dairy Development Board (NDDB) at the request of the National Wastelands Development Board. The objective was to assist village communities in restoring degraded commons in order to meet their subsistence needs for fuel wood and fodder. In 1988, the National Tree Growers Cooperative Federation (NTGCF) was registered as an apex national level multi-state cooperative society, with a mandate to work with the institutional form of tree growers' cooperatives. The Foundation for Ecological Security (FES) was formed in March 2001 and the implementation of the project was transferred from the NTGCF.

The NTGCF focus on the strengthening of the federation of cooperatives formed under its aegis at appropriate inter-village levels taking up issues of common cause. Currently the project is in operation in 18 districts of seven states of India. The Project has been working for the last 15 years with rural communities in ecologically fragile zones to restore, conserve and sustain their natural common property resources. An important aspect of the work is helping village level institutions gain access and control over their village common lands, through secure tenure and by developing democratic institutions for their governance. The Foundation provides, where necessary, financial and technical assistance to village institutions such as Tree Growers Cooperatives, Watershed Committees, Van Panchayats, Gramiya Jungle Committees, Joint Forest Management Committees and Sub-Committees of Village Panchayats in different states. The Foundation assists in strengthening the institutional arrangements in the governance of commons, helps local communities in undertaking soil and water conservation activities and work on revegetation and protection measures.

One of the criticisms against the cooperative model is lack of professional management and absence of profit making motive. To take care of these deficiencies, producer company (PC) model can be considered [TERI, 2005][1].

5.5 Cooperative Model for Bio-ethanol

The emergence and successful functioning of sugar cooperative industry in Western and Southern India, has made this model rather popular. The factories employ professionals who help to organize and plan cultivation, harvesting, crushing and processing of sugarcane and marketing. Many factories have started distilleries for alcohol or acetone production from molasses and a few have put up papermaking units based on sugarcane bagasse.

The unique feature of the sugar cooperatives in these States lies in the fact that the farmers have used part of the profit for the overall development of the area, the people and water resources, providing educational and health facilities, helping the farmers in diversifying into horticulture, dairy, poultry and animal production, arranging loans on easy terms etc. This provides additional income to the farmers and employment to the landless labourers working in the area.

In States like Maharashtra, Gujarat, Karnataka and Andhra Pradesh the majority of sugar factories are in the cooperative sector, while in the States of Uttar Pradesh, Bihar etc. most of the factories are in the private sector.

[1] *The concept of the producer company has been introduced through Companies (Amendment) Act, 2002*

5.6 Summary

Because of varying tenural rights and socio-cultural factors, it is not possible to recommend one model for the entire country. Various organizations and individuals are considering different models for promoting private sector participation in biofuel development. The models discussed above are primarily to promote rural livelihoods, seed collectors interest, to avoid middleman, to provide better pricing and returns to primary producer or seed collector, and to promote decentralized production and usage of biofuel. Thereby, reducing transport costs of biofuel transportation from centralized production and processing models, as in case of fossil fuels.

Besides the models discussed above, there are other options also; such as leasing of government wastelands to private investors. The choice of model will depend to a large extent on the main objective (s) of the biodiesel programme i.e. whether it is for employment generation, production of transport fuel, waste land regeneration, or village energy security. At times one particular model may not suit the requirements of the entire country or a state. Hence states like Chhattisgarh are opting for a combination of options (Box 5.4).

Box 5.4: Chhattisgarh government action plan for Jatropha plantations

The key strategies proposed in the action plan are:

- Identification of government waste/fallow land for Jatropha plantations.
- Pilot Jatropha demonstration plantation in 300 acres land of farmers in each district.
- Free distribution of 70 million Jatropha saplings amongst farmers.
- Encouraging private investors for contract farming
- Allotting government wasteland on lease to private investors.
- Setting up biodiesel based power plants for rural electrification in a cluster of 50 remote villages

Source: Chhattisgarh Biofuel Development Authority, 2005

However, the concerned agencies have to take care of maintaining the standards of biofuel. One option is follow indigenously developed similar fast moving consumer good models like Dhara (edible ground nut oil brand), or mother dairy milk across the country. While brands may be different, there are apex bodies to effectively monitor and control the standards.

But before any of the models discussed above are launched, India needs to experiment on a pilot basis in a few places. The refined process with lessons learnt may be replicated gradually.

6 Large Scale Development of Biofuels: National and International Implications

6.1 Impact of biofuels on the crude oil import and foreign exchange

With only 33-34 million tonnes (MT) of domestic crude oil production, India has to depend largely on its import, which increased sharply from 20.7 MT in 1990-91 to 90.4 MT in 2003-04. The foreign exchange spent on this trade was INR 61.18 billion in 1990-91and that increased to INR 835.28 billion in 2003-04 [TEDDY, 2004].

Owing to increasing urbanization and expanding population, the total energy demand is expected to grow at more than 4% [Panigrahi et. al, 2004]. The Tenth Five Year Plan Working Group on petroleum and natural gas had estimated annual import of crude oil to go up from 85 MT in 2000-01 to 147 MT by the end of 2006-07.

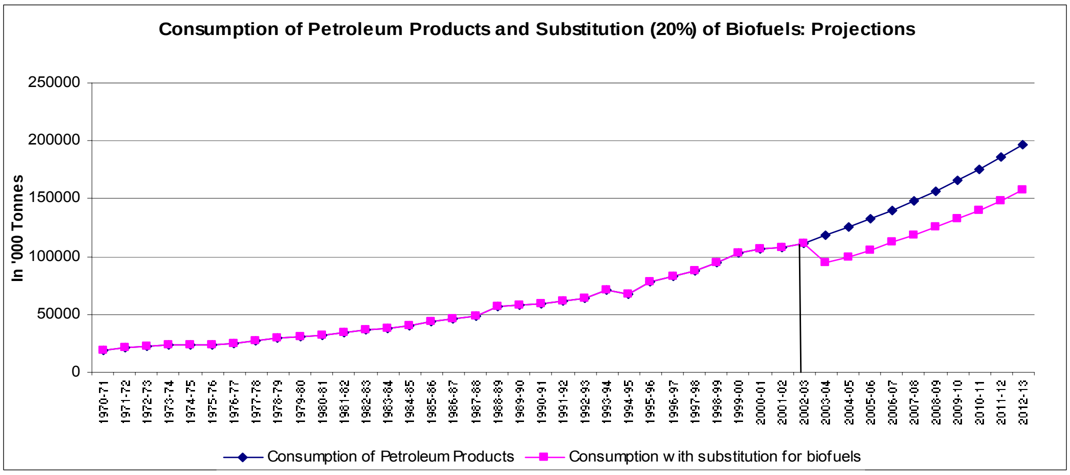
As shown in the Table 6.1, the demand for Petrol (motor spirit) is projected to grow from 7.07 MT in 2001-02 to 10.07 MT in 2006-07 at a rate of 7.3% per annum, and for Diesel (HSD) to grow from 39.81 MT in 2001-02 to 52.32 MT in 2006-07 at a rate of 5.6% per annum.

Table 6.1: Projected growth of crude oil requirements and domestic supply

Item	Projection in thousand tonnes				Domestic supply %		
	2001-02	2006-07	2011-12	2016-17	10th plan	11th plan	12th plan
Motor Gasoline (MS)	7070	10067	12848	16398	22.2	Lower than 10th	
Aviation Turbine Fuel (ATF)	2299	2691	3150	3687	22.2	Plan projection	
High Speed Diesel (HSD)	39815	52324	66905	83575	22.2	If foreign JV is ignored	
Source : Panigrahi et al (2004)							

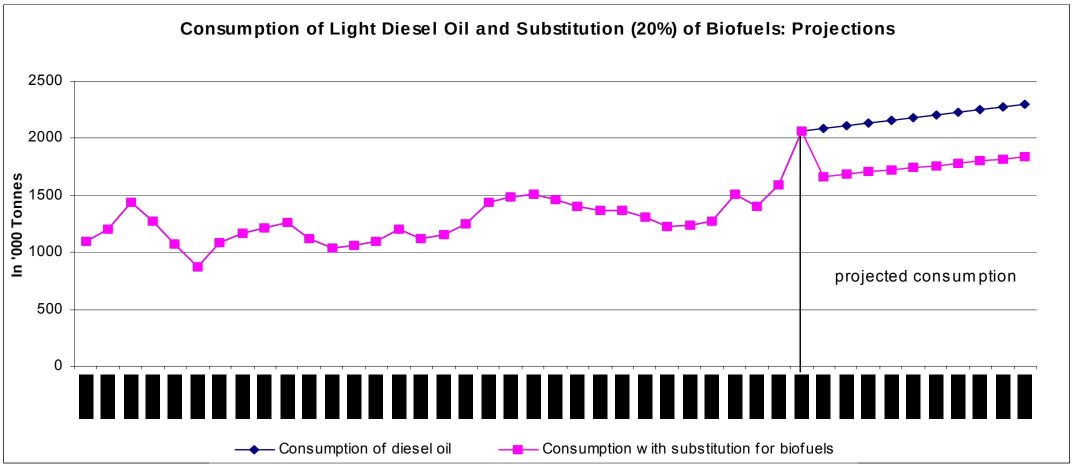
While crude oil based fuels will continue to dominate the transport sector in the foreseeable future, their consumption can be minimized by the implementation of biofuels programme. Effect of 20% substitution of biofuels on diesel fuel and petroleum product consumption is given in the Figure 6.1 and Figure 6.2.

Fig. 6.1: Projected consumption of light diesel oil and substitution (20%) of Biofuels



Source: Raju K.V. 2005

Fig. 6.2: Projected Consumption of Petroleum Products and Substitution (20%) of Biofuels



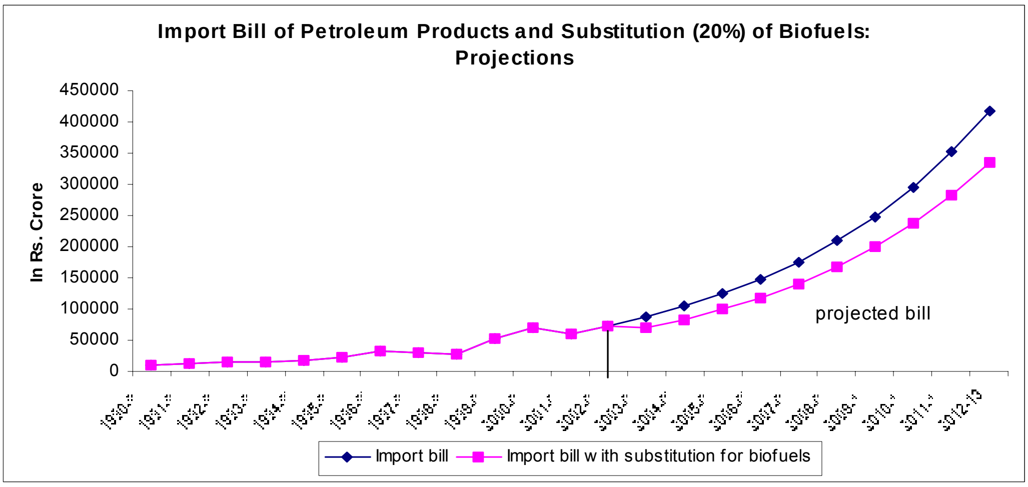
Source: Raju K.V. 2005

The above scenario is built on one time 100 percent substitution assumption with a mixture of 20% bio-diesel with 80% of fossil fuel. We are aware that such assumption is not feasible but the utility of the scenario is not to track the path but to view the achievable goal.

Source: Raju K.V. 2005

India spent US$15 billion, equivalent to 3% of its GDP, on oil imports in 2003. This is 16% higher than its 2001 oil-import bill (IEA, 2004). Currently about 30% of our total foreign exchange earnings are required to meet the oil import bill (CBMD 2002). Rising demand for crude oil is likely to further increase the country's import bill without even taking into consideration the global oil price rise. The impact of 20% substitution of biofuels on oil import bill at present fuel prices, is presented in the figure 6.3.

Fig. 6.3: Projected Import Bill of Petroleum Products and Substitution (20%) of Biofuels



Source: Raju K.V. 2005

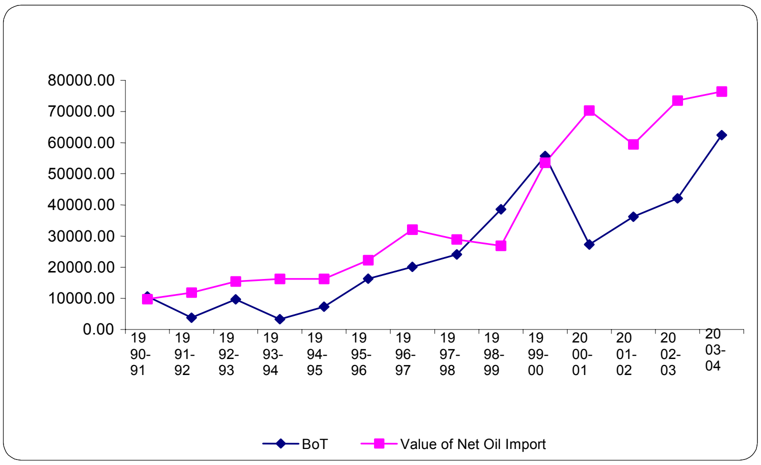
From figure 6.3 it is evident that even if only 20 percent of the transport sector fuel is gradually substituted by biofuels, it can help the country save about INR 1,17 billion worth of foreign exchange by the year 2012-13. In light of the recent trends in global oil price rise, these savings could only increase.

6.2 Impact on Trade

In the macro economic aspects, Balance of Trade (BoT) is quite an important determinant of a country's trade performance. India had its bad phase in Trade Balance during early nineties and a large share of it was contributed by the oil sector.

The relationship between the aggregate trade balance and value of net imports of oil is quite strong and the correlation works out to be 0.84 (significant at 1 percent level of significance) (figure 6.4).

Fig 6.4: Trends in the Balance of Trade and Value of Net Oil Import



Source: Raiu K.V. 2005

Note: The Balance of Trade is negative throughout the period but modulus values are taken to allow better understanding

This is supported by the International Monitory Fund's (IMF) estimates on the impact of oil price rise on India's GDP and Trade Balance. In case of sustained $10 increase in price of oil, India, which imports the bulk of its oil, would experience a 1% fall in economic output (GDP) and a 1.2% point deterioration in its current Trade balance (expressed as a share of GDP) one year after the price increase (IEA 2004).

In this context, the substitution of biofuels will improve the trade balance by at least 15 percent if one excludes the spill over effects. An important aspect is the price effect of the components. The crude oil price increase will slow down the demand growth and may also reduce the intensity of hydrocarbon fuel consumption through use of more efficient vehicles and engines.

6.3 Economic Growth and Employment

6.3.1 Economic Growth and Fuel Consumption

India ranks sixth in the world in terms of energy demand, which accounts for 3.5% of the global commercial energy demand in 2001 (Panigrahi, 2004). Crude oil accounts for about one third of India's energy consumption. The steady growth in GDP and purchasing power on part of the Indian population has resulted into a corresponding growth in consumption of petroleum products in India. The Indian GDP and energy consumption have each grown at the rate of about 6% per annum from 1991 to 2001 (http://www.ril.com).

A simple relationship between GDP growth and the fuel demand in the country has been developed using the time series data for nineties.

The estimated equation is:

$$FuelDm = \xi \, (GDP \; ; \tau \,)$$

Estimated equation is linear in logs: Fuel Dm = 6.341 + 0.278 GDP + 0.043 τ

(4.001) (2.18) (6.77)

R^2 = 0.996

(Figures in brackets are t values; all coefficients are statistically significant at 1 % level)

Where 'FuelDm' is the consumption of fuel of all types and GDP is at constant prices and despite using the GDP at constant prices we have used time (τ) as a filter variable.

The relationship between the fuel consumption and GDP at constant prices has been worked out above and it was noted that fuel consumption has a strong and positive relationship with GDP. It comes out clearly that the fuel demand has an elasticity of 0.278 with respect to GDP growth. But at the same time we also find time effect quite significant.

From the above equation it is clear that with the growth in GDP the increased fuel demand is inevitable. In order to support the growth of GDP at around 7 percent per annum, the rate of growth of fuel supply needs to be over 10 percent annually. If the government of India does not want to keep allocating a substantial portion of the national GDP to fossil fuel imports, it has to take proactive measures to promote biofuels.

6.3.2 Employment

With 260 million people in the country living below the poverty line, India is a home for 22% of the World's poor. The poor are major victims of environmental degradation and at the same time they pay substantially higher price for energy services than any other group in society in terms of time, labour and health. Since the poor are largely dependent on natural resources for their survival, depletion of natural resources accompanied growing population size and lack of income generating activities further increases the poverty.

In such a scenario, a programme that generates employment is therefore particularly welcome. The National Biodiesel Programme under which Jatropha curcas plantation will be the most dominant component will provide employment for 313 person days per hectare in the first year of plantation [TERI, 2005]. In subsequent years, about 50 person days per hectare would be required to take care of the plantation and collection of oilseeds [Becker and Francis]. If in one scenario we consider about 10 million hectares of energy tree plantation to be taken up, it will create employment equivalent to 3130 million person days for plantation in the first year and 500 million person days for rest of the life of the plantation i.e. 30 to 40 years.

6.4 Global policy environment

In the global policy environment biofuels enter from three distinct perspectives. First it is considered in the context of environmental agreements, both due to its dependence on the biomass and the impact on the forest use. While on one hand it is feared that the utility of certain species may lead to their over exploitation, on the other hand production of biodiesel may effect biodiversity by the development of contiguous tracts of a few select species (mono-culture).

Second the emission standards in the case of biofuels also feature as an important point for discussion. The issue has already been discussed at length in Chapter 4. It is stated in an official report of the India's Planning Commission, as well as discussed in Chapter 4 earlier, the biodiesel emission standards are globally accepted (GoI, Planning Commission, 2003). In the case biofuels the reduction in the engine emissions will have its beneficial effects. The standards have been different globally but now almost a consensus seems to be emerging about 20% level of biofuels mixed with traditional fuels. The Report on Combustion Testing Of A Bio-Diesel Fuel Oil Blend In Residential Oil Burning Equipment, Prepared For: Massachusetts Oilheat Council & National Oil heat Research Alliance Submitted By John E. Batey, Pe, Energy Research Center, Inc. July 2003, gives the standards and testing procedures for the right combination.

Third, since biofuels will be largely substituting the fossil fuels the trade angle enters into picture. It is quite expected that the Oil Exporting Countries will be losing a share of their markets and that may provoke discussion on the quantum and value of trade. It may also provoke discussion of the policy in the WTO forum.

6.4.1 Current WTO situation

Biofuels sector interfaces with WTO regime from five important angles.

First, it involves de-minimis Market Access (Art XXXVII) featuring from the viewpoint of the Oil Exporting countries. The international market for fossil fuels is well organised and any large-scale intervention in this situation is likely to be strongly resented. But probably that is a distant possibility due to the lower limits in the provision as well as the size of biofuel trade. Therefore this issue may not come for discussion in the immediate future, at least under this provision.

Second issue will arise from the Domestic Support angle, and here there is a possibility that trade in fuels may get restricted due to the possible generous support to the biofuels sector. The aggrieved countries may consider these as trade distorting support mechanisms and therefore these supports have to be classified into non-actionable groups or ‘Green Box’ with the help of environmental sustainability argument.

Third, from the Sanitary and Phyto-Sanitary agreement point of view, acceptable standards of the biofuels have to be fixed before it gets into the trade discipline. These have to be internationally agreed standards. It is conceived by many that biofuels will be produced under small-scale sector and if that happens then these standards will have to accommodate the conditions prevailing in the production system.

Fourth issue crops up from the Intellectual Property Rights (IPR) regime of WTO; here the product patents have to be viewed before embarking on large-scale production of the product, if the production process as well as the product is going to be standardized.

Last, the environmental angle and carbon trading arguments enter in to the picture. As already discussed in the last section on trade barriers, the world community is discussing Kyoto protocol and incorporated in it, is the carbon trading argument. The protocol has set binding targets for reductions of emissions for each developed country. The protocol also provides instruments such as Clean Development Mechanism (CDM), Joint Implementation System and Emission Trading to promote activities for mitigating harmful impacts of climate change. These are likely to enter the WTO discipline when the interested countries insist upon that. As such the Kyoto protocol has all that material needed for the trade regulations that is the central point of the WTO discipline.

6.4.2 Biofuel Trade Opportunities

In the recent years, biofuels have become a priority issue across the world due to the concerns about oil dependence, reduction in CO2 emissions or restrictions on other octane enhancement additives. Under the Kyoto protocol, industrialized countries must reduce their carbon emissions by at least 5% from 1990s levels during the commitment period 2008 – 12. Many of these countries have already passed specific legislations establishing voluntary or mandatory replacement of fossil fuels by biofuels.

In 2000, ethanol and biodiesel accounted for less than 1% of gasoline & diesel consumption in the EU. The proposed EU indicative target of 5.75% oil replacement by 2010 would require large and rapid investment in conversion facilities (Coelho 2005). Domestic production will not suffice to meet the target and EU’s and increased crop production for biofuels may lead to reduction in other agricultural subsidies. In 2001, the European Commission also proposed a policy to promote the use of biofuels in the transport sector allowing the Member States to apply a reduced rate of excise duty on biofuels and mineral oil containing biofuels[1].

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[1] *In 2003, two commission’s decisions allowed British and German biofuels to benefit from up to 100% cuts in excise duties*

In fact, there are no technical or environmental reasons to limit the use of biofuels in developed nations. The real problem lies in the high cost of local producers of biofuels in the developed countries and protective trade barriers applied against the import of cheaper alternatives from the countries that have natural endowment for biofuel production. Biofuels can be produced more cheaply in countries or regions situated outside the EU and US. For example, Brazil produces ethanol at a rate of half the cost it would cost to produce it in EU (Coelho, 2005).

6.4.3 Trade Barriers

Importing biofuels from developing countries could help developed countries reach their Kyoto targets. However, many biofuel exporting countries face technical trade barriers. To prevent irregularity between trade liberalization objectives and Kyoto protocol reduction targets, new approaches and policy spaces are warranted so that trade liberalization and implementation of Kyoto protocol became truly and mutually supportive.

Since biofuels are obtained from agricultural feedstock, it can compete in many cases with subsidized products internationally. Therefore, these are affected by the protective legislation and are subjected to rules currently under discussion in the WTO's Doha work programme (refer Box 6.1). In this context, it is necessary to define the scope and clarify existing WTO provisions in order to clearly consider biofuels as EGS and thereby making it possible for them to benefit from progressive world trade liberalization as foreseen in paragraph 31 of WTO Doha's Declaration.

Box 6.1: The Doha Ministerial Declaration and trade of EGS

With the mandate to work towards global trade liberalization and environmental sustainability, the WTO's Fourth Ministerial Conference adopted in November 2001 "*The Doha Ministerial Declaration*". The declaration agreed to negotiations on the elimination of tariff and non-tariff barriers to environmental goods and services (EGS). A more general commitment to market access is one of the foundations of the Doha Development Round Agenda. It includes supporting the accelerated liberalization of trade in green goods of special interest to developing countries.

Biofuel sector has significant potential to use biotechnology tools to improve the economic competitiveness of biofuel production. In biofuels, biotechnology could be utilized mainly in two ways. One is to genetically modify plants to improve the yield. Second is to develop new enzymes or organisms that increase the conversion efficiency. International law, including the trade law is struggling to accommodate products created using modern biotechnology tools.

WTO rule states that there must be acceptable evidence of risk if imports of products have to be restricted. This is specifically to ensure that safety regulations are not used as illegitimate barriers to provide protection to domestic producers. However opponents of the existing WTO structure argue that it does not allow governments to respond adequately to unknown risks and consumer protection. As a result a new multi-lateral environment agreement "The Cartagena Protocol on Biosafety (BSP)" which explicitly allows countries to use the "Precautionary Principle" and to block products that have used biotechnology anywhere in its production was negotiated . The European Union is also highly opposed to any product that has used biotechnology anywhere in its production process, which poses a threat for biofuels under WTO.. This may have implications for the substitution of biofuels on the trade of petro products. On May 13, 2003, Canada, Argentina and the US requested formal WTO consultations on the EU moratorium on genetically modified organisms (GMO's), and that puts the issue in question again. As biofuels have no implication for human consumption, it is unlikely that a ban can be introduced on biofuels under Cartagena Protocol as the use of biotechnology would be found WTO compliant. Nevertheless, it is important that WTO gives due consideration to above mentioned aspects before taking decision on future measures in the biofuel sector.

Canada in 1999 suggested setting up of a working group on biotechnology to find out adequacy and effectiveness of the existing WTO rules as well as the capacity of the member countries to implement these rules (WT/GC/3/359/, 12th October, 1999). If the group is established it may have to consider all these aspects.

6.5 Summary

India is an energy importing country and its crude oil imports have grown rapidly from 20.7 MT in 1990-91 to 90.4 MT in 2003-04 costing this country around US$ 15 billion in foreign exchange. The recent rise in the oil prices has raised concerns among various stakeholders that if such a trend continues then the country's economy could be seriously affected. The Indian government is conscious of the need to diversify its sources of energy supply and thereby de-risking country's oil needs. The large-scale implementation of biofuels could help reduce the country's import bill, thereby saving precious foreign exchange. At the same time this programme would contribute towards the nation's economy by creating numerous jobs across the country.

Globally, the biofuels offer a unique opportunity to simultaneously enhance export from developing countries, promote rural development, diversify sources of energy supply, meet Kyoto protocol reduction targets and promote real investment through the Clean Development Mechanism. However, local subsidies and protective hinder the development of free trade in this sector. Regional cooperation and clarification of WTO provisions could help support the trade in biofuels.

7 Conclusions and Future Outlook

With a growing concern over country's increasing dependence on imported petroleum fuels, energy security is the chief rationale for promoting biofuels in India. During 2003-04, the country imported 90.4 million tonnes (MT) of crude oil valued at US $ 18 billion. Petroleum imports are projected to rise to 166 MT by 2019. In the absence of an economic alternative to petroleum-based fuel so far, they will continue to dominate the transport sector in the foreseeable future. However, by expeditiously implementing the biofuels programme, the consumption of petro-based fuels can be reduced.

India has been experimenting with the use of 5% bio-ethanol blend as transport fuel in selected regions of the country since 2003. The primary source of ethanol production in India is molasses — a by-product of sugar production. The doped petrol has not caused any technical problems in its use; however, the supply of ethanol has fallen short of the demand. This has been mainly due to drought conditions in Western and Southern India during 2004, leading to reduction in sugarcane production and molasses. As a result, lately the prices of ethanol quoted by the ethanol industry to oil companies have exceeded the import parity price for petrol. With the prospects of a better sugarcane crop during 2005, the supply of fuel ethanol is expected to improve in next few months.

While SVOs have been traditionally used in India, biodiesel is a relatively new biofuel in the Indian context. For biodiesel development, a National Mission on Biodiesel was launched in 2003. Owing to food security issues and the fact that India imports edible oils, the biodiesel programme in India focuses on the propagation of non-edible tree based oilseeds (TBOs) especially Jatropha and Pongamia on wastelands. In its demonstration phase (which is under consideration with the government since 2003), the programme proposes to take up Jatropha plantations in 400,000 ha for biodiesel production.

Some states, private companies and NGOs have already initiated Jatropha and Pongamia based plantation programmes. Although a couple of commercial biodiesel plants are expected to be operational in near future, in the absence of any announcement from Government of India regarding use of biodiesel as a transport fuel, at present pilot plants are producing only a small quantity of biodiesel mainly for research purposes.

The major conclusions that can be drawn about the Indian biofuel experience may be categorized as follows:

7.1 Key conclusions

7.1.1 Production and application potential

The long term production potential of biodiesel is constrained by the limited availability of cultivable wastelands that could be brought under biodiesel plantations under the National

Biodiesel Mission. In the near future, the overall contribution of biofuels to the fuel demand is expected to remain small. As per the plans of the demonstration phase even if the Jatropha plantations on 400,000 ha of wastelands are taken up by 2007, at the current yield levels, the biodiesel contribution is expected to be a meagre 0.5% of the total diesel requirement in 2012.

Constraints in the supply of molasses has severely impacted the bio-ethanol production and even reaching a target of 5% blending in a few select states is proving to be a challenge.

In the Indian context, the biofuels cannot be considered only in the context of transport fuels. Perhaps a far more important application of the biofuels could be electricity generation and providing motive power for rural communities not having access/ facing severe shortages of modern forms of energy.

7.1.2 Appropriate feedstock

Owing to food security issues the biodiesel programme in the country has been focused on Jatropha and Pongamia – non-edible tree based oilseeds (TBOs). However, there are large uncertainties over the yields of oilseeds as well as appropriate agronomic practices.

At present, ethanol production is totally dependent on sugarcane molasses, there is an urgent requirement to search for alternate feedstock to enhance ethanol supply. Sweet sorghum is one option, however, concerted research effort should be focused on producing ethanol from ligno-cellulosic materials like bagasses, rice straw, etc.

7.1.3 Research and development

As far as technology is concerned, India has the basic know-how for the production of ethanol as well as biodiesel. However, there is a need that future work should be aimed at correct scaling of the technology, cost reduction and improving overall efficiencies.

Research on Jatropha and Pongamia is in a rather primitive phase and needs technological advancements to harness the full potential of these resources. These efforts need to focus on:

- Suitability of Jatropha and Pongamia to different agro-ecological regions.
- Identification and multiplication of improved cultivars
- Application of bio-technological tools for yield and oil content enhancement
- Standardization of agronomic practices for different agro-ecological regions

For bio-ethanol there is a need to develop technology to produce ethanol from abundantly available lingo-cellulose materials.

7.1.4 Financial viability

As there are large uncertainties over the yields of oilseeds, for which sufficient field data is not yet available, the financial viability of the biofuel options is yet to be proven. The latest price of ethanol quoted by the ethanol manufacturers to oil companies is INR 19.55/litre which is more than the import parity price for petrol (INR 18 /litre). While Pongamia based SVOs are available for less than INR 30 /litre, the current price of biodiesel ranges between INR 55 to 110 /litre which, as per various studies, are projected to stabilize between INR 16 to 50 /litre in future.

The financial viability of biodiesel does get considerable strength from the availability of by-products including de-oiled cake, which is a good quality organic manure and fetches between INR 2 –6.50 /kg and glycerol, which is used in cosmetics, soaps and by the pharmaceutical industry can get INR 15 – 100 /kg depending on its purity.

The varied experience in yield levels and crop management practices has raised a lot of apprehension among farmers to take up planting of biofuel crops. The gap created by the lack of adequate marketing infrastructure has left the seed collectors at the mercy of large traders who offer anywhere between INR 3 – 4/ kg of seeds (as against INR 7-8 /kg in state agricultural produce marketing centres) collected making it unviable for them to invest time and effort in seed collection.

7.1.5 Socio-economic development

The promotion of biofuel development is attractive for a country like India because of its potential for creating employment opportunities for the rural poor as well as offering opportunities for promoting local level entrepreneurship and enhances women’s participation. It is estimated that one hectare of Jatropha plantation will generate 313 person days in the first year itself. The availability of technologies for decentralised production of biofuels offers opportunities for the development of local level entrepreneurship. The potential for engaging women in raising nurseries and in collection of TBOs could lead to their enhanced participation in the village economy

7.1.6 CDM opportunities

The potential for gaining carbon credits under the Kyoto Protocol’s Clean Development Mechanism (CDM) adds to the economic benefits available through biofuel development. Although discussions on emission trading in transport sector are still underway, its introduction has a potential to create new opportunities for biofuel promotion by making it financially viable.

7.1.7 Environmental sustainability

To date, very little work has been done on studying the environmental sustainability of biofuel development initiatives in India. The environmental impacts of biofuels, primarily energy consumption and emissions over complete production cycle (land-to-wheel analysis) and impact on biodiversity have not been studied in detail There is a concern that with the government focus only on Jatropha, could lead to the development of large tracts of mono-culture plantations.

7.1.8 Institutional aspects

Models including, industry-farmer partnership, Joint Forest Management (JFM), oil-producers cooperative and decentralized production and utilization are some of the options that are being considered for biofuel cultivation, production and marketing. As the creation of employment generation opportunities and distribution of benefits of biofuel development will depend to a large extent on the model chosen, there is a need to assess these models to appreciate their advantages and limitations. Also before selected models are launched on a wider scale, there is a need to test the same on a pilot basis in a few places.

7.1.9 Legal framework and Policy environment

In India, there is no comprehensive legal framework for the use and promotion of the biofuels. In the short term, for the initial trial phase, the biofuel production and use could be well legalized under the ambit of existing laws in the country. Later on as the programme grows in its scope it would be desirable to have a separate legislation exclusively dealing with all aspects of biofuels.

As of today, there are no National level policy guidelines to support the promotion of the biofuel programme. There are isolated cases of State governmental policy interventions to promote the small scale and experimental programs.

7.2 Future outlook

Notwithstanding the tardy progress in the development of biofuels in India, it is expected that the market for biofuels will develop in future chiefly because of:

- The shortage and rising price of the fossil fuels that will make it necessary to shift towards an alternative.
- The pollution created by the increased density of vehicles using traditional fossil fuels will make it obligatory to search for alternatives.
- Bringing wastelands under use, automatically leading to more vegetative cover and protect the land from further degradation.
- Targeting poverty alleviation through the creation of employment opportunities for the rural poor.

The Government of India has prepared an ambitious programme to promote the development of biodiesel in the country, however before making a full blue print large-scale introduction of biofuels in the economy, it is clear that a number of issues still need to be addressed before such a programme could be a success. Some of the aspects which need immediate attention include:

7.2.1 Policy Aspects

Implementation of a nation-wide Biofuels programme could see a need to reorganize the village community where plantation is expected, understand the impacts of such large scale plantation on productive agriculture lands, learn the nature and effects (both positive and negative factors) depending on the category of the plantation such as the effects of Jatropha, Pongamia and the like, the associated environmental clearance for both industrial and for transportation, the need to provide subsides and customs and excise duty cuts and reduction to push the programme, and other measures for which the government needs to take proactive measures. All these can be done only through a comprehensive policy outline, which clearly delineates:

- Provisions to promote production and wide usage of biofuels
- Quality standards for biofuels
- Duties and taxes on biofuels
- Ownership issues related with government owned wastelands
- Incentives for biofuel production
- Production targets for the future.
- Role of private sector

7.2.2 Legal Framework

For smooth implementation of the biofuel programme, the policy should be adequately supported by legal enactments that promote, sustain and cover all aspects of the biofuel production and use. Although the scope of biofuels could be well legalized under the ambit of existing laws, in the long run, as the programme would be implemented throughout the country, it would be advisable to enact a separate legislation exclusively dealing with all the aspects of biofuels. This will facilitate, the administrative agencies both at the centre and at the state to activate and coordinate in better way. .

7.2.3 Programme Administration

In the national effort of such immense importance there are many institutions, both Government, Quasi-Government and Voluntary Organizations, which have to play major roles and their responsibilities have to be clearly defined. Even within the Government the Ministries of Rural Development, Agriculture, Petroleum and Natural Gas, Panchayati Raj, Environment and Forests all have interest in the planning and implementation of the Biofuels initiative. Their roles will often enmesh with each other and can at times be overlapping.

Therefore, a clear understanding and coordination among the different institutions involved is necessary.

In addition, the role of State Government Departments: Departments of Rural Development and Panchayati Raj, Agriculture and Forest Ministries, would be paramount for programme implementation. These departments could directly help in raising nurseries, promote raising of plantations and their management.

Panchayati Raj[1] Institutions and other local bodies should be educated and made aware of biofuel programme. They should be encouraged to take up its implementation as essentially it helps the rural population to raise its income and employment levels. Panchayats could supplement their revenue earnings by leasing out village common lands to local community groups or their private parties for biofuel plantations. In addition, a number of models for biofuel production and marketing are under active consideration. It is important that models, which ensure creation of employment opportunities for the weaker sections and distribution of benefits of biofuel development to rural populace, are promoted.

To promote the development of biofuels, it would be equally important to explore linkages with other central and state level programmes targeted at rural development, employment generation, poverty alleviation, natural resource management and food for work.

7.2.3 Financial Support and Incentives

To popularize the production of biofuel the initial five - ten years would require the support of the Government agencies. This support could be offered in the form of incentives and subsidies, tax holidays, which can be gradually withdrawn as the sector stabilizes and markets for biofuels are established in the country.

Field –to-Tank

All aspects of production and distribution of non-edible oilseeds /biofuel should be fully exempted from all taxes and duties by the Central and State governments for ten years as a matter of firm policy declaration.

As part of the promotion, government should provide tax benefits to producers and processors at decentralised level. A tax holiday for five years for all newly set up units of production and processing of biofuels from non-edible oils.

[1] *Panchayati Raj provides a three-tier system of self-governance in rural India. Under three-tier system of democratic decentralization, Zilla Parishad is the apex body at the district levels followed by the Panchayat Samitis, at block level as second-tier and gram Panchayats, the third-tier*

It is important that nationalized banks and cooperatives are encouraged to provide adequate finances for setting up small scale biofuel processing units, and to farmers or entrepreneurs to go for large scale plantations of trees which provide non-edible vegetable oils.

Agencies like National Bank for Agriculture and Rural Development (NABARD) could play an active role in promoting use of biofuels in rural areas and specifically for agriculture and agro-processing activities. Future loan assistance directly or indirectly should tie up with promoting biofuels all over the country.

Tank-to-Wheel

The Government of India along with the state governments could offer incentives to public sector transport organizations to initiate biodiesel blending, thereby creating a reading consumer.

In order to popularize the use of biofuels, and provide an impetus for the sector to compete with conventional fuels, biofuels should be offered sales tax exemption for initial five years all over the country.

Provide one-time concessional loans to enable manufacturers of all types of engines to make necessary modifications, if necessary, to use and to enhance the efficiency levels of biofuel use.

7.2.4 Marketing Mechanism

Field –to-Tank

Khadi and Village Industries Commission is already involved in the oilseeds production, collection and marketing at the village level. They could take a more pro-active role in creating awareness, funding and marketing aspects for non-edible TBOs.

Tank-to-Wheel

One of the options for the establishment of biofuel distribution network could be to route them through the existing fuel vendors and possibly by connecting a market chain incorporating the existing petro-products. The government should seek active participation of the private sector in this endeavour.

Particularly, in rural areas, the government should facilitate provision of outlets for selling biofuelbiofuels and to take care of both economic and technical grievances.

7.2.5 Private sector participation

Field-to-tank

Farmer's owning cultivable wastelands should be offered incentives to raise biofuel plantations both as block plantations and hedge rows. Community based groups should also be encouraged to raise these plantations on village common lands. Lands available with various government departments and lying unused should be either leased or allowed for management to other public or private bodies for the specific purpose of raising nurseries and biofuel trees and supplying to farmers.

The private sector companies, even large scale industry, should be encouraged to raise biodiesel plantations as in the case of tea, coffee, farm forestry in India and palm oil in Malaysia and Indonesia.

The Commodity Boards of Coffee, Tea, Rubber, should educate and persuade their members, whose estates have large area of land which are not exhaustively planted with coffee, tea or rubber, to grow biofuel trees and may be even to process them to supplement their income which is now rather precarious due to global competition and low prices for various other reasons.

The private sector including, small entrepreneurs, community groups as well as large corporate groups, should be offered incentives to set up processing plants for the production of biodiesel.

Tank-to-wheel

Private sector companies who already have an established network for the distribution of fossil fuel could use the same network for the distribution of biofuels throughout the country. Private sector could play a lead role in the promotion of use of biofuels by developing stationary engines and vehicles that can operate on these fuels.

7.2.6 Research and Development

Field –to-Tank

Both scientific and agricultural research bodies should be involved directly and on a regular basis to regularly enhance the efficiency levels of both production and processing of biofuels. Some of the activities that they could focus at include:

- to select and evolve quick growing and high-yield varieties and improved methods of propagation to produce better quality oil.
- to provide farmer's with a choice of TBO species that are most appropriate to local agro-climatic conditions
- to standardise agronomic practices for different agro-ecological regions
- to develop mechanisms to produce ethanol from ligno-cellulosic materials like bagasses, rice straw.
- help in the development and provision of suitable processing technology.

Tank-to-Wheel

Scientific organizations should be engaged to carry out research on the efficient use of different SVOs and blends of biofuels as well as necessary engine modification for enhanced efficiency in both vehicles and stationary engines. The costs involved in R&D can be reduced by collaborating with private vehicle / engine manufacturers.

Another area where scientific institutions could play an important role is in the monitoring of biofuel quality at various levels. In order to assess the environmental sustainability of biofuel development, research organizations should be encouraged to undertake Life Cycle Analysis exercise for biofuels produced from varied feedstock being used India. A detailed assessment of Carbon cycle would also assist in gauging the impact of promoting biofuels in the national as well as Global context.

7.3 Strength-weaknesses Analysis (SWOT) of the three main biofuel options in India

For a quick overview, strengths, weaknesses, opportunities and threats to the three main biofuel options in Indea are shown in the following table. The reader should keep in mind that the three different biofuels are not really in competition, as they require different engine types.

Table 7.1: SWOT-analysis biofuels

<table>
<tr><th>Bioethanol</th><th>Straight Vegetable Oils (SVOs)</th><th>Biodiesel</th></tr>
<tr><td colspan="3">Strengths</td></tr>
<tr><td>Has been commercially blended since 2003</td><td>Are being commercially produced from non-edible oils seeds of Pongamia, jatropha, neem</td><td>Partly based on utilisation of non-edible oils</td></tr>
<tr><td rowspan="3">At present commercially more viable, as its price matches the import parity price for petroleum</td><td>Have been successfully utilised as fuel in the transport sector as well as in electricity generation and motive power</td><td rowspan="3">Successful trials on their use in both road and rail transport</td></tr>
<tr><td>Extraction process is decentralised and therefore SVOs available at local level</td></tr>
<tr><td>Lower costs than biodiesel because of cutting down of trans-esterification costs</td></tr>
<tr><td rowspan="3">Better environmental performance through reduction in vehicular pollution and Green House Gas (GHG) emissions</td><td colspan="2">Help reduce vehicular pollution and GHG emissions</td></tr>
<tr><td colspan="2">Pongamia and Jatropha can be grown successfully underrainfed condition</td></tr>
<tr><td colspan="2">De-oiled cake is a good organic fertilizer and is widely used in agriculture</td></tr>
<tr><td rowspan="2">Policy and institutional environment for promoting use of bioethanol is in place</td><td>-</td><td>Recent Biodiesel purchase policy would strengthen the sector</td></tr>
<tr><td colspan="2">Credit facilities are available in for raising plantations / nurseries, establishments of seed collection and oil expelling centres and biodiesel manufacturing units</td></tr>
<tr><td colspan="3">Weaknesses</td></tr>
<tr><td>Dependence on a single source – sugarcane molasses – for bioethanol production</td><td>There are still concerns on engine performance and maintenance requirements</td><td>A relatively new fuel in the Indian context</td></tr>
</table>

Bioethanol	Straight Vegetable Oils (SVOs)	Biodiesel
Sugarcane cultivation is resource intensive, and in its present form is unsustainable in the long term		High costs because of lack of commercial production at the moment
Production at the moment depends a lot on the vagaries of nature, including drought and pest attacks	Seed yields show enormous variations because of difference in germ-plasm, plantation practices and edapho-climatic conditions	
Only those farmers who have ready access to cash or credit, irrigation and water supply, fertilizers and pesticides can farm sugarcane	Economic viability depends a lot on seed yields and income from by-products	
High water use necessary for sugarcane cultivation is generally associated with significant runoff of polluted water	Jatropha seed is highly toxic. Studies have demonstrated the toxicity of the oil, fruit and the pressed cake.	
	Lack of appropriate legal set up to promote their use	
Opportunities		
Utilisation of sweet sorghum as feedstock	Opportunity for utilising Non edible oils	
Research is being carried out to develop technology to produce ethanol from cellulose materials, e.g. rice straw, bagasse	Opportunity for greening of wastelands and prevention of further land degradation	
Utilisation of drip irrigation systems can help extend sugarcane cultivation	Generation of new employment opportunities in raising, reaping and processing of TBOs	
	Detoxification of the jatropha seedcake can lead to the increased value addition as the seed cake can then be used as cattle feed	
Threats		
Use of food grains for production of ethanol is not viable because of the issues related to food security	Limited availability of un-encroached wastelands and planted stock for raising TBOs	
The limited water resources constrain the expansion of area under sugarcane cultivation	Little plant improvement work has been carried out till date. The existing low yield levels of 1-2 tonne per ha further constrain the production potential	
The land ownership system which discourages ownership of vast tracts of land by private entities	Ensuring good prices for by-products is central to making biodiesel production an economically viable enterprise	
Small scale of sugar producing units affects the cost of bioethanol	-	Trans-esterification requires certain scale of production for the sake of economy

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