REPORT OF THE COMMITTEE ON DEVELOPMENT OF

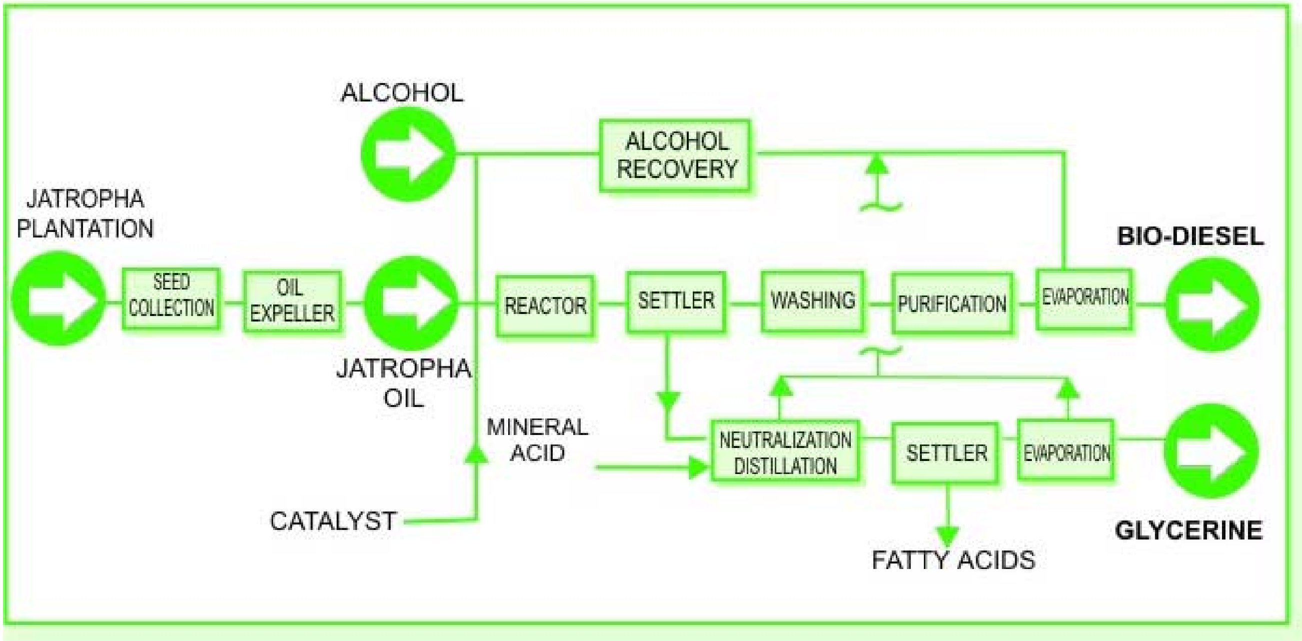
BIO-FUEL

PLANNING COMMISSION

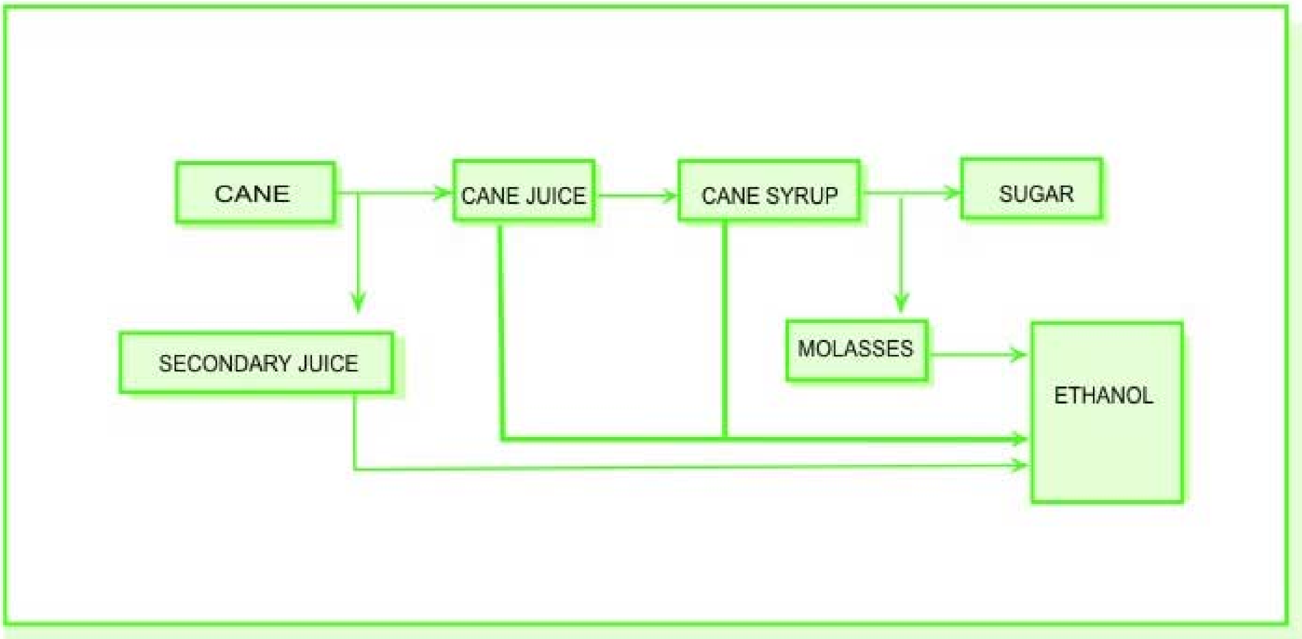
GOVERNMENT OF INDIA

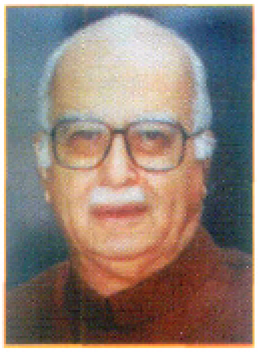
NEW DELHI-110001

PRODUCTION OF BIO DIESEL USING JATROPHA AS FEEDSTOCK



PRODUCTION OF ETHANOL USING SUGARCANE AS FEEDSTOCK





L. K. ADVANI

DEPUTY PRIME MINISTER

MESSAGE

Petroleum resources are finite and therefore search for alternative is continuing all over the world. Development of bio-fuels as an alternative and renewable source of energy for transportation has become critical in the national effort towards maximum self-reliance- the corner stone of our energy security strategy. Bio-fuels like ethanol and bio-diesel being environment friendly, will help us to conform to the stricter emission norms. International experience has demonstrated the advantages of using ethanol and methanol as automotive fuel. Since blends below 10% of ethanol do not present any problem and reduce harmful emission, a decision has already been taken to blend 5% ethanol with motor spirit w.e.f. 1.1.2003 in a number of States. To achieve higher blending, a concerted programme for use of bio mass for conversion to alcohol is essential including expansion of area under sugarcane cultivation.

High Speed Diesel (HSD) is the main transport fuel hence introduction of bio diesel both as a diesel substitute and for blending with Petroleum diesel both as a diesel substitute and for blending with Petroleum diesel is an imperative need. Bio-diesel commands crucial advantages such as technical feasibility of blending in any ratio with petroleum diesel fuel, use of existing storage facility and infrastructure, superiority from the environment and emission reduction angle, its capacity to provide energy security to remote and rural areas and employment generation. Moreover, crops like sunflower, rapeseed and tree borne oil seeds like *Jatropha curcas* provide rich bio mass and nutrients to the soil and check degradation of land -a major problem affecting nearly 65 million hectares of land.

The nation is facing a shortage of edible and non-edible oil. The existing high price of edible oil and the full use of tree borne oil seeds for various purposes suggest that organized bio diesel production for blending is possible only if plantation of selected species is taken up in compact areas and backed by infrastructure for procurement, primary processing, and production at the plant duly equipped to produce quality bio diesel for the oil industry. Since the demand for diesel will continue to rise steadily with economic growth, the processing facilities as well as plantation have to necessarily expand. This will serve two important purpose e.g. blending will result in part oil substitution and thereby reduce crude oil import, save foreign exchange and help us to move towards stricter emission norms.

The proposal to launch the National Mission on Bio Diesel is therefore, a timely initiative of the government to address socio-economic and environmental concerns. I compliment the Planning Commission for taking this bold and timely initiative and hope that the Mission will lay a strong foundation of an integrated bio fuel production capability in the Tenth Plan helping the nation's efforts towards optimum self-sufficiency in energy.

I wish the National Mission all success.

(L.K. Advani)

कृष्ण चन्द पन्त
K. C. PANT

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April 16, 2003

Foreword

The gases emitted by petrol and diesel driven vehicles have an adverse effect on the environment and human health. There is universal acceptance of the need for reducing such emissions. As a responsible member of the global community, and also in our own interest, India must play an active role in exploring and adopting ways to reduce emission without affecting the process of growth and development. One of the ways in which this can be achieved is through the use of ethanol and bio diesel and blending them with motor spirit and diesel respectively. It is in this context that the Committee on Development of Bio Fuels was set up.

The Committee has taken note of the present glut of sugar in the market which in turn affects the livelihood of sugarcane growers and landless labourers who depend on cultivation and processing of sugarcane. One way to help resolve the problem is to promote production of ethanol direct from sugarcane juice and use of bagasse for generating electricity, in addition to production of ethanol from molasses. The introduction of blending of 5% ethanol with motor spirit from 1.1.2003 in 8 States is, therefore, a step in the right direction which simultaneously meets three objectives - reducing emissions, reducing energy imports and improving the livelihood of farmers.

The prospects offered by bio diesel are equally attractive. It is technically feasible as up to 20% of bio diesel is being blended successfully with diesel for some years in a number of countries. India enjoys some special advantages in taking up plantation of tree-borne oil seeds for production of bio diesel as we have vast under-utilized or unutilised land, either fallow, barren, degraded or understocked, as in forests which are in drought prone areas. Additionally such trees can go along with normal crop raising.

Through a consultation process involving farmers, NGOs, Automobile manufacturers, State Governments and Central Government Department, it has been possible to identify Jatropha curcas as the most suitable Tree Borne Oilseed (TBO) for production of bio-diesel in view of its ability to thrive under a variety of agro-climatic conditions, low gestation period and higher seed yield.

The capacity of Jatropha curcas to rehabilitate degraded or dry lands, from which the poor mostly derive their sustenance, by improving their water retention capacity, makes it an instrument for up-gradation of land resources and especially for helping the poor. Thus, grown on a significant scale, Jatropha can clean the air and green the country, add to the capital stock of the farmers and the community and promote crop diversification which is imperative in Indian agriculture. The chain of activities from raising nurseries, planting, maintaining, primary processing and oil extraction is labour intensive and will generate employment opportunities on a large scale, particularly for the rural landless and help them to escape poverty.

I am glad to see that the committee has envisaged a mechanism for networking each activity like plantation, research related to the various aspects of bio diesel and its use, technology development, quality control and marketing with appropriate institutions. The responsibilities of every stake holder as well as a system for coordination at the Central, State and field levels have also been clearly laid down.

I commend the painstaking efforts make by. Dr. D.N. Tiwari, Member, Planning Commission and his team in bringing out this valuable Report. I trust that the Report will give a timely impetus to effort being made to move towards more sustainable fuel alternatives in our country.

(K.C. Pant)

PREFACE

Ever increasing consumption of fossil fuel and petroleum products has been a matter of concern for the country for huge out-go of foreign exchange on the one hand and increasing emission causing environmental hazards on the other. Public at large are raising their concerns over the declining state of environment and health.

With domestic crude oil output *stagnating*, the momentum of growth experienced a quantum jump since 1990s when the economic reforms were introduced paving the way for a much higher rate of development leading the demand for oil to continue to rise at an ever increasing pace. The situation offers us a challenge as well as an opportunity to look for substitutes of fossil fuels for both economic and environmental benefits to the country.

Ethanol is one such substitute that can be produced from sugarcane and used in blend with gasoline for automobiles. Similarly, bio-diesel can be produced from oil bearing seeds of many plants grown in the wild like *Jatropha curcas*, and blended with High Speed Diesel for transport vehicles, generators, railway engines, irrigation pumps, etc. Large volumes of such oils can also substitute imported oil for making soap.

Methanol is produced in sugar-mills as a by-product and it can be converted to ethanol. Ethanol can also be produced directly from sugarcane juice. On account of *continuing* glut of sugar in the market, there is *a* strong case for producing ethanol directly from sugarcane juice. This will, on the one hand, help farmers and labourers engaged in growing sugarcane *resulting in the sustainability of the source of their livelihood* and substitute imported crude on the other.

While the decision to blend 5% ethanol with petrol effective in eight major cities from 1.1.2003 is a step in the right direction, the ratio should gradually be increased to 10 and 20% over a period of time and extended to cover remaining parts of the country.

Similarly, oil extracted from seeds of plants like *Jatropha curcas* and processed into bio-diesel could be blended with petroleum diesel. *Jatropha curcas* is a quick maturing plant species that starts bearing fruits within a year of its planting and following the extraction and trans-esterification the oil can be blended with petroleum diesel for use. It is a very hardy plant and grows in a wide variety of agro-climatic conditions from arid (200 mm of rainfall) to high rainfall areas and on lands with thin soil cover to good lands. It is also not browsed by cattle and so its plantation can be easily under taken in the farmers' fields and their boundaries, under-stocked forests, public lands and denuded lands facing increasing degradation. Its plantation, seed collection, oil extraction etc. will create employment opportunities for a large number of people, particularly the tribals and the poor, and will help rehabilitate unproductive and wastelands and save precious foreign exchange by substituting imported crude.

A modest beginning is proposed to be made by launching a National Mission on Bio-Diesel comprising six micro missions covering all aspects of plantation, procurement of seed, oil extraction, trans-esterification, blending and trade, and research and development. The financial requirement of the Demonstration Project is estimated at little over Rs.1496.00 crore during the Tenth Plan. The proposed plantation in 4 lakh ha. in phases will generate 127.6 million person days of work in the Tenth Plan. In addition, the seed collection will provide sustainable employment to the tune of 8 million person days or 1.22 lakh person years and primary processing, oil esterification, transport etc. will create additional jobs. There will be manifold increase in employment generation once the Demonstration Project under the National Mission has been successfully implemented and gives rise to the Second Phase in the Eleventh Plan. Thus Bio-diesel development by itself could become a major poverty alleviation programme for the rural poor apart from providing energy security to the country in general and to the rural areas in particular and upgrading the rural non-farm sector.

The concept and the project profile of the National Mission on Bio-diesel has been the outcome of an intensive consultation process with the various stake holders viz. the automobile manufacturers, the farming community, NGOs, concerned Central & State Government Departments and research bodies. Space does not allow me to mention here the names of all individuals and institutions who have contributed to the formulation of the Mission Programme. A list of such persons and bodies is appended with the report. I am especially thankful to *Shri Nishi Kant Sinha, Secretary, Shri Mantreshwar Jha, Principal Adviser (Environment & Forests), Shri Vinay Shankar and Shri Rangan Dutta (Senior Consultants), Dr. R. Mandal, Adviser (Environment & Forest), Shri Parveen Mithra, Consultant and Shri B.K. Tiwari, Joint Adviser* in the Planning Commission for their valuable contribution.

I am confident that the proposed action programme of the National Mission on Bio-diesel will lay a strong foundation for a *clean and green India, energy security, employment generation and sustainable development.*

(D.N. Tewari)
Member, Planning Commission

List of Abbreviations

S.No.	Abbreviation	Expanded Form
1	ASTM	American Society for Testing and Materials
2	B20-20%	20% biodiesel and 80% petrodiesel
3	BHP / bhp	Horsepower
4	BIS	Bureau of Indian Standards
5	BOD	Bio-Chemical Oxygen Demand (a measure of effluent pollution)
6	BTEX	Benzene Toluene Ethylebenzene and Xylene
7	Bu	Barrel = 34.8 litre
8	CAPART	Council for the Advancement of People's Action and Rural Technology
9	CDM	Clean Development Mechanism
10	CFPP	Cold Flow Plugging Point
11	CNG	Compressed Natural Gas
12	COD	Chemical Oxygen Demand (a measure of effluent pollution)
13	CPCB	Central Pollution Control Board
14	Cr	Crore
15	CSIR	Council of Scientific and Industrial Research
16	CSt	Centistoke – a measure of viscosity
17	DDGS	Dried Distillers Grains & Solubles (residue left after fermenting corn)
18	DF	Diesel Fuel
19	EPA	Environment Protection Agency
20	ETBE	Ethyl Tertiary Butyl Ether
21	FCI	Food Corporation of India
22	FFA	Free Fatty Acid
23	FIP	Fuel Injection Pump
24	FY	Financial Year
25	GHGs	Green House Gases
26	Ha or ha	Hectare
27	HC	Hydrocarbons
28	HSD	High Speed Diesel
29	ICAR	Indian Council of Agricultural Research
30	ICFRE	Indian Council of Forestry Research & Education
31	IIP	Indian Institute of Petroleum
32	IIT, Delhi	Indian Institute of Technology, Delhi
33	IOC (R&D)	Indian Oil Corporation (Research & Development)
34	IWDP	Integrated Watershed Development programme
35	KL	Kilolitre
36	KVIC	Khadi and Village Industries Commission
37	KwH	Kilo Watt Hour
38	LCA	Life Cycle Analysis
39	Mb/d	Million Barrel per day

40	Mha or M ha	Million Hectare
41	MMSCMD	Million Standard Cubic Metres per day (a measure of gas flow)
42	MMT	Million Metric Ton
43	MMTPA	Million Metric tonne per annum
44	MPD	Million Person Days
45	MTBE	Methyl Tertiary Butyl Ether
46	MW	Mega Watt
47	NABARD	National Bank of Agriculture and Rural Development
48	NOVOD	National Oilseeds and Vegetable Oil Development Board
49	Nox	Nitrogen Oxides
50	NPAH	Nitrated PAHs
51	OEM	Original Equipment Manufacturers
52	ON	Octane Number
53	OTRI	Oil Technological Research Institute, Ahmedabad
54	PAH	Polycyclic Aromatic Hydrocarbons
55	PM	Particulate matter
56	RON	Research Octane Number
57	RSME	Rape Seed Methyl Ester or Biodiesel made from Rapeseed oil
58	SGRY	Swarnajayanti Gram Rozgar Yojna
59	SGSY	Swarnajayanti Gram Swarozgar Yojna
60	SIAM	Society for Indian Automobile Manufacturers
61	SIDBI	Small Industries Development bank of India
62	TBOs	Tree Borne Oilseeds
63	TEL	Tetra Ethyl Lead
64	Th	Thousand
65	Th. KL	Thousand Kilo Litre
66	U.S.EPA	United States Environment Protection Agency
67	WG	Working Group

REPORT OF THE COMMITTEE ON DEVELOPMENT OF BIO-FUEL

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REPORT OF THE COMMITTEE ON DEVELOPMENT OF BIO-FUEL

EXECUTIVE SUMMARY

i. Introduction

Oil provides energy for 95% of transportation and the demand of transport fuel continues to rise. The requirement of Motor Spirit is expected to grow from little over 7 MMT in 2001 –02 to over 10 MMT in 2006-07 and 12.848 MMT in 2011-12 and that of diesel (HSD) from 39.815 MMT in 2001-02 to 52.324 MMT in 2006-07 and just over 66 MMT in 2011-12. The domestic supply of crude will satisfy only about 22% of the demand and the rest will have to be met from imported crude. Our dependence on import of oil will continue to increase in the foreseeable future. It has been estimated that the demand for crude oil would go up to 85 MMTPA from about 50 MMTPA in 2001-02 while the domestic production will be around 22% of the demand. The crude prices and availability are subject to great volatility depending upon the international situation and, therefore, attempt needs to be made to reduce dependence on imports.

In biofuels the country has a ray of hope. Biofuels are renewable liquid fuels coming from biological raw material and have been proved to be good substitutes for oil in the transportation sector. As such biofuels – ethanol and biodiesel- are gaining worldwide acceptance as a solution to environmental problems, energy security, reducing imports, rural employment and improving agricultural economy.

Ethanol is used as fuel or as an oxygenate to gasoline. Raw material used for producing ethanol varies from sugar, cereals, sugar beet to molasses in India. Brazil uses ethanol as 100 % fuel in about 20 per cent of vehicles and 25% blend with gasoline in the rest of the vehicles. USA uses 10 % ethanol-gasoline blends whereas a 5% blend is used in Sweden. Australia uses 10% ethanol-gasoline blend. Use of 5% ethanol-gasoline blend is already approved by BIS and is in progressive state of implementation in the country. BIS standards for 10% blend need to be drafted after conducting trials and fixing parameters.

Biodiesel is made from virgin or used vegetable oils (both edible & non-edible) and animal fats through trans-esterification and is a diesel substitute and requires very little or no engine modifications up to 20% blend and minor modification for higher percentage blends. The use of biodiesel results in substantial reduction of un-burnt hydrocarbons, carbon monoxide and particulate matters. It has almost no sulphur, no aromatics and has about 10 % built in oxygen, which helps it to burn fully. Its higher cetane number improves the combustion.

Sunflower and rapeseed are the raw materials used in Europe whereas soyabean is used in USA. Thailand uses palm oil, Ireland uses frying oil and animal fats. It is proposed to use non-edible oil for making biodiesel.

ii. Rationale of Biofuels for Transport in India:

The rationale of taking up a major programme for the production of bio-fuels for blending with gasoline and diesel in our country emanates from a variety of factors. First, there is no alternative to the petroleum based fuels i.e., motor spirit or gasoline and High Speed Diesel (HSD) for the transport sector which is the major consumer of petroleum products. Secondly, biofuels are environmentally superior fuels and their use becomes compelling if the prescribed emission norms are to be achieved. Thirdly, there is need to meet the global environmental concern about climate change, ensure energy security, reduce imports, generate employment for the poor and achieve a number of other objectives of the Tenth Plan.

iii. Automotive Engines

Automobiles use two groups of engines, based on -

- Constant pressure cycle which in practice is diesel engine and alternatively called compression ignition engine. The fuel for this kind of engine is diesel a major fraction of crude oil distillation. These are used for all our heavy vehicles in railway transport, in tractors etc.
- Constant volume cycle which in practice is our gas engines and alternatively called spark ignition engine. The fuel for this kind of engine is gasoline cut of the crude oil. These engines are used for all light vehicles like cars, three wheelers and two wheelers. Gasoline gives the advantage of making possible two stroke engines for motor bikes, scooters etc without the need of cumbersome valve mechanism The advantages are in the form of quick start, fast acceleration, no large quantity of carbon emission, particulate matter (PM). Gasoline has high calorific value of 10000 kcal/kg and all the desirable properties for storage, ignition, combustion and handling. The demand for light vehicles continues to grow faster than for heavy vehicles.

From environmental aspects, to achieve Bharat II emission standards, there are problems in using petrol and diesel as fuels. There are strong reasons why substitutes should be found and used for motor spirit/gasoline and diesel.

iv. Gasoline (Motor Spirit) & Its Substitute – Ethanol

a. Problems with gasoline:

There are several problems in using gasoline or motor spirit or petrol which are derived from crude oil. Petroleum reserves are finite. Emissions from engines using gasoline or motor spirit such as Nitrogen Oxides, Sulphur Dioxide, Carbon Dioxide and particulate matter cause pollution. Gasoline has knocking tendency which limits the compression ratio of the gas engine. TEL is an additive that improves the anti-knocking rating of the fuel dramatically. The harmful effect of the lead led to banning of its use. Benzene or cyclic compounds also increase the octane rating. Benzene is, however a known carcinogenic material. Alternatively, MTBE and ETBE are used as additives to improve anti-knocking tendency and to reduce other vehicular emissions. The oxygenated fuels burn more completely and so reduce carbon monoxide emission upto 20%.

b. Ethanol as an automotive fuel:

The advantages of using ethanol and methanol as automotive fuels are that they are oxygenates containing 35% oxygen and are renewable. They reduce vehicular emission of Hydrocarbons and Carbon Monoxide and eliminate emission of lead, benzene, butadiene etc.

While the calorific value of ethanol is lower than that of gasoline by 40% it makes up a part by increased efficiency. Blends below 10% of ethanol do not present problems. However, blends above 20% pose certain difficulties such as (i) higher aldehyde emissions, (ii) corrosiveness, affecting metallic parts (iii) higher latent heat of vaporisation causing startability problem, (iv) higher evaporation losses due to higher vapour pressure and (v) requiring large fuel tank due to lower calorific value .

As there is a theoretical decrease in the energy content of gasoline blended with oxygenates, a decrease in mileage, km/ltr of fuel consumed is expected. But in urban use a significant increase in fuel efficiency has been reported.

The higher latent heat of vaporisation of ethanol than gasoline is expected to cause startability problem. But blend up to 25% ethanol in gasoline poses no problem.

Ethanol is corrosive in nature, absorbs moisture readily and can affect metallic parts (ferrous/non-ferrous). However with the 10% ethanol blend no compatibility problems have been found.

Standards For Ethanol Use As Fuel Blending have been prescribed:

c. Production Of Ethanol:

1. Raw Material

Three classes of vegetative sources (raw materials) can be used:

- starch as grain, corn and tubers like cassava
- sugar plants (sugar beet or sugar cane)
- cellulose plants (general tree and biomass)

2. Process:

Ethanol production is very ancient linked with making potable alcohol. The liquor containing corn, grapes juice, molasses etc are fermented by adding yeast to it in batch fermentators for a number of hours (minimum 40 hours) when fermentation gets completed it is distilled to remove water and undesirable compounds for achieving 99%+ purity.

Through Sugarcane:

Through sugar cane- sugar route: The major source of ethanol production in the country is via sugarcane-sugar-molasses route. This provides better economy by sale of sugar, molasses becomes the by-product of the sugar. Average sugar cane productivity in India is about 70 MT per hectare and ethanol produced from one MT of sugarcane is 70 litre.

Through sugar beet:

In European countries sugar beet is preferred. Sugar beet has certain advantages over sugarcane. It provides higher yield (12.5 to 17.5 ton per hectare of sugar against 7.5 to 12 ton of sugar per hectare from sugarcane in addition to low requirement of water, lower maturity time and lower power requirement for crushing.

Sugar beet cultivation and its processing to ethanol needs to be promoted in the country

Starch based alcohol production:

Alcohols are produced from a large number of different starch crops as barley, wheat, corn, potato, sorghum etc. The conversion of starch into alcohol follows the same process of fermentation and distillation as that of sugarcane.

Corn can provide about 275 litre of ethanol from one MT. With productivity of 2 MT per hectare, 550 litre of ethanol can be produced from one hectare of corn plantation. In addition to lower yield per hectare of ethanol, corn presents the problem of disposal of residue, but it can be used as animal feed. It can, however, be utilised for value added products which can provide starch based alcohol production economical. Corn oil is edible and its use in India for production of ethanol is not economically feasible.

Ethanol made from cellulosic biomass

In the coming years it is believed that cellulosic biomass will be the largest source of bioethanol. The broad category of biomass for the production of ethanol includes agricultural crops & residues and wood. Biomass resources are abundant and have multiple application potential. Among the various competing processes, bioethanol from lignocellulosic biomass appears to have economic potential. The crops residues such as rice straw, bagasse etc are not currently used to derive desired economic and environmental benefits and thus they could be important resource base for bioethanol production. As for example one MT of rice straw or bagasse can give over 400 litre of ethanol

Cellulosic material are polymers of sugar and are difficult to decompose by enzymes and need breaking of bonds before hand. Two different routes are being tried. One is by action of chemical (Acid or new generation of enzymes) and the second is the thermal route of gasification. The first route is being generally followed as in paper pulp industry. However, for ethanol production economics are not favourable. The gasification route provides better economics but looks to be very complicated. It is as yet in an experimental stage.

d. Economics of production:

The major factors that affect the ethanol cost are, the yield of sugarcane and cycle of production, the sugar contents in the juice, efficiency in juice extraction as well as in fermentation, and lastly utilisation of waste.
Under the existing price structure, sugar production provides higher value addition than sugarcane to ethanol.

In $ /MT

	U.S.A.	**Brazil**	**India**
Sugarcane to sugar	28.28	10.71	9.36
Sugarcane to ethanol	-4.21	8.21	5.66

e. Utilisation of waste:

Two major waste products are generated in the ethanol production from sugarcane namely, Bagasse that can be used as boiler fuel and also as raw material for news print and spent wash that can be used for generation of biogas which is a gaseous fuel of medium heating value.

f. Research areas in the field of bioethanol

Ethanol producers in the United States produce around 1.5 billion gallons of ethanol each year, mostly derived from corn. As demand for ethanol increases, other biomass resources, such as agricultural and forestry wastes, municipal solid wastes, industrial wastes, and crops grown solely for energy purposes, will be used to make ethanol. Research activities over the past 20 years have developed technology to convert these feedstocks to ethanol.

Fuel ethanol is currently produced from the easily fermented sugar and starch in grain and food processing wastes. Soon, new technologies will be economically viable for converting plant fiber to ethanol. A portion of the agricultural and forestry residues (corn stover ,stalks, leaves, branches) which are presently burned or left in the field may therefore be harvested for biofuel production. There will be many benefits by connecting the established corn ethanol industry with the emerging technologies that produce ethanol from agricultural wastes and other types of biomass.

Sweet sorghum can be grown in temperate and tropical regions. Sweet sorghum produces a very high yield in comparison with grains, sugar, lignocellulosic biomass (on average a total of 30 dry tons/ha per year) Plantations need less seed than for other crops: 15 kg/ha compared with 40kg/ha for corn, or 150 kg/ha for wheat.

g. Meeting the Ethanol demand for blending:

The ethanol demand for blending can be calculated from the plan projection of the future growth in gasoline use as tabulated below:

Ethanol Demand And Supply For Blending In Gasoline

Year	Gasoline demand	Ethanol demand	Molasses production	Ethanol Production			Utilization of Ethanol		
				Molasses	Cane	Total	Potable	Industry	Balance
	MMT	Th KL	MMT	Th KL	Th KL	Th KL	Th KL	Th KL	Th KL
2001-02	7.07	416.14	8.77	1775	0	1775	648	600	527
2006-07	10.07	592.72	11.36	2300	1485	3785	765	711	2309
2011-12	12.85	756.35	11.36	2300	1485	3785	887	844	2054
2016-17	16.4	965.30	11.36	2300	1485	3785	1028	1003	1754

Notes:
1. Area under sugarcane cultivation is expected to increase from 4.36 mha in 2001-02 to 4.96 in 2006-07 which would add additional cane production of around 50 MMT.
2. About 30% of cane goes for making gur and khandsari. If there is no additional increase in khandsari demand, sugar and molasses production would increase.
3. The present distiller capacity is for 2900 Th kL of ethanol and looks to be sufficient for 5% blend till 12 th plan
4. A growth of 3% in potable use and a 3.5% in chemical and other use has been assumed.

The Government has taken the decision to make the 5% blending in gasoline as mandatory in phased manner. From the table it is clear that the present production of ethanol is mainly from molasses. It is projected that in the year 2006-07, 1485 thousand kl of ethanol from sugarcane directly will be produced in addition to 2300 thousand kl from molasses. Thus for meeting the demand of ethanol for 10 % blending, capacity to produce ethanol in the country is sufficient. But for blending purposes anhydrous ethanol is required and the distilleries will have to put up facility to dehydrate ethanol and produce anhydrous ethanol . For higher percentage of blending and till the demand becomes stable, correspondingly higher quantities of ethanol, and consequently more sugarcane and other raw material, would be needed. The target should be to raise the blending in stages to 10% by the end of the X Plan.

h. Recommendations on Ethanol

- The country must move towards the use of ethanol as substitute for motor spirit. Though it is technically feasible to design and run automobiles on 100% ethanol, for the reason of its limited availability and compatibility with vehicles presently in use, blending of ethanol with motor spirit needs to make a very modest beginning to be raised to 10%, as capacity to produce anhydrous ethanol is built up.

- Ethanol may be manufactured using molasses as the raw material. The industry should be encouraged to supplement the production of alcohol from molasses by producing alcohol from sugarcane juice directly in areas where sugarcane is surplus. For this purpose restrictions on movement of molasses and putting up ethanol manufacturing plants may be removed.

- Imported ethanol should be subject to suitable duties so that domestically produced ethanol is not costlier than the imported one.

- Ethanol diesel blending requires emulsifier and also poses certain storage and technical problems. Indian Institute of Petroleum is working on the subject. Ethanol diesel blending should await the solution of the problems.

- Buyback arrangement with oil companies for the uptake of anhydrous alcohol should be made.

- To reduce cost of production of ethanol, the following measures may be considered:

- Provision of incentives for new economic sized distilleries incorporating state of art technology such as, molecular sieve technology for making anhydrous alcohol.

- Integration of distillery with sugar plant to have multiple choice of making sugar, or direct sugarcane to ethanol.

- Economics of ethanol production from other feedstocks such as sugar beet, corn, potatoes, grain, straw etc should be studied. R&D should be carried out to develop technologies which are competitive in cost of production of ethanol from molasses.

v. Biodiesel

a. Problems in Using Petroleum Derived HSD:

Like all fossil fuels the use of HSD also makes net addition of Carbon to the atmosphere. In addition, diesel emits particulate matter (PM), specially below micron 2.5 which passes the protection system of the body to get lodged in lungs causing reduction in its vital capacity. In association with the particulate matter the un-burnt oil is carcinogenic. In addition Carbon Monoxide, Hydrocarbon, Sulphur and PAH emissions are on the higher side.

Attempts to reduce particulate matter emissions have not been entirely successful. A 15% ethanol –diesel blend reduces particulate matter emission, however the blend provides certain technical problems for which satisfactory solution has not been found. These have been discussed in the succeeding paragraphs.

b. Characteristics of Biodiesel

Bio-diesel is fatty acid ethyl or methyl ester and has properties similar to petroleum diesel fuels. Similar to the HSD, bio diesel is its substitute. The specifications of bio-diesel are such that it can be mixed with any diesel fuel. Cetane number (CN) of the bio-diesel is in the range of 48-60 and the sulphur content is typically less than 15 ppm. Studies conducted with bio-diesel on engines have shown substantial reduction in Particulate matter (25 – 50%). However, a marginal increase in NO_x (1-6%) is also reported; but it can be taken care of either by optimization of engine parts or by using De-NO_x catalyst . HC and CO emissions were also reported to be lower. Non-regulated emissions like PAH etc were also found to be lower. Thus, bio-diesel can supplement the supply of environment friendly fuels in our country in future. In conventional diesel fuels, the reduction in sulfur content is compensated by adding additive for lubricity of fuel injection pump (FIP). Bio-diesel is reported to have superior lubricity. Flash point of bio-diesel is high (> 100^o C). Its blending with diesel fuel can be utilized to increase the flash point of diesel particularly in India where flash point is 35^o C well below the world average of 55^o C. This is important from the safety point of view. The viscosity of bio-diesel is higher (1.9 to 6.0 cSt) and is reported to result into gum formation on injector, cylinder liner etc. However, blends of up to 20% should not give any problem. While an engine can be designed for 100% bio-diesel use, the existing engines can use 20% bio-diesel blend without any modification and reduction in torque output. In USA, 20% bio-diesel blend is being used, while in European countries 5 -15% blends have been adopted. Bio-diesel can be blended in any ratio with petroleum diesel fuel. It can be stored just like the petroleum diesel fuel and hence does not require separate infrastructure. Bio-diesel has been accepted as clean alternative fuel by US . Due to its favorable properties, bio-diesel can be used as fuel for diesel engines (as either,B5-a blend of 5% bio-diesel in petro-diesel fuel,) or B20 or B100). USA uses B20 and B100 bio-diesel, France uses B5 as mandatory in all diesel fuel.

Sunflower, rapeseed is the raw material for Bio-Diesel used in Europe whereas soybean is used in USA. Thailand uses palm oil, Ireland uses frying oil and animal fats. In India it is proposed to use non-edible oil for producing Biodiesel. Presently many species are being grown which yield seed containing non-edible oil. The present production is being used and much surplus is not available. It is proposed to take up a major plantation programme of *Jatropha curcas*, for reasons which are given in the later part of this report, to provide the oil needed.

c. Rationale:

The rationale of taking up a major programme for the production of bio-diesel in India for blending with diesel lies in the context of :

- Bio-diesel being a superior fuel than HSD from the environmental point of view;
- **Use of bio-diesel becomes compelling in view of the tightening of automotive vehicle emission standards and court interventions;**
- The need to provide energy security, specially for the rural areas;
- The need to create employment;
- Providing nutrients to soil, checking soil erosion and land degradation;
- Rehabilitating degraded lands through greening;
- Addressing global concern relating to containing Carbon emissions as provided in the Framework Convention on Climate Change; and
- Reduce dependence on crude oil imports.

d. Feasibility Of Producing Bio-Diesel As Petro-Diesel Substitute

For the reason of edible oil demand being higher than its domestic production, there is no possibility of diverting this oil for production of bio-diesel. There are many tree species which bear seeds rich in oil. Of these some promising tree species have been evaluated and it has been found that there are a number of them such as *Jatropha curcas* and *Pongamia Pinnata* ('Honge' or 'Karanja') which would be very suitable in our conditions. However, ***Jatropha curcas*** has been found most suitable for the purpose. It can be planted on under-stocked forest lands managed by the J.F.M. Committees, farmers field boundaries to provide protective hedge, fallow lands, on farmers' holdings as agro-forestry along with agricultural crops, public lands along railway tracks, highways, canals and community and government lands in villages. It can also be planted under the poverty alleviation programmes that deal with land improvement.

e. Economics of Biodiesel from *Jatropha curcas:*

The by products of Bio-diesel from *Jatropha* seed are the oil cake and glycerol which have good commercial value. These bye-products shall reduce the cost of Bio-diesel depending upon the price which these products can fetch. The cost components of Bio-diesel are the price of seed, seed collection and oil extraction, oil trans-esterification, transport of seed and oil. The cost of Bio-Diesel produced by trans-esterification of oil obtained from *Jaropha curcas* seeds will be very close to the cost of seed required to produce the quantity of biodiesel as the cost of extraction of oil and its processing in to biodiesel is recoverable to a great extent from the income of oil cake and glycerol which are bye-products.

Taking these elements into account, the price of Bio-diesel has been worked out assuming cost of seed as Rs. 5 per kg, 3.28 kg of seed giving one litre of oil and varying prices of by-products. The cost of Bio-diesel varies between Rs. 16.59 to 14.98 per litre if the price of glycerol varies between Rs 60 and 40 per Kg.

f. Target of bio-diesel production:

Targets need to be set up for bio-diesel production. The objective is to gradually raise it to take it to 20% in the year 2011 – 12 beginning with 5% in 2006-07. It is estimated that HSD demand by the end of 11th Plan (2011-12) shall be 66.9 MMT requiring 13.38 MMT of Biodiesel which in turn will require plantation of *Jatropha curcas* over about 11.2 million ha of land. In order to achieve 5% replacement of petro-diesel by bio-diesel by the year 2006-07, there is need to bring minimum 2.19 million ha area under plantation of *Jatropha curcas*. Year wise projected consumption of HSD, the requirement of Biodiesel for different rates of blending and the area that needs to be brought under *Jatropha* plantation are given in the following table.

Diesel & Biodiesel Demand, Area Required under Jatropha For Different Blending Rates

Year	Diesel Demand MMT	Bio-Diesel @ 5% MMT	Area for 5% Mha	Bio-Diesel @ 10% MMT	Area for 10% Mha	Bio-Diesel @20% MMT	Area for 20% Mha
2001-02	39.81	1.99	N.A.	3.98	N.A.	7.96	N.A
2006-07	52.33	2.62	2.19	5.23	4.38	10.47	8.76
2011-12	66.90	3.35	2.79	6.69	5.58	13.38	11.19

g. Potential availability of land for Jatropha Plantation:

With appropriate extension and availability of planting material it should be easy to cover 13.4 Million hectare of land with *Jatropha curcas* as indicated below:

- Forests cover 69 Million hectares of which 38 million hectare is dense forest and so 31 million hectare is under-stocked. Of this 14 million hectare of forests are under the Scheme of Joint Forestry Management. 3.0 million hectare (notional) of land in forests should easily come under *Jatropha curcas* plantation.
- 142 million hectare of land is under agriculture. It will be reasonable to assume that farmers will like to put a hedge around 30 million hectare of their fields for protection of their crops. It will amount to 3.0 million hectare (notional) of plantation.
- The cultivators are expected to adopt it by way of agro-forestry. Considerable land is held by absentee land lords who will be attracted to *Jatropha curcas* as it does not require looking after and gives a net income of Rs 15000 per hectare. 2 Million Hectare of notional plantation is expected.
- Culturable fallow lands are reported to be 24 million hectare of which current fallow lands are 10 million ha and other fallows are 14 million hectares. Ten percent of such land (2.4 million hectare) is expected to come under *Jatropha curcas* plantation

- On wastelands under Integrated Watershed Development and other poverty alleviation programmes of Ministry of Rural Development a potential of 2 million hectare of plantation is assessed..
- On vast stretches of public lands along railway tracks, roads and canals. One million hectare of notional coverage with *Jatropha curcas* is a reasonable assessment.

In addition about 4 Million hectare of waste lands could also be brought under such plantation.

h. Specifications and Quality Standards for Bio-fuels

ASTM has issued bio-diesel standard D 6751 in December 2001, which covers the use of pure bio-diesel (B100) into conventional diesel fuel up to 20 % by volume (B20). This replaces the provisional specification PS 121 issued in1999. Austria (ON C 1191), France (JO), Italy (UNI 10635) and Germany (DIN E 51606) had issued bio-diesel standards in 1997, Sweden in 1996 and a common draft standard EN 14214 for the European Union has also been announced. The new Italian bio-diesel standard, which will replace UNI 10 635, has been finalized and will be released this year for public. The standards for Bio-Diesel in India are under formulation and are proposed to be based on standards adopted by European Union. It is necessary that the approval of Vehicle, Engine and Fuel Injection manufactures is taken before finalizing standards and implementing fuel change. By getting warranties from OEMs and FIE manufacturers, the customer acceptance of bio-fuels will increase and shall go a long way in enhancing the use of bio-fuels.

i. R&D Issues Needing Attention:

- **Raw Material (Jatropha seed and oil):**

Selection of improved germ-plasm material for quality and quantity of oil ; Selection of the bio-crop for production of Biodiesel i.e *Jatropha curcas* & others; Developing agro-technologies for different agro-climatic regions; Total chemical analysis of all potential non-edible oils with special reference to *Jatropha Curcas* Oil.

- **Production Technology :**

Research efforts for perfecting an efficient chemical/ catalyst conversion process ; Development of Bio-catalyst i.e. Lipase catalyzed esterification ; Development of Heterogeneous Catalyst i.e. use of smart polymers ; Alternate uses of by-products i.e. glycerol and meal cake.

- **Utilization as Fuel :**

Data generation & Production of bio-diesel from all possible feed stocks ; Response of different available additives and their dosages on the bio-diesel ; Effect of bio-diesel on elastomers, corrosion etc ; Stability of Bio diesel - Oxidation stability, Thermal Stability and Storage Stability; Engine Performance and emissions based on different feedstock based Bio-diesels ; Toxicological Studies and Tests to check Adulteration

- **Plants in operation/ under construction**

Different technologies are currently available and used in the industrial production of bio-diesel, which is sold under different trademarks. For example, there are the Italian processes Novamont, and the French IFP. A number of units are manufacturing bio-diesel worldwide. These units are using sunflower oil, soybean oil, rapeseed oil, used-frying oil, *Jatropha* oil, etc. as a source of triglycerides . Out of 85 plants identified, 44 plants were in Western Europe with Italy as the leading country with 11 plants, 29 plants in Eastern Europe, 8 plants in North America and 4 plants in the rest of the world. Overall capacity grew from 111,000 tons in 1991 to 1,286,000 in 1997. USA is the fastest growing newcomer and a number of companies are emerging there. Additional capacities are expected in Japan and the palm oil producing countries, Indonesia and Malaysia. Actual production grew from 10,000 tons in 1991 to 661,000 tons in 1997. France is the leading producer with 227,000 tons (in 1996).

- **Blending of Esters & Diesel**

Blending conventional Diesel Fuel (DF) with esters (usually methyl esters) of vegetable oils is presently the most common form of bio-diesel. The most common ratio is 80% conventional diesel fuel and 20% vegetable oil ester, also termed “B20,” indicating the 20% level of bio-diesel; There have been numerous reports that significant emission reductions are achieved with these blends and no engine problems were reported in larger-scale tests with B20. Another advantage of bio-diesel blends is the simplicity of fuel preparation, which only requires mixing of the components. Ester blends have been reported to be stable. One limitation to the use of bio-diesel is its tendency to crystallize at low temperatures below 0°C. causing problems in fuel pumping and engine operation. One solution to this problem may be the use of branched-chain esters, such as isopropyl esters. Another method to improve the cold flow properties of vegetable oil esters is to remove high-melting saturated esters by inducing crystallization with cooling, a process known as winterization.

- **Storage & handling of Bio-Diesel:**

As a general rule blends of bio-diesel and petroleum diesel should be treated like petroleum diesel. Though the flash point of bio-diesel is high, still storage precautions somewhat like that in storing the diesel fuel need to be taken. Based on experience so far, it is recommended that bio-diesel can be stored up to a maximum period of 6 months. Bio-diesel vegetable methyl esters contain no volatile organic compounds that can give rise to poisonous or noxious fumes. There is no aromatic hydrocarbon (benzene, toluene, xylene) or chlorinated hydrocarbons. There is no lead or sulphur to react and release any harmful or corrosive gases. However, in case of bio-diesel blends significant fumes released by benzene and other aromatics present in the base diesel fuel can continue.

- **Engine Development & Modifications**

The use of unrefined vegetable oil leads to poor fuel atomization due to high viscosity resulting in poor combustion and also more gum formation in fuel injector, liner etc. The results of emissions of using unrefined vegetable oils were unfavorable and were also accompanied by deposit formation . Therefore, it is necessary to esterify the vegetable oil for use in engines. However, these problems can be addressed by use of a suitable additives package. Engine oil dilution is a potential problem with biodiesel since it is more prone to oxidation and polymerization than diesel fuel. The presence of biodiesel in engine could cause thick sludge to occur with the consequence that the oil becomes too thick to pump. Engine oil formulations need to be studied to minimize the effect of dilution with biodiesel. It must be noted that the light duty diesel engines are sufficiently different from heavy duty diesel engines in many aspects and one should not expect that the emission behavior of the two types of engines would be same. This fact should be kept in mind while transferring conclusions of studies done on one type of engine to other type of engines.

- **Marketing & Trade**

Biodiesel mixes easily in any proportion with the conventional diesel and by virtue of its high density it can be easily blended in a tank containing petroleum diesel. Its handling and storage is just like the petroleum diesel and no separate infrastructure is required. Therefore, the blending of biodiesel, which transported by tankers, should be carried out at depots of diesel marketing and distribution companies. The biodiesel blends do not need separate dispensing and existing diesel dispensing station can also dispense biodiesel blends. Since the percentage of Biodiesel to be blended will have to start from a low level, say 5%, and gradually increase, studies related to blending will need to be carried out.. The role of marketing companies in distribution, pricing, taxation,, interstate movement and the direct and indirect impact of biodiesel e.g. employment generation, balance of trade, emission benefits etc need to be studied.

- **R&D Work done in India**

In India, attempts are being made for using non-edible and under-exploited oils for production of esters. Punjab Agricultural University is actively involved in R&D work on plant oils and their esters (bio-diesel) as alternate fuel for diesel engines since early eighties. Indian Institute of Petroleum (IIP) is actively pursuing the utilization of non-edible oils for the production of bio-diesel, additives for lubricating oils, saturated and unsaturated alcohols and fatty acids and many other value added products. Indian Institute of Chemical Technology extracted oil from *Jatropha curcas.* A catalyst-free process (Indian patent filed, US Patent being filed) that is insensitive to moisture or high FFA content has been developed at IICT, and an oil of any FFA content can be converted to the alkyl ester. Besides, preliminary studies on the utilization of non-edible oils such as Neem, Mahua, Linseed etc. as fuel are being carried out at IIT, Delhi and IIT, Madras. IOC R&D is also doing some work on the transesterification of vegetable oils. IOC (R&D) has already set up a biodiesel production facility of 60 kg/day at Faridabad. Mahindra & Mahindra Ltd has a pilot plant utilizing Karanj for biodiesel production and has carried out successful trials on tractors using this fuel.

vi. National Mission on Biodiesel:

a. Necessity:

For reasons mentioned under 'Rationale' above, it is clear that Biodiesel must be produced in the country in quantities sufficient to enable its blending with HSD to the extent of 20% in '2011-12. The estimated production of bio-diesel will require plantation of *Jatropha curcas* over 11 million hectares of land in and outside forests and mobilisation of initiative and enterprise of large numbers of stake holders including individuals, communities, entrepreneurs, oil companies, business, industry, financial institutions, government and its institutions. It is, therefore, necessary that an integrated programme based on the initiative and enterprise of these stakeholders and participants be prepared and implemented.

Accordingly a National Mission on Biodiesel is proposed. However, before the National Mission becomes a mass movement and assume the envisaged form, it will be necessary for the Government to demonstrate the viability of the programme with all its linkages in different parts of the country and widely inform and educate the potential participants and stake holders.

b. Phasing:

The National Mission on Biodiesel, is therefore proposed in two phases as below:

- Phase I consisting of a Demonstration Project to be implemented by the year 2006-07.
- As a follow up of the Demonstration Project, Phase II will consist of a self sustaining expansion of the programme beginning in the year 2007 leading to production of Biodiesel required in the year 2011-12.

c. Objectives of Demonstration Project:

The Demonstration Project will have the following objectives:

- To lay the foundation of a fast-growing and self-sustaining people and enterprise driven programme of Biodiesel production in the country.
- To produce enough seed for the production of bio-diesel.
- To test, develop and demonstrate the viability of all the components of the programme, and its estimated costs and varied benefits with all its forward and backward linkages,

- To inform and educate the potential participants of the programme.

d. Area Coverage Under Demonstration Project:

It will involve plantations on 4 lakh hectares of land in compact areas each of 50000 to 60000 Ha and ensuring setting up of facilities for all the activities involved in forward and backward linkages. A total of eight compact areas are proposed, one in each State– four for implementation by the JFM Committees and the Forest Department and four by other agencies on non-forest lands. The Implementation by JFM Committees are proposed in the States of Tamilnadu, Chhattisgarh, Gujarat and Tripura. Non-forest lands proposed to be covered lie in the States of UP (near Allahabad), M.P. (near Ujjain), Maharashtra (near Nasik) and Andhra Pradesh in Telangana.

The areas chosen are such as have good potential and would lead to massive dissemination of information, awareness generation and education through visits to actual *Jatropha* plantations and other components of the Project of very large numbers of persons. The size of the compact area selected is such that all the activities can be carried out in a cost effective manner. Experience in Europe has demonstrated that a trans-esterification plant of an annual capacity of 80,000 tons is economical. This much of oil is expected to be produced from a plantation over an area of 50 to 70 thousand hectares depending upon the agro-climatic conditions. This area under plantation in each of the eight States will support one unit of trans-esterification. These compact areas will be subdivided in to blocks of about 2000 Ha of plantation each to facilitate supply of planting material, procurement of seed and primary processing through expellers.

e. Mission Mode of Demonstration Project:

The Demonstration Project is proposed to be planned and implemented in a mission mode. For this purpose, 6 Micro Missions are proposed to optimize the activities to be undertaken under the project including plantation, procurement of seed and extraction of oil, processing of seed oil into Biodiesel (trans-esterification) , blending and marketing and Research & Development. These micro-missions and their nodal agencies are given below:

- Micromission on Plantation on Forest lands on 2 lakh hectares in four States each covering about 50000 hectares through the Joint Forestry Management Committees and FDAs with the Ministry of Environment & Forests acting in coordination with the State Governments, as the nodal agency.

- Micromission on Plantation on non-forest lands in four States each covering about fifty thousand hectares making a total of two lakh hectares. The National Oilseeds and Vegetable Oil Development Board (NOVOD) under the Ministry of Agriculture will perform the nodal role.

- Micromission on Plantation on Other Lands–Implementation by Ministry of Rural Development. *Jatropha curcas* plantation has all round positive implications for poverty alleviation and upgradation of land resources. Therefore, various programmes of the Ministry of Rural Development; such as IWDP, SGSY, SGRY, PMGY etc. could include *Jatropha* plantation as a part of their programme to help the farmers to escape poverty for which necessary funds are already provided under the Plans of the respective Ministries. The Ministry of Rural Development and its two departments namely the Department of Rural Development and the Department of Land Resources and CAPART may be made responsible for plantation in degraded and wastelands, and other areas (but not included in the Micromission to be implemented by NOVOD).

- Micromission on Procurement of Seed and Oil Extraction. KVIC will be the nodal agency. Similarly, KVIC may step in to support setting up the Seed Procurement Centres, procurement of seeds, oil extraction activity, developing and providing technology, Extension and training, mobilization of funds from the financial institutions and sale of oil for trans-esterification

- Micromission on Trans-esterification, Blending and Trade. Ministry of Petroleum and Natural Gas will perform the nodal role.

- Micromission on Research and Development. Since the project will be implemented for the first time in the country, problems are likely to be encountered. The institutions under ICAR, ICFRE, CSIR, other Research and Training Institutions supported by the Government of India, State Agriculture Universities and interested institutions in the industry – both public sector and private sector will be invited to make their contribution to problem solving.

f. Institutional Framework

There should be co-ordinated effort among the ministries, departments and governmental and non-governmental agencies assigned a role in the implementation of Bio-Diesel Programme. It is proposed that an inter-ministerial Coordination Committee be constituted under the chairmanship of Deputy Chairman, Planning Commission to formulate policy, give general guidance for effective implementation dealing with issues of coordination and monitoring of the programme. A Steering Committee under Member (S&T) involving officers from the concerned Ministeries is also proposed. A cell to service the two Committees may be set up in the Planning Commission.

g. Financial Requirement:

The financial requirement of the demonstration project has been estimated at Rs.1496 cr. during the Tenth Plan as detailed at Table IV, Chapter IV. This includes government contribution of Rs. 1384 Cr consisting of Rs.1200 cr. for Nursery, plantation and protection which has to be provided by the Govt. as a promotional measure as well as the administrative expenses of Rs.68 cr and R&D expenses of an equal amount. For the component of setting up Seed Collection and Oil extraction unit, the funds could be a mix of entrepreneurs' own contribution of Rs. 16 Cr (margin money), subsidy from the Government of Rs. 48 Crore and loan of Rs. 96 Cr from NABARD and SIDBI in the ratio of 10:30:60. Since *Jatropha* has never been used as a source of automotive fuel, some studies will have to be conducted relating to planting material, agro technologies, detailed studies of properties of oil and biodiesel produced from it, its behaviour in various kinds of vehicles and problems which have been listed in the relevant place. As regards the Trans-esterification Unit, it will be a commercial venture involving relatively large sum of money (Rs.75 crore). It is expected that the oil companies guided by the Ministry of Petroleum will induce private sector to set up such plants with financing from Financial Institutions; but the funds for R & D should be contributed by the Government, oil companies, associations of automobile manufacturers (SIAM) and other companies and associations connected with petroleum and automobiles.

h. Benefits of Demonstration Project:

The Demonstration Project will result in the following benefits:

- It will establish the feasibility of production of *Jatropha* based Biodiesel as a substitute for diesel and a source for energy security particularly for rural areas. In this process, output of 0.48 MMT of Biodiesel on a sustained basis will be achieved. 10.52 MMT of compost will also be produced.
- The country will become self sufficient in good quality planting material to take up plantation on the scale required for achieving 20% blending of diesel.
- It will be a major pro-poor initiative generating massive income and employment for the poor and thus an effective instrument of poverty alleviation.
- It will be a major tool for achieving the emission standards approved by the Government.
- It will address the concern of global warming under the Framework Convention on Climate Change.
- It will be major step towards improving the land resources through drought proofing, greening of degraded lands, soil and moisture conservation etc.
- Infrastructure for providing R&D support, standards and specifications, required legal cover, changes in manufacture of automotive engines and other parts will be firmly put in place to prepare the ground for future expansion as envisaged in the Mission.
- It will generate by the year 2007 cumulative employment of 127.6 million mandays in plantation and 36.8 million person days in seed collection. The employment generation on a sustained basis will be 16 MPD per year. Employment generated on a sustained basis for running seed collection and oil extraction centers will be 1600 Person years.
- On an overall basis, the income generated from the output of 1.5 million tons of seed will be Rs. 750 Crore. The income derived from *Jatropha* plantation and seed will be supplementary and assuming that the income from one hectare of

plantation will be shared by four families, the aforesaid amount will be distributed among not less than 1.9 million poor families helping them to escape poverty.

- The entire project will be community and farmer driven from plantation up to primary processing stage involving seed collection, procurement and oil extraction at the village level thus resulting in empowerment of the poor and their community in resource poor areas of endemic poverty.
- The Demonstration Project of the National Mission will establish the capacity of community, private and public sectors and market driven initiatives to achieve national objectives.

vii. Phase II of the National Mission:

On the basis of experience of the Demonstration Project, a Project will be formulated in the year 2006-07 for Phase II of the National Mission with the objective to achieve a self sustaining expansion of plantation and other related infrastructure with support of the Government. The aim will be to produce enough seed and Biodiesel for 20% blending with diesel. The villagers are expected to be attracted to *Jatropha* plantation on their field boundaries, fallow lands, fields, community lands government lands and, above all, understocked forests. A scheme of margin money, subsidy and loan may need to be instituted. Companies having lands could be encouraged to undertake *Jatropha* plantation.

Funds for plantation in degraded forests through JFM could come from the JFM members provided tree pattas can be given to each member who may be then induced to spend his own money as margin money and the remainder may come from the banks.

The funds for the Seed Collection Centres and oil extraction units, trans-esterification units and R&D will be mobilized in the same manner as during the Demonstration Project (Phase I).

Since bio-diesel programme will address global environmental concerns and will make a definite impact on poverty alleviation within a short period, the Project formulated for Phase II is likely to attract the support of bilateral and multilateral funding agencies.

viii. Recommendations relating to Biodiesel:

- A National Mission on Biodiesel as mentioned above should be launched with the objective of producing by the year 2011-12 biodiesel enough to enable its blending with HSD to the extent of 20%. A Demonstration Project as its First Phase be taken up immediately.
- The Demonstration Project be taken up in a mission mode with micro-missions described above.

- In addition, the Ministry of Rural Development may take up plantation under the IWDP and other poverty alleviation programmes. The Department of Rural Development, the Department of land Resources and CAPART will be responsible for plantation in degraded and wastelands in districts outside the districts included in the Demonstration Project, using the funds available under IWDP, SGRY and SGSY etc.

- After the completion of the Demonstration Project in the year 2007, the next phase of the National Mission should be a self sustaining expansion of plantation and setting up of corresponding facilities for seed collection, oil extraction, trans-esterification etc.

- Phase II should rest mainly on the initiative of the individuals, community, organizations, business and industry supported by financial institutions. The Government should act mainly as a facilitator providing policy support and interventions / incentives in critical areas as may be identified during monitoring and evaluation of the Demonstration project.
- Efforts should be made to get external funding for Phase II of the national Mission.

While legal framework would need to be provided for enabling the biofuel programme to make progress, in the beginning there is need for flexibility as a very rigid legal regime may hamper the development of biofuels in India. Hence it is proposed that a separate legislation on biofuels need not be considered at this stage and the needed legal requirements may be met by using the already available statutes such as the Environment Protection Act, Air (Prevention & Control of Pollution) Act and Motor Vehicles Act.

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Chapter 1

Introduction

1.1. Constitution of Committee on Development of Biofuels:

It is high time for India that the use of ethanol for blending with Petrol and bio-diesel for blending with petro-diesel is seriously considered. Accordingly, the Planning Commission has set up a Committee on Development of Biofuels with composition and terms of reference as given in **Annexure I**.

1.2. Biofuel For Transport:

Oil provides energy for 95% of transportation and the demand of transport fuel continues to rise. The extract from the third assessment report of the IPCC to Climate Change **(Annexure II)** provides the most accepted forecast on the subject. According to this assessment global oil demand will rise by about 1.6% from 75 mb/d in the year 2000 to 120 mb/d in 2030. Almost three quarters of the increase in demand will be from the transport sector. Oil will remain the fuel of choice in road, sea and air transportation. Our country being a developing country, the increase in demand in our country for oil for use in the transport sector will grow at a much higher rate. All countries including India are grappling with the problem of meeting the ever increasing demand of transport fuel within the constraints of international commitments, legal requirements, environmental concerns and limited resources. In this connection transport fuels of biological origin have drawn a great deal of attention during the last two decades.

Biofuels are renewable liquid fuels coming from biological raw material and have been proved to be good substitutes for oil in the transportation sector. As such biofuels – ethanol and Biodiesel- are gaining worldwide acceptance as a solution for problems of environmental degradation, energy security, restricting imports, rural employment and agricultural economy.

Ethanol is used as fuel or as an oxygenate to gasoline. Raw material used for producing ethanol varies from sugar in Brazil, cereals in USA, sugar beet in Europe to molasses in India. Brazil uses ethanol as 100 % fuel in about 20 per cent of vehicles and 25% blend with gasoline in the rest of the vehicles. USA uses 10 % ethanol-gasoline blends whereas a 5% blend is used in Sweden. Australia uses 10% ethanol-gasoline blend. Use of 5% ethanol-gasoline blend is already approved by BIS and is in progressive state of implementation in the country. BIS standards for 10% blend need to be drafted after conducting trials and fixing parameters.

Biodiesel is ethyl or methyl ester of fatty acid. Biodiesel is made from virgin or used vegetable oils (both edible & non-edible) and animal fats through transesterification. Just like petroleum diesel, biodiesel operates in compression ignition engine; which essentially require very little or no engine modifications up to 20% blend and minor modification for higher percentage blends because bio diesel has properties similar to petroleum diesel fuels. Biodiesel can be blended in any ratio with petroleum diesel fuel. It can be stored just like the petroleum diesel fuel and hence does not require separate infrastructure. The use of biodiesel in conventional diesel engines results in substantial reduction of unburnt hydrocarbons, carbon monoxide and particulate matters. Biodiesel is considered clean fuel since it has almost no sulphur, no aromatics and has about 10 % built in oxygen, which helps it to burn fully. Its higher cetane number improves the combustion even when blended in the petroleum diesel.

Biodiesel has been accepted as clean alternative fuel by US and its production presently is about 100 million Gallons. Each State has passed specific bills to promote the use of biodiesel by reduction of taxes.

Sunflower and rapeseed are the raw materials used in Europe whereas soybean is used in USA. Thailand uses palm oil, Ireland uses frying oil and animal fats. Due to its favorable properties ,biodiesel can be used as fuel for diesel engines (as either,B5-a blend of 5% biodiesel High Speed Diesel) or B20 or B100). USA uses B20 and B100 biodiesel, France uses B5 as mandatory is all diesel fuel. It can also be used as an additive to achieve the following objectives:-

1) To reduce the overall sulfur content of blend (Refineries can meet, to some extent, the requirement of low sulfur diesel fuel).
2) To compensate for lubricity loss due to sulfur removal from diesel fuel
3) To enhance the cetane number of diesel fuel (North-East refineries can greatly benefit by meeting the cetane requirement)

1.2.1. Rationale of Biofuels for transport in India:

The rationale of taking up a major programme for the production of bio-fuels for blending with gasoline and diesel in our country lies in the context of

- ethanol and biodiesel being superior fuels from the environmental point of view
- use of biofuels becomes compelling in view of the tightening of automotive vehicle emission standards and court interventions,
- the need to provide energy security, specially for the rural areas,
- the need to create employment, specially for the rural poor living in areas having a high incidence of land degradation,
- providing nutrients to soil, checking soil erosion and thus preventing land degradation,
- addressing global concern relating to containing Carbon emissions,
- reducing dependence on oil imports.
- usability of biofuels in the present engines without requiring any major modification,
- the production of biofuels utilizing presently under-utilised resources of land and of molasses and, in the process, generating massive employment for the poor.
- the use of biofuels not requiring major or time consuming studies or research,
- as will follow in this report, the programme of production of biofuels in the

country is feasible, is environmentally desirable and is less injurious to health and would address a variety of concerns expressed in the X Plan document.

These contexts are briefly discussed below.

1.2.2. Bio-fuels as Superior Transport Fuels:

a. Ethanol-Gasoline Blends:

The value addition of ethyl alcohol as an octane improver has been greatly enhanced because of improved fuel quality requirements. Ethanol vehicles have received high marks in performance, driveability, and reliability tests. Power, acceleration, payload and cruise speed are all-comparable with those for equivalent gasoline-fueled vehicles. Most conventional vehicles on the road today can use E10 (a 10% ethanol- 90% gasoline blend also known as gasohol) without any special modifications. The use of ethanol blending reduces the harmful emissions like Carbon Monoxide and Hydrocarbons.

b. Bio-Diesel

Similar to the HSD, bio diesel is a substitute for petro-diesel, the main liquid fuel for our heavy vehicles, railways, trucks, tractors, marine engines etc. The specifications of biodiesel are such that it can be mixed with any diesel fuel. Cetane number (CN) of the biodiesel is in the range of 48-60 and the sulfur content is typically less than 15 ppm. (The standards allow 200 ppm). It may be noted that blending of biodiesel can be used to supplement Bharat-I diesel to be formulated to Bharat – II compliant fuel by getting benefit of high cetane number and low sulfur content of Biodiesel.. Similarly, Bharat-II fuel can be upgraded to Bharat-III fuel.

Studies conducted with bio-diesel on engines have shown substantial reduction in Particulate matter (25 – 50%). However, a marginal increase in NO_x (1-6%) is also reported; but it can be taken care of either by optimization of engine parts or by using De-NO_x catalyst (De-NO_x catalyst will be necessary for Bharat-III / IV compliant engines). HC and CO emissions were also reported to be lower. Non-regulated emissions like PAH etc were also found to be lower.

In conventional diesel fuels, the reduction in sulfur content is compensated by adding additive for lubricity of fuel injection pump (FIP). Biodiesel is reported to have superior lubricity. Flash point of biodiesel is high (> 100^o C). Its blending with diesel fuel can be utilized to increase the flash point of diesel particularly in India where flash point is 35^o C well below the world average of 55^o C. This is important from the safety point of view.

The viscosity of biodiesel is higher (1.9 to 6.0 cSt) and reported to result into gum formation on injector, cylinder liner etc. However, blends of up to 20% should not give any problem.

While an engine can be designed for 100% bio-diesel use, the existing engines can use 20% bio-diesel blend without any modification and reduction in torque output.

In USA, 20% bio-diesel blend is being used, while in European countries 10-15% blends have become mandatory.

1.2.3. Tightening Vehicular Emissions Norms:

Introduction of biodiesel is particularly important for our country where the vehicular emission standards recommended by the Auto Fuel Policy Report have to be achieved. The Euro emission norms are given in **Annexure III.** Equivalent norms are to be adopted in Inida as Bharat Standards. The new vehicles (except two and three wheelers) are to comply with the Bharat Stage II emission norms in the entire country from 1.4.2005 and Bharat Stage III norms by 1.4.2010. In addition to 4 metros where Bharat Stage II norms are already in place, Bangalore, Hyderabad, Ahmedabad, Pune, Surat, Kanpur and Agra should also meet these norms from 1.4.2003. The four metros and the other seven cities should comply with Bharat Stage III and Bharat IV emission norms from 1.4.2005 and 1.4.2010 respectively. The two and three wheelers should conform to Bharat Stage II norms from 1.4.2005 all over the country and Bharat Stage III norms preferably from 1.4.2008 but not later than 2010. For new vehicles there is a separate road map.

It would be clear that the production and use of biodiesel duly blended with HSD is inescapable if the emission standards were to be achieved within the time prescribed.

1.2.4. Energy Security:

India ranks sixth in the world in terms of energy demand accounting for 3.5% of world commercial energy demand in 2001.The energy demand is expected to grow @ of 4.8% per annum. A large part of India's population, mostly in the rural areas, does not have access to it. At 479 kg of oil equivalent the per capita energy consumption is very low. Hence a programme for the development of energy from raw material which grows in the rural areas will go a long way in providing energy security to the rural people.

1.2.5. Creation Of Employment:

At the beginning of the new millennium, 260 million people in the country did not have incomes to access a consumption basket which defines the poverty line. India is home to 22% of world's poor. A programme which generates employment is therefore particularly welcome. The Biodiesel programme, under which the plantation will be the most dominant item of expenditure, will give employment to 313 person days in plantation over one hectare of land and will generate employment of 41 man days per year through out the life of the jatropha curcas plant. Production of ethanol will result in processing of molasses and greater requirement of sugarcane leading to increase in area and consequent job creation.

1.2.6. Stagnation In Domestic Production And Increase In Import Of Petroleum

The Indian scenario of the increasing gap between demand and domestically produced crude oil is a matter of serious concern. Our crude oil production as per the Tenth Plan Working Group is estimated to hover around 33-34 MMTPA. though there will be increase in gas production from 86 MMSCMD (2002-03) to 103 MMSCMD in 2006-07). Only with joint venture abroad there is a hope of oil production to increase to 41 MMTk by 2016-17). The gas production would decline by this period to 73 MMSCMD

On the other hand the growth in energy consumption in all forms is expected to continue unabated. Our energy is expected to grow at more than 4% owing to increasing urbanisation, standard of living and expanding population with stablisation not before mid of the current century. A shown in the table below the demand of motor spirit is projected to grow from 7.07 million tons in 2001-02 to 10.067 million tons in 2006-07 @ 7.3 % per annum, and of H.S.D @ 5.6% per annum with projected demand rising to 52.3 MMT in 2006-07 from 39.8 MMT in 2001 –02.

In other words, our dependence on import of oil will increase in the foreseeable future. The Working Group has estimated import of crude oil to go up from 85 MMTPA to 147 MMTPA by the end of 2006-07 correspondingly increasing the import bill.

The table given below gives the estimated demand and domestic production of transport fuel.

Table 1.1

Demand And Domestic Production Of Transport Fuel

Item	Projection in Thousand MT				Annual Growth %			Domestic supply %		
	2001-02	2006-07	2011-12	2016-17	10 plan	11 plan	12 plan	10 plan	11 plan	12 plan
MS	7070	10067	12848	16398	7.3	5.0	5.0	22.2	lower than 10	
ATF	2299	2691	3150	3687	3.2	3.2	3.2	22.2	plan projection	
HSD	39815	52324	66905	83575	5.6	5.0	4.5	22.2	if JV abroad ignored	
NG	81.33	179	313					47.9		

1. Figures from the WG report on Petroleum and NG for 10 Plan.
2. NG is expressed in terms of MMSCMD(Million Standard Cubic Meter Per Day).

Transport sector remains the most problematic sector as no alternative to petroleum based fuel has been successful so far. Hence petroleum based fuels will continue to dominate the transport sector in the foreseeable future.

1.2.7. Feasibility of producing bio-fuels as petrol and diesel substitutes

While the country is short of petroleum reserve, it has large arable land as well as good climatic conditions (tropical) with adequate rainfall in large parts of the area to account for large biomass production each year. The country, therefore, has very good potential to produce biomass that can be processed in to biofuels that are substitutes of transport fuels.

Ethanol:

In India ethanol is currently produced mainly from molasses that is a renewable source and a bio-product of the sugar industry.. It can be also produced from starch as potatoes or even wood. The sugar cane juice and its products both sugar and molasses can be diverted for production of ethanol to be blended in gasoline. However, ethanol has other uses such as beverage and industrial alcohol. The feasibility of producing sufficient quantity of ethanol for blending with motor gasoline is discussed in Chapter 2 on Ethanol.

Bio-diesel:

For the reason of the demand for edible oil being higher than its domestic production, there is no possibility of diverting this oil for production of bio-diesel. Fortunately there is a large area of degraded forest land and unutilised public land, field boundaries and fallow lands of farmers where non-edible oil can be grown.

There are many tree species which bear seeds rich in oil. Of these some promising tree species have been evaluated and it has been found that there are a number of them such as *Pongamia Pinnata* ('Honge' or 'Karanja') and *Jatropha curcas* which would be very suitable in our conditions. However, ***Jatropha carcus*** has been found to be the most suitable species for the purpose on many grounds that are discussed in the Chapter 3 on Bio-diesel.

It will use lands which are largely unproductive for the time being and are located in poverty stricken areas and in degraded forests. It will also be planted on farmers' field-boundaries, fallow lands and on public lands such as along the railways, roads and irrigation canals.

1.2.8. Economics of Biodiesel from Jatropha curcas:

America which produces bio-diesel from edible oil (mainly soya oil), the 100% bio-diesel costs around $ 1.25 to $2.25 per gallon depending upon purchase volume and the delivery costs and competes with low sulfur diesel oil. However it is costlier to normal diesel and the B20 blend costs 13 to 22 cents more per gallon than diesel. It takes about 7.3 pounds of soybean oil which costs about 20 cents per pound, to produce a gallon of biodiesel. Feedstock costs alone, therefore are at least $ 1.5 per gallon of soya - diesel. Fats and greases cost less and produce less expensive biodiesel, sometimes as low as $ 1 per gallon. Under the mustard seed program oil can be produced today for approximately 10 cents per pound and the total cost of producing mustard biodiesel is around $ 1 per gallon. The mustard oils, a low value product in the USA, contains as much as 90% mono-saturated fatty acids which makes it perfect for biodiesel, balancing cold flow issues with NO_x emission issues. The total biodiesel production in the country is around 1.9 billion gallons, mainly constrained by feedstock limitations. DOE is planning to add 5-10 billion gallons of biodiesel through mustard seeds having mustard meal a high value pesticide that helps keep the price of mustard oil low.

The bye products of Biodiesel from Jatropha seed are the seed oil cake and glycerol. The seed oil cake is a very good compost being rich in plant nutrients. It can also yield biogas which can be used for cooking and the residue will be used as a compost. Hence oil cake will fetch good price. Glycerol is produced as a bye product in the transesterification of oil. That too has very good value.

The cost components are the price of seed, seed collection and oil extraction, oil transesterification, transport of seed and oil. Cost recovery will be through sale of cake and of glycerol. Taking these elements in to account the price of Biodiesel has been worked out, assuming a net return of Rs. 3 per kg to the seed producer, the price of glycerol between Rs. 60 and 40 per Kg and the price of oil cake @ Re 1 per kg, the cost of Biodiesel works out to Rs. 13.24 to Rs. 14.10 per litre ex-transesterification plant. The details are discussed in the Chapter on Biodiesel.

Thus the plantation, oil estraction and production of Biodiesel is is economically feasible.

1.3. Target of bio-fuel production:

The requirements of biofuels have been worked out for blending ratios of 5, 10 and 20 perecent.

Table 1.2

Requirements Of Biofuels

Year	M.S Demand Million Ton	Ethanol requirement for blending Million Ton			Diesel Demand Million Ton	Biodiesel requirement for blending Million Ton		
		@ 5%	@ 10 %	@ 20%		@ 5 %	@ 10 %	@ 20 %
2001-02	7.07	0.35	0.70	1.40	39.81	1.99	3.98	7.96
2002-03	7.62	0.38	0.76	1.52	42.15	2.16	4.32	8.64
2003-04	8.20	0.41	0.82	1.64	44.51	2.28	4.56	9.12
2004-05	8.81	0.44	0.88	1.76	46.97	2.35	4.70	9.40
2005-06	9.42	0.47	0.94	1.88	49.56	2.48	4.96	9.92
2006-07	10.07	0.50	1.00	2.00	52.33	2.62	5.24	10.48

1.4. Environmental and Health Effects of Bio-diesel and Ethanol Blends of Gasoline:

These fuels are significantly safer from the view of their impact on environment and health. This has been discussed in detail in the portion dealing with Environmental & Legal Issues.

1.5. Prescribing Specifications And Quality Standards:

The issues of prescribing specifications and quality Standards for biofuels should not take a long time as ethanol-gasoline or Biodiesel-HSD blends have been in use in many parts of the world. Bureau of Indian Standards has already issued specifications of 5% Ethanol-gasoline blends (5% gasohol or E5). Specifications of 10% Ethanol – gasoline blends are under active consideration.

The report has also concluded that due to its favorable properties biodiesel should be used as fuel for diesel engines (as either,B5-a blend of 5% biodiesel in petro diesel fuel) or B20 or B100). USA uses B20 and B100 biodiesel, France uses B5 as mandatory is all diesel fuel It has also been recommended that some technical issues and of warranties from OEMs and FIE manufacturers issues should be resolved.

1.6. Engine Development & Modification

Need for engine development & modification have been felt in case of higher blends and that of diesel-ethanol emulsions which pose certain technical problems. Corrosion of Fuel Injecion System by use of ethanol/Biodiesel in higher blends calls for study and coordination with vehicle manufacturers.

1.7. Research & Development:

Considerable research has been done in Europe and USA on edible oils being used as a source of Biodiesel; but we propose to use the non-edible oil of Jatropha curcas seed. Though the essential composition of both varieties of oil is similar, there could be minor differences that need to be taken care of in production as well as in its use in HSD blends. The results of such studies will enable optimization of fuel injection systems, esterrification process and engine design. The chapter on R&D (IIP) identifies the subjects that would need to be studied. For some issues the institutions that may have interest in the subjects have also been identified. is proposed.

1.8. Conclusion:

It is thus clear that ethanol, presently produced mainly from molasses in India, is a suitable material for blending with motor gasoline and Biodiesel produced from non-edible oil is suitable for blending with diesel i.e. H.S.D.. The Ministry of Petroleum has already provided for blending of petrol with ethanol up to 5%. As the production capacity of anhydrous ethanol increases it should be possible to blend it in higher proportions.

To increase the production of anhydrous ethanol some of the initiatives that need to be taken are mentioned below:

- Distilleries may be encouraged to supplement their units to produce anhydrous ethanol.
- Sugar factories may be encouraged to set up distilleries.
- In areas of surplus sugarcane setting up of plants for direct conversion to ehanol may be encouraged.
- Removal of control on sugar releases, sugar-cane prices etc. may be considered.
- Inter-state tariff on molasses may be removed.
- Import of ethanol should be subjected to such tariff that the domestic ethanol is not more expensive than imported ethanol.
- Buy-back arrangements with oil companies need to be in place.

The promotion of ethanol production and its use are discussed in the chapter on Ethanol.

Ethanol produced from other raw matrerials, though feasible, is not likely to be competitive in the present circumstances. However, studies for using alternative feed stocks to produce ethanol should be encouraged and carried out. Since the use will be market driven, if it is economical, increase in production of ethanol will take place enabling a higher percentage of blending.

In so far as bio-diesel is concerned its blending with HSD is inescapable if the emission standards from transport vehicles have to be achieved by the prescribed dates and if other significant benefits associated with Jatropha plantation, extraction of oil and its processing have to be realised.

This report proposes that a National Mission on Biodiesel be launched to produce enough seed for the production of bio-diesel required for its 20 % blending with HSD. As a part of the National Mission, a Demonstration Project to establish the viability of the Mission is proposed. It will cover 0.4 million hectares of land in and outside the Forests under *Jatropha curcas* plantation of which 0.2 million will be in the forests in four States of Tamilnadu, Chhattisgarh, Gujarat and Tripura and 0.2 million will be in lands outside forests in contiguous districts each in the States of Uttar Pradesh, Madhya Pradesh, Maharashtra and Andhra Pradesh. The Mission will be an integrated one and will include all the linkages including forward linkages such as procurement of seed, extraction of oil, transesterification, blending and marketing. A large number of stake holders both within the Governments and outside will have to play active role in the Mission. Their roles have been discussed in the chapter on Institutional Arrangements. The Demonstration Project of the Mission is proposed to be implemented in a period of three years. The funds for this Demonstration Project are to come mainly from the Government.

The programme elements and objectives of the National Mission are in consonance with the ongoing schemes of the Ministry of Rural Development such as the SGSY, SGRY, IWDP. As such it is proposed that plantation of Jatropha curcas be dovetailed with these programmes and implemented out of the funds available for them. This plantation to be undertaken by the Ministry of Rural Development will cover suitable areas all over the country and will be in addition to the 4 lakh hectares to be covered in eight States mentioned in the previous paragraph.

The Demonstration Project is expected to demonstrate the viability of the proposal and, at the end of three years, attract the growers, entrepreneurs and financial institutions so that a self sustaining programme of expansion takes off on its own with the Government playing mainly the role of a facilitator. Hence for the expansion phase, the government will need to give only marginal financial support. The rural community will have the first right of access to the oil for its use. The surplus oil will be sold to the Units that would be established for processing the raw oil in to bio-diesel and blending it with petroleum diesel. The responsibility for ensuring that such facilities are set up will be that of the Ministry of Petroleum.

The National Mission will consist of Micro-missions each covering a major component of the entire programme. Institutional Arrangements are crucial for the success. The details are given in the Chapter on the subject.

Chapter 2

Ethanol

2.1. Ethanol programme

In the introduction, it has been stated that need for automotive fuel is going to increase and, dependence of internal combustion engine as a source for transport will continue with other technological developments not posing any significant challenge to it. Among the automobiles, there are two groups of their engines, based on -

- Constant volume cycle which in practise is our gas engines and alternatively called spark ignition engine. The fuel for this kind of engine is gasoline cut of the crude oil.

- Constant pressure cycle which in practice is diesel engine and alternatively called compression ignition engine. The fuel for this kind of engine is diesel a major fraction of crude oil distillation.

While the latter is used for all our heavy vehicles in railway transport, in tractors etc, the former is used for all light vehicles like cars, three wheelers and two wheelers. Overall efficiency of a gasoline engine is lower than that of a diesel engine, still it offers certain advantages due to its operation based on gasoline, a light fuel. The advantages are in the form of quick start, fast acceleration, no large emission of particulate matter (PM), no frequent major engine over-hauling requirement etc. One of the major concerns of the diesel engine is the emission of 100 to 200 times smaller sized PM than that in the gasoline engine exhaust. Gasoline gives the advantage of making possible two stroke engines for motor bikes, scooters etc without the need of cumbersome valve mechanism. The demand for light vehicles continues to grow faster than for heavy vehicles. If the diesel and petrol prices are near to each other as is the case in other countries, the tendency of having diesel engines in cars would not be there. The recent price trends show that the gap between the prices of petrol and diesel would close. The demand for auto cycles is growing very fast. With increase in trade and urbanisation, a larger segment of population is finding it essential to use two wheelers. The per capita income is growing, and there is a corresponding increase in the use of cars also.

The fuel for such engines (spark ignition) is petrol derived by distilling crude oil aking out from the petroleum reserves. It is composed of hydro-carbons which give it a high calorific value of above 10000 kcal/kg. Gasoline has all the desirable properties for storage, ignition, combustion and handling.

However, as narrated earlier, gasoline has two drawbacks which every petroleum derived fuel has namely that it is derived from a depleting resources and that its engines' emission increases the level of NOx, CO2, particulate matter and hydro-carbons in the atmosphere. For the emission of green house gases (GHGs) as NOx and CO2, it is a major contributor to climate change, the greatest concern of the present day.

2.2. Problems with gasoline:

Besides the problem associated with the finiteness of petroleum reserves there is the problem of pollution caused by the engine emissions. Emission of the acid gases cause respiratory problem wheras Nox and CO2 are linked to the climate change problem. CO2 is the major contributor in the GHGs but since all fossil fuels invariably contain carbon there is no way out except increasing the efficiency so that growth in consumption gets retarded. The same is the case with NOx, whose formation during combustion of gasoline or any fuel with air can not be checked. Next is incomplete combustion of the fuel due to very small time to it in the engine and perfect mixing not possible. Partly burnt hydro-carbon emissions from the exhaust of automobile engines are found to be carcinogenic in nature. The problem of incomplete combustion and NOx can be managed by using a catalytic converter in the exhaust. Sulphur compounds, however, poison the catalyst of the converter and so it should not be present in the gasoline. This condition is not compatible with TEL (tetra ethyl lead) which in small quantity is doped in gasoline for Octane improvement.

2.3. Octane improvement requirement in gasoline engines:

The average efficiency of Internal Combustion engine is in the range of 30-45%. Among other parameters, compression ratio is an important factor that has a large influence on efficiency. Higher the ratio the better is the efficiency. Problem with gasoline is its knocking tendency when a higher compression ratio is sought in order to achieve higher thermal efficiency. The knocking tendency of the fuel limits the compression ratio of the gas engine that can be used. Different class of hydro-carbons have a difference in their tendency towards resistance to knocking. Oil companies carry out blending of different class of hydro-carbons for increasing the octane rating of the fuel. Still, in the past, they could not achieve a reasonable value of octane number till the discovery of TEL an additive to improve the anti-knocking rating of the fuel dramatically was not made. Addition of TEL in a small quantity became a practice. The harmful effect of the lead led to banning of its use and oil companies were forced to seek other sources of improving the anti-knocking tendency of the gasoline. One is to increase benzene or cyclic compounds in it. Benzene is, however a known carcinogenic material and its content is being limited in the gasoline. Alternatively, MTBE (methyl tertiary butyl ether) and ETBE (ethyl tertiary butyl ether) are being used as additives to improve anti-knocking tendency.

MTBE and ETBE are compounds manufactured from the petroleum source but contain oxygen in addition to hydro-carbons. They are termed as **oxygenates** and their use improves not only anti-knocking tendency but results in the reduction in other vehicular emissions. The oxygenated fuels burn more completely and so reduce carbon monoxide emission upto 20%.

2.4. Diesel engine problem, higher emission of respiratory particulate matter:

The major problem with diesel is emission of large particulate matter. US, Environmental Protection Agency, EPA is putting increasingly strict exhaust emissions standard for truck and bus engines. EPA has proposed a gradual reduction of PM reduction from 0.1 g/bhp-hr rule in 2002 to 0.01 g/bhp-hr in 2006. Even stricter regulations are being initiated in EU. Use of oxygenate is expected to improve combustion efficiency and hence reduction in PM. In India also under the orders of the Supreme Court strict emission norms are being introduced in a phased manner.

2.5. Ethanol as an oxygenate:

Ethanol and methanol can serve as oxygenates. Ethanol and MTBE are now the most accepted fuel oxygenates. Compared to MTBE which is petroleum derived and contains 18% oxygen, ethanol is not only renewable but contains 35% oxygen. MTBE is both very water soluble and highly toxic; one teaspoonful being sufficient to contaminate whole water of a large swimming pool. When gasoline is spilled or leaked, it would contaminate ground water. Use of MTBE is going to receive a set back due to recent findings in USA where drinking water is found contaminated with MTBE in a very large section of population (27% of urban water supply) and the state has been asked to phase put MTBE in gasoline. Attempts were made to get a waiver but it was not granted. This clearly leaves the choice to ethanol. Eleven states in USA have acted to curtail MTBE use. With lower use of light vehicles, the MTBE problem may not be as serious as that in USA, still on economical ground, ethanol deserves preference over MTBE.

2.6. Oxygenates Permissible In India

BIS specs of 1995 for Motor Gasoline allows oxygenates as follows:

Table 2.1

Component	Limit, Percent (V/V), Max
Methanol*	3.0
Ethanol**	5.0
Isporopyl alcohol	5.0
Tertiary butyl alcohol	7.0
Ethers containing five or more carbon atoms	15.0
Other organic oxygenates ***	7.0

* Stabilizing agents essential
** Stabilizing agents may be added
*** Acetone is not permitted.

Table 2.2 Properties Of Conventional & Alcohol Fuels

Characteristics	Diesel	Gasoline	Methanol	Ethanol
Energy content (MJ/kg)	42.5	44.0	20.0	26.9
Heat of vaporisation (KJ/kg)		305		904
Kin Viscosity (mm^2/s)	4.01	0.6		1.5
Boiling point ^oC	140-360	37-205	65	79
Flash point ^oC	55-65	-40		13
Auto ignition temperature ^oC	230	300		366
Flammability limits (%gas in air)	0.0-5.6	1.4-7.6		3.3-19.0
Research octane no.	-25	87-98	106	107
Motor octane no.	-	80-9-	92	89
Cetane no.	45-55	0-5	5	5

Table 2.3 Properites of Most Common Alcohols and Ethers in Oxygenating of Fuels

Property	**MeOH**	**EtOH**	**MTBE**	**ETBE**	**Gasoline**
Density, g/ltr	796	789	746	747	730
Boiling point, ^oC	64	78	55	73	25…230
Heat value, Mj/ltr	15.9	21.2	25.5	27.1	32.6
Carbon, w-%	37.5	52.1	68.1	70.5	86
Oxygen-w-%	49.9	34.7	18.2	15.7	--
Heat of evaporation, kj/l	875	731	240	234	260
Reid vapor pressure, kPa	32	17	54	27	70…100
Vapour pressure in blend, kPa	414	124	62	30	70…100
Octane, RON/MON	133/99	130/96	118/100	118/102	
Blending octane	116	113	109	110	
Solubility in gasoline	Problems	Quite good	Good	Good	

2.7. Ethanol as an automotive fuel:

While the calorific value of ethanol is lower than that of gasoline by 40% it makes up a part by increased efficiency. So far its use as 100% fuel is concerned it has no problem in designing an engine to run on only ethanol. However, for the reason of compatibility as well as availability its use for blending is only being practised. It can be blended both in diesel as well as gasoline. The advantages and problems associated with the blends are summarised in the following paragraphs.

As can be seen from above, ethanol improves the octane number, has a higher volumetric efficiency leading to increased power and has advantages of wider flammability limits and higher flame velocity. It has, however, certain disadvantages (i) higher aldehyde emissions, (ii) corrosiveness, affecting metallic parts (iii) higher latent heat of vaporisation causing startability problem, (iv) higher evaporation losses due to higher vapour pressure and (v) requiring large fuel tank due to lower calorific value . Blends above 15% ethanol would require a few engine modifications to address –

- Corrosion problem of the metal parts.
- Compatible elastomers for oil seals and rubber components.
- Larger orifice for more flow of fuel through carburetor/injector.
- Retarding ignition timing
- increasing compression ratio to take advantage of higher cetane number of ethanol.

However, below the 10% value, the disadvantages are not serious and there is no need of modifying the engine, i.e it would be compatible with the blends.

2.8. Ethanol diesel blends (eDiesel):

In addition to the concern because of reserves of petroleum being limited, the environmental concern is even greater. Diesel generation in general emits large quantity of particulate matter and specially below micron 2.5 which being very small pass the protection system of the body to get lodged in lungs causing reduction in its vital capacity. More seriously than this is the association of the particulate matter with unburnt oil that are potential carcinogenic to human or animals. For this reason, such particles are called respiratory particulate matter and in metro diesel driven vehicles are being phased out. A 15% ethanol blend reduces PM emission, however the blend provides certain technical problems –

- The ethanol reduces the flash point of blend to 13 ^{o} C i.e. at the level of pure ethanol which is 50^{o} C lower than that of diesel. For the higher ambient temperature of the country, this disadvantage is not desirable and some additive may be required.
- Blend reduces the lubricity of the fuel and increases the wear of the piston rings and injector. In coming years, the sulphur content of the diesel is expected to be lower to 15 ppm and the lubricity of the blend may get further reduced.

- Ethanol and diesel fuel do not mix properly. It is found that the presence of water, or extreme cold temperature, causes the mixture to separate. The fuel mixture is known as a micro-emulsion and is prepared by splash blending in presence of a blending agent. Tolerance of water is influenced by the amount of aromatics level in diesel but generally is of the order of 0.1%. E-Diesel owes its commercial viability to the development of the effective emulsifier, Puranol, invented by Pure Energy Corporation (PEC). Development of more effective emulsifiers is required.

- The cetane number of the ethanol is just 8 and so reduces the cetane number of diesel on blending.
- The calorific value of ethanol is 42% lower than that of diesel on volume basis and would decrese the fuel economy and torque and would need higher injector size to obtain the same peak power. This problem is, however, of not much concern for blends lower than 5%.

2.9. Gasoline ethanol blend:

The gasoline-ethanol blend is more in practice for the reason of the ability of ethanol to increase octane rating of the fuel without adding to pollution or un-sustainability. The issue of octane improvement has been discussed earlier. Performance parameters of ethanol blends with gasoline are discussed below.

a. Fuel efficiency:

As there is a theoretical decrease in the energy content of gasoline blended with oxygenates, a decrease in mileage, km/ltr of fuel consumed is expected. No definite data is available to correlate the increase in fuel consumption, but with a blend upto 10% not more than 1-3% reduction in vehicular fuel economy in terms of km/ltr could be expected in the highway driving. It would be insignificant and will not be noticed. On the contrary in urban use a significant increase in fuel efficiency has been reported.

b. Engine performance and drivability:

The higher latent heat of vaporisation of ethanol than that of gasoline is expected to cause startability problem. But 25% blend of ethanol in gasoline is in use in Brazil for the last 25 years without any such problem. The consumption of ethanol in gasoline blend has been more than 10 billion litres there. 10% ethanol blend in gasoline is also in use in USA for the last 18 years and no problem has been encountred as to drivability etc.

c. Material compatibility:

Ethanol is corrosive in nature, absorbs moisture readily and can affect metallic parts (ferrous/non-ferrous). However with the 10% ethanol blend the phillips petroleum study has found no compatibility problem of various components with respect of corrosion tests and swell tests etc. in fuel systems. The experience of using ethanol blended gases in Brazil and USA shows no significant material problems even with older vehicles whereas newer vehicles are having better materials to fight corrosion like flouroelastomers.

d. Emission issue:

One of the major reasons for using blend is reduction in vehicular emission and eliminating the otherwise emission of lead, benzene, butadiene etc.

e. Hydro-carbon emission:

With better combustion, the ethanol blended gasoline provides a reduction in total hydro-carbon emissions though there is a slight increase in the emission of acetaldehyde. The increase in acetaldehyde emission with 5% ethanol blend has been found marginal, 260 mg vs 233mg per test cycle. With catalyst converters now being used in vehicles reduces aldehydes level by ten times. And therefore the problem is not considered serious. No limits have been set for aldhydes in ethanol by EU, Brazil or USA as emissions are well within tolerable limits. In fact formaldehyde emissions from MTBE are more and greater degree of concerned from health angle.

f. Carbon Monoxide emission:

For the same reason as above CO emission also gets reduced as confirmed by many studies.

g. Sulphur Dioxide emission:

As ethanol does not contain sulphur, a corresponding decrease in SO2 emission results.

h. Carbon-cycle-emission:

For the ethanol part, it can be taken as zero as it is derived from the plant. Some increase in gasoline emission is likely due to decreased fuel mileage. But in overall consideration there would be decrease in carbon emission.

2.10. Standards For Ethanol Use As Fuel Blending:

Because of low water tolerance of alcohol gasoline blends, ethanol can be blended only in anhydrous form. For 25% blend less than 2% of water can cause seperation. Two stroke engines require oil to be mixed with gasoline. Since oil is not properly miscible with gasoline some additive is required to be added to this.

Table 2.4 ASTM D4806-9 Fuel Ethanol Specifications

Property	Limit
Ethanol, vol. %	92.1
Water, vol. %	1.0 max
Methanol, mg/L	0.5 max
Acetic Acid, wt %	0.007
Chlorine, mg/L	40 max
Copper, mg/l	0.1 max
Denaturants, vol. %	1.96 –4.76

2.11. Production Of Ethanol:

In all, three different class of sources can be used:

a. starch as grain, corn and tubers like cassava
b. sugar plants (sugar beet or sugar cane)
c. cellulose plants (general tree and biomass)

2.12. Process:

Ethanol production is a very ancient activity linked with making potable alcohol. The liquor containing corn, grapes juice, molasses etc are fermented by adding yeast to it in batch fermentators for a number of hours (minimum 40 hours) when fermentation gets completed with no increase in alcohol content. The fermentation process consists of breaking of starch or cellulose chain into individual sugar molecules and then fermenting the sugar into ethanol and carbon dioxide. The major reaction is depicted below. The equations should show that fermentation of glucose/sugar to ethanol is energy efficient, about 93% of the feed energy is converted as ethanol and only a small amount is taken by fermenting organism (yeast).

Hydrolysis	$[C_6H_{10}O_5]_n + nH_2O \rightarrow nC_6H_{12}O_6$ (glucose)
Fermentation	$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$
Energy balance	Glucose$\rightarrow$ 2 ethanol + 75 KJ 180 gms 2 x 46 gms 2.82 MJ 2 x 1.37 MJ

2.13. Making anhydrous ethanol:

By fermentation alone not more than 10% ethanol content can be achieved, whereas the requirement for potable or industry is of getting over 95% purity. The traditional method is distilling the fermented liquor which can provide a purity upto 95%. Water in ethanol is undesirable in its use in gasoline blend and a purity over 99% (i.e. anhydrous alcohol) is required. Ethanol forms constant boiling mixture with water at 95.6% that does not allow simple distillation to meet the purpose. As a solution to the problem, azeotrophic distillation through solvent benzene or cyclohexane is used.

Azeotrophic distillation, however, increases production cost of ethanol considerably. The cost effective solution is found through the use of molecular sieve to eliminate water by an adsorbent, properly known as Pressure Swing Adsorption-Molecular Sieve Dehydration Technology (MSDH). It uses a synthetic adsorbent to dehydrate alcohol and results into high level of dryness with low energy requirement. Use of vapour phase adsorbtion has resulted into further energy saving in the process.

Fermented wash with approx. 8% v/v ethanol from the wash holding tank is fed to the top of the degasifying column after preheating and spent stillage cooler. Overhead vapor of approx. 40% w/w from the degasifying column is then fed to the bottom of the heads column. Impure spirit with approx. 95% v/v is removed from the vent condenser of the heads column. Heads column bottoms are fed to the alcohol column for recovery of alcohol.

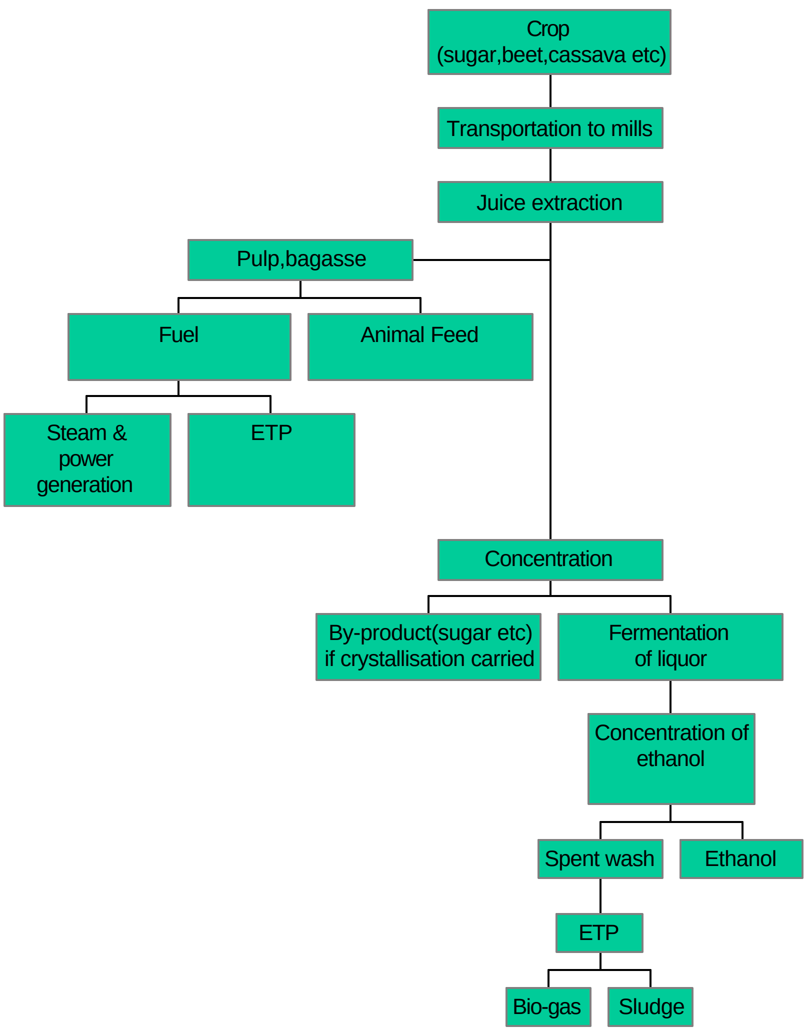
The wash column is heated through the forced circulation reboiler with the condensing vapors from the rectifying column, which is operated under pressure. Analyzer column vapors are condensed and fed to an extractive distillation column. This column is operated with high dilution to enable the removal of fusel oils. Vapors are condensed and sent to the recovery column for alcohol recovery.

The alcohol water stream from the bottom of the extractive distillation column is fed to the rectifying column. The rectifier vapors are used to heat the analyzer by using the pressure cascading technique. Ethanol (concentration of 96% v/v) is removed from the top three plates and fed to the demethylizer column for separating methanol. The product Rectified Spirit (RS) is removed from the bottom of the methanol column and cooled in the product cooler. Anhydrous alcohol is produced from 96% RS by molecular sieve technology. Anhydrous ethanol with purity above 99.8–99.9 is produced in the system, using vapor phase adsorption with pressure swing for regeneration. This is the most economical technology for producing anhydrous alcohol.

2.14. Feed stock -sugar cane- sugar route - technology and economics of production:

2.14.1. Feed Stock

The major source of ethanol production in the country is via sugarcane-sugar-molasses route. This provides better economy by sale of sugar, molasses becomes the by-product of sugar.



2.14.2. Through sugar beet:

In European countries sugar beet is preferred. Sugar beet has certain advantages over sugarcane. The advantages are: lower cycle of crop production, higher yield, high tolerance of wide range of climatic variation, low water and fertilizer requirement (compared to sugar cane, sugar beet requires 35-40 % water and fertilisers). From the table below it will be clear that ethanol yield is higher per year per unit of land even taking only one crop and (no credit for other crops) which will be there in case of sugar beet. Harvesting of sugar beet is also easier as well as requires lower energy for juice extraction. The pulp can be used for cattle field for steam generation.

Table 2.5 Comparison of cane and sugar beet

Properties	Cane	Sugar Beet
Cycle of crop	10-11 months	5-6 months
Yield per acre	25 to 30 tons	35 to 40 tons
Sugar content on weight	12 to 16%	14 to 18%
Sugar yield	3.0 to 4.8 tons/acre year	4.9 to 7.2 tons/acre year
Ethanol yield (100%)	1,700 to 2,700 lit/acre/yr	2,800 to 4,100 lit/acre/yr (with one cycle/yr).

Considering the surplus sugar production in the country it will provide an outlet for the cane production if some sugar is diverted to ethanol production. A part of juice can be directly converted into ethanol thus saving energy and achieving higher yield and reduction in spent wash.

2.14.3. Economics of production:

2.14.3.1. General:

The major factors that affect the ethanol cost are, the yield of sugarcane and cycle of production, the sugar contents in the juice, efficiency in juice extraction as well as in fermentation, and lastly utilisation of waste.

Sugarcane production requires long time as well as high irrigation and chemical fertiliser. This increases the cost of production and puts some question on its competitiveness with other crops.

A lower sugarcane content affects greatly the efficiency of farm production as it provides lower tonnage of sugar for the same inputs “irrigation, fertiliser and labour” . A lower sugar content also results in higher extraction cost per tonne of sugar extracted. Next is their efficiency in extracting the juice. Some of the sugar remains in the bagasse.

A higher level of extraction, however, increases the power cost and the effort reaches a trade off. a higher level of extraction obeviously reduces the cost of juice and therefore cost of sugar/ethanol.

Presently, the fermentation does not provide alcohol content above 10% and lot of energy is wasted in removing the balance water to get an hydrous alcohol necessary for blending in gasoline. A higher level of alcohol by fermentation would automatically reduce the cost of purification.

Two major waste products are generated in the ethanol production from sugarcane-

- bagasse:
- spent wash

Bagasse is utilised presently for boiler fuel needed for steam raising while spent wash is a effluent which requires treatment for COD removal before discharge into the land or river. It is possible through anaerobic digestion to utilise the spent wash in production of two valuable commodities – one methane rich fuel gas and another nutrient rich bio-sludge suitable for soil nutrition. The gas production can be sufficient to meet the fuel requirement as well as power for electric derives through co-generation.

2.14.3.2. Sugarcane-molasses –ethanol route:

A detailed costing of ethanol production from molasses in the country is given in the table below. Cost of Molasses varies widely across the different States and in the last six years it has been as low as Rs. 50/- per tonne and as high as Rs. 2000/- per tonne. The sizeable part in the cost is central excise duty, sales tax, transportation cost etc. and the statutory controlled sugarcane and sugar prices, as well as free sale prices coupled with with the release of sugar in the market. If we assume that molasses cost Rs. 1000/- per tonne the feed stock cost will be Rs. 4.5 per litre of ethanol with production of 220 litres ethanol per tonne of molasses. The raw material cost should not represent more than 50% cost of the ethanol production in general and on that basis the ethanol cost would work out less than Rs. 9/- per litre and would be quite competitive to the present imported cost of gasoline around Rs. 10-12 per litre.

Table 2.6

Cost of Ethanol Production from Molasses in India

			Stand alone distillery	**Integrated with sugar production**
	Cost of Molasses	Per MT	1000	1000
	Transportation cost	Per MT	150	0
	Total		1150	1000
	Recovery of ethanol/MT molasses	litres	220	220
	Cost of production		**Rs/litre.**	**Rs/litre**
	Molasses cost after milling (Recovery cost)		**5.23**	**4.55**
	Steam Cost @ Rice Husk Rs. 500/T		0.25	0
	Power Cost @ Rs. 4.50/Kwhr		0.59	0
	Chemical Cost		0.2	0.2
	Labour cost		0.25	0.25
	Repair & Maintenance		0.15	0.15
	Cost of Replacement of Molecular Sieve		0.02	0.02
	Total Direct costs		**6.69**	**5.17**
	Finance & other costs			
	Indirect costs including overheads		0.56	0.28
	Interest @12% for borrowed capital of Rs. 7.2 cr, (Debt/equity=1.5:1)		0.96	0.96
	Interest @12% for Working Capital for one month of Molasses & Ethanol		0.2	0.2
	Depreciation @ 10% for Rs. 12 cr		1.33	1.33
	Total Finance & other costs		**3.05**	**2.77**
	Total costs		**9.74**	**7.94**

Assumptions:

1. Recovery of 220 litres of Anhydrous Ethanol from one tonne of molasses.
2. Molasses price Rs. 1000 per tonne
3. Annual production of Ethanol @ 30,000 litres per day & 300 working days = 90000 litre/year
3. Alcohol plant assumed to be fully depreciated so capital related charges ignored except that of putting up the facility of making anhydrous alcohol via molecular sieve.
4. Life of Molecular sieve assumed to be 5 years and cost = 3000 kg x Rs.250/kg = Rs. 7,50,000/-; Avg cost per year Rs. 1,50,000/-. Cost/litre of ethanol = Rs 5/300 ≡ 0.02
5. Power cost of Rs. 4.50/kwh & Rice Husk cost of Rs. 500/MT with steam raising @ 3T/T of rice husk.
6. Biogas generation can provide enough energy to meet all energy demand but it has not been taken into account.
7. No taxes (excise or sales etc) on inputs considered.

2.14.3.3. Industry Survey in UP and Uttaranchal:

The present status of industry and prospects of improvement can be gauged from the survey conducted by UP Pollution Control Board (2001) for the 43 distillery units in UP and Uttranchal, out of which 37 units were functional and 35 among these were molasses based while 1 was based on grain and another on malt. It was found that 22 units have capacity utilisation below 74%. There was a wide variation ranging from 4.53 to 6.28 tonne molasses for production of 1 kL of alcohol against the norm of 4.87 mt/kl. Only 14 units have alcohol recovery above the norm of 472.5 litres/MT of TRS (total reducible sugar). A very wide variation in water consumption ranging from 14.69 KL to 512.88 KL per KL of alcohol and 9 units have specific water consumption in excess of 139 KL (norm 15 kl/kl). Again there was a wide variation in energy consumption ranging from 10.17 GJ/KL alcochol to 123.56 GJ/KL as many as 10 units have their specific energy consumption in excess of 24GJ (modal value 18.32 GJ/kl). The survey found variation from 7.92 to 100% of the content of renewable energy in the total energy consumed. 8 units have renewable energy consumption below 77% (model value 93%). 30 units have their specific net external energy consumption below 31 GJ/KL alcohol while one unit was having no need of external energy (model value 9.5 Gj/kl). There was a wide variation among the units ranging from 10.87 KL to 38.34 KL of spent wash per litre of ethanol produced. However, for most of the units it was within 10.87 to 17.7 KL (model value 14.92 kl/kl). For production of biogas from the spent wash, the data from 26 units out of 33 units show a variation from 7.26 Nm3/KL to 54.3 Nm3/KL (model value 30 Nm^3/kl) while 2 were not functional.

2.15 Economics of Sugarcane to sugar to Ethanol:

No definite view can be expressed as economy differs widely depending on the local prices of the products and their respective substitutes. A comparative position in the econimics of ethanol producton from sugarcane is shown in the tables below as provided by Mr Hosein Shapouri[1],

Table 2.7

Value Added Benefits U.S.

Sugarcane to sugar	Sugarcane to ethanol
Sugarcane -$28.77/metric ton	Sugarcane - $28.77/metric ton
Raw sugar@ 120/kg x $0.46/kg = $55.2	Ethanol @ 20.3 gal.x$1.21/gal.=$24.56
Molasses @ 37 kg x $0.05/kg = $1.85	Vinasse 1,000 liters @ /liter and excess electricity
Value of sugar and mollases $57.05	Value of ethanol $24.56
Value-added +$28.28	Value added -$4.21

Table 2.8

Value Added Benefits, India

Source: Nizam Sugars Limited P. Srimannarayana, General Manager, Hyderabad, India.

Sugarcane to sugar:	Sugarcane to ethanol:
Sugarcane – $19.08/metric ton	Sugarcane - $19.08 /metric ton
Plantation white @100 x Kgx$0.268/kg = $26.80	Ethanol @ 19.79gal.x $1.25/gal. = $24.74
Mollasses @ 40 kg x $0.041 kg = $1.64	Vinasse 1,000 liters @ /liter and excess electricity
Value of sugar and molasses $ 28.44	Value of ethanol $ 24.74
Value – added +$9.36	Value-added +5.66

Table 2.9

Value Added Benefits, Brazil

Source: UNICA, Sao Paulo Sugarcane, Agroindustry Union, Mr. Luiz Carlos Correa Carvalho, Consultant.

Sugarcane to sugar:	Sugarcane to ethanol
Sugarcane - $6 /metric ton	Sugarcane - $6/metric ton
Raw sugar @ 120kg	Ethanol @20.3 gal. X $ 0.70/gal. = $14.21
Molasses @ 37 kgx $0.03/kg = $1.11	Excess electricity ?
Value of sugar and molasses $16.71	Value of ethanol $14.21
Value-added +10.71	Value – added +$8.21

The conclusion is that under the existing price structure, sugar production provides the highest value addition in all the three countries, US, Brazil and India as indicated in the table below-

Table 2.10 Value addition from sugar cane to sugar and ethanol

In $ /MT

	U.S.A.	**Brazil**	**India**
Sugarcane to sugar	28.28	10.71	9.36
Sugarcane to ethanol	-4.21	8.21	5.66

2.16 Starch based alcohol production:

2.16.1 Process

Alcohols are produced from a large number of different starch crops as barley, wheat, corn, potato, sorghum etc. The conversion of starch into alcohol follows the same process of fermentation and distillation as that of sugarcane. The difference lies in additional two steps, namely,

- Milling of the corn
- Removal of by-products, as DDGS, corn oil, corn gum etc

Milling of the corn is an energy intensive step and is carried by one of the two main processes-

- Wet-milling
- Dry grinding

Wet milling plants are capital intensive but produce high valued by-products whereas dry grind plants cost less but provide lower valued products. Corn contains some cellulose which does not ferment. A residue called dried distillers grains and solubles (DDGS) is obtained. Presently one bushel of corn gives 2.5 gallons of ethanol, 17 lbs of DDGS and 19 lbs of co2. DDGS utilisation/disposal presents few problems. The present usage is animal feed but can be converted into high valued products also. The efficiency of ethanol conversion would improve if the following two major technological developments are used-

- Use of enzymes produced by solid state fermentation (SSF), which can breakdown cellulose part also increasing the yield from 2.5 gallons/bu (maxim 2.8 gallon/bu) to 3.52 gallons/bu. This also reduces the DDGS from 17 lbs to 7 lbs/bu and increase its protein content.
- Use of high temperature yeast as Thermosac capable to operate at 35-40^{o} C, producing 18-20% ethanol.

A typical value addition by ethanol conversion is shown in the table below-

2.16.2 Value – Added Benefits, U.S.

Corn 1 bushel	-$2.40
Ethanol 2.8 gallons	+$3.39
Byproducts, DDGS	+$0.60
Value of ethanol & byproducts	+$3.99
Value added	+1.59

Yield and economics would improve when the fermentative abilities of the distillery and the rumen microbes are combined as shown in the table below-

Table 2.11

	TODAY	FUTURE
Alcohol yield		
Per day	2.75/bu	3.52/bu
Per don	98.2	125.69
Revenue @ $1.40/gal	137.48	175.97
DDG produced/bu	17 lbs.	7 lbs.
Yield DDG/ton	607 lbs.	250 lbs.
Price	$0.04 oer lb.	$0.06 per lb.
Revenue	$24.28	$14.99
Total revenue	$161.76	$190.96
Difference		$29.20/ton = $0.81 /bu= $0.29 per gallon alcohol

1 bushel (bu) = 34.8 litres

2.16.3 Sweet sorghum as a feedstock:

At present, two thirds of world sugar production is obtained from sugar-cane and one third from sugar beet. These two crops are not in competition, but complementary, being cultivated for their specific requirements in two different climatic belts. In contrast, sweet sorghum can be cultivated in temperate and tropical regions, increasing its potential benefits. Other crops that can yield oligosaccharides (potatoes, cereals, grapes, etc.) are generally not much utilized for bioethanol production (with the exception of corn in the USA). However, particular varieties of sweet sorghum recently developed in China, the USA, and the EU have very attractive and economically promising characteristics.

Sweet sorghum can be grown in temperate and tropical regions. Sweet sorghum produces a very high yield in terms of grains, sugar, lignocellulosic biomass (on average a total of 30 dry tons/ha per year) Plantations need less seed than for other crops: 15 kg/ha compared with 40kg/ha for corn, or 150 kg/ha for wheat.

2.17Bioethanol:

2.17.1 Biomass for Bio-ethanol

Ethanol made from cellulosic biomass is called bioethanol. A major challenge is developing biocatalysts capable of fermenting lignocellulosic biomass for efficient industrial application. In the coming years it is believed that cellulosic biomass will be the largest source of bioethanol. The broad category of biomass for the production of ethanol includes agricultural crops & residues and wood. Biomass resources are abundant and have multiple application potential. Among the various competing processes, bioethanol from lignocellulosic biomass appears to have near-term economic potential. The crops residues such as rice straw, bagasse etc are not currently used to derive desired economic and environmental benefits and thus they could be important resource bases for bioethanol production. The table below indicates potential of such biomass for ethanol production.

Table 2.12

Potential for ethanol from cellulosic matter

Feedstock	Gallons ethanol/dry ton
Bagasse	112
Corn stover	113
Rice straw	110
Forest thinnings	82
Hardwood sawdust	101
Mixed paper	116

2.17.2 Review of Technologies for Manufacture of Bioethanol

The degree of complexity and feasibility of biomass conversion to ethanol depends on the nature of the feedstock. The three largest components of the biomass sources are cellulose, hemicellulose, and lignin ranges of which are presented in Table 2.13. Ranges of sugar content in hardwoods, softwoods, and agricultural residues are provided in Table 2.14. Lignin remains as residual material after the sugars in biomass have been fermented to ethanol. Economic use of this byproduct is critical to the financial feasibility of biomass-to-ethanol technology.

Table 2.13:

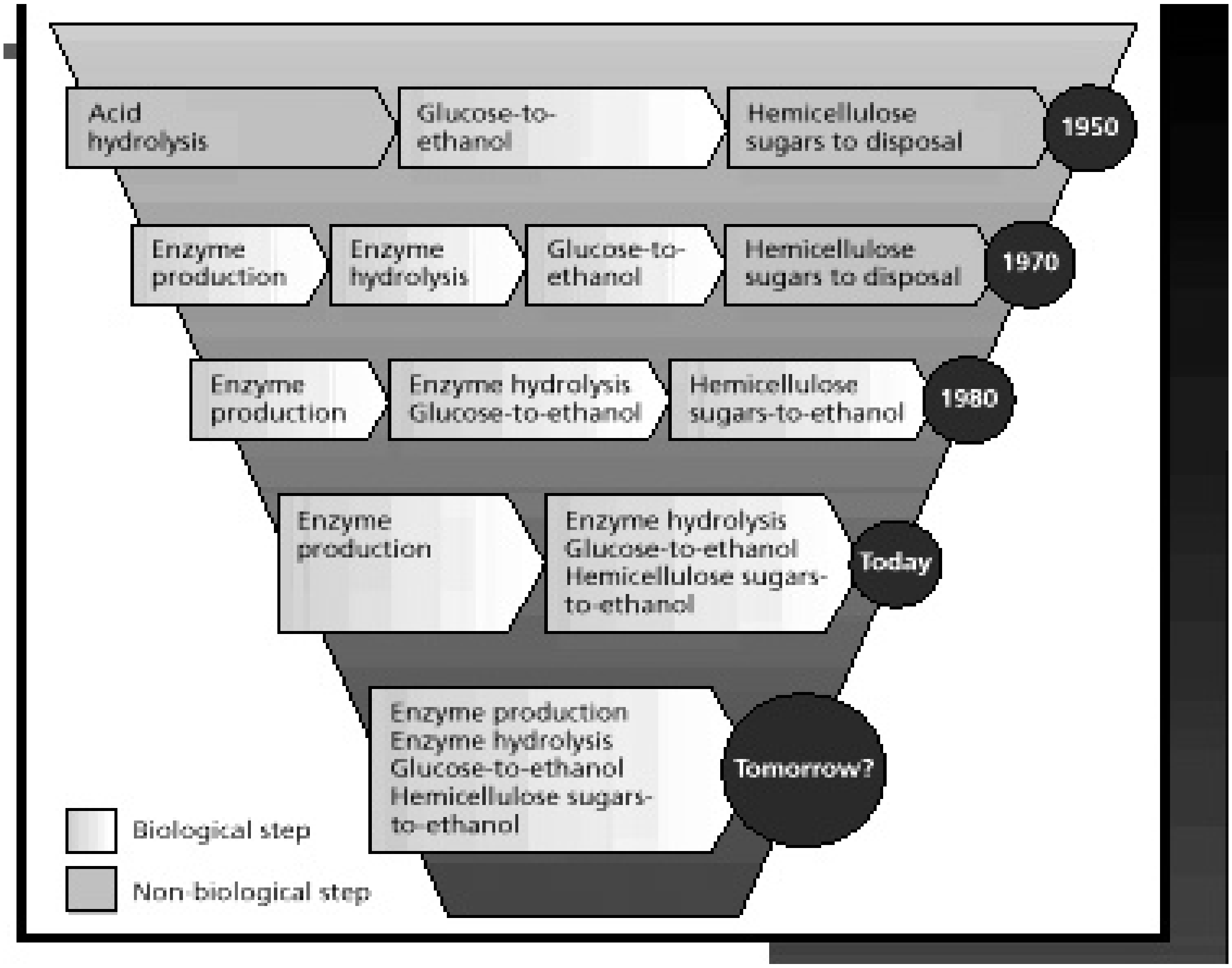
Typical levels of cellulose, hemicellulose and lignin in biomass

Component	Percent Dry Weight
Cellulose	40-60%
Hemicellulose	20-40%
Lignin	10-25%

Table 2.14:

Sugar and Ash Composition of Various Biomass Feedstocks (Weight Percent)

Material	Sugars	Lignin	Ash
Hardwoods	57-78%	15-28%	0.3-1.0%
Softwoods	49-69%	24-27%	0.1-0.4%
Ag Residues	42-81%	11-29%	2-18%



DEVELOPMENTS IN BIOETHANOL PRODUCTION TECHNOLOGIES

2.17.3 Process steps

There are four basic steps in converting biomass to bioethanol:

1. Producing biomass results in the fixing of atmospheric carbon dioxide into organic carbon.

2. Converting this biomass to a useable fermentation feedstock (typically some form of sugar) can be achieved using a variety of different process technologies. These processes for fermentation feedstock production constitute the critical differences among all of the bioethanol technology options.

3. Fermenting the biomass intermediates using biocatalysts (microorganisms including yeast and bacteria) to produce ethanol is probably the oldest form of biotechnology developed by humankind.

4. Processing the fermentation product yields fuel-grade ethanol and byproducts that can be used to produce other fuels, chemicals, heat and/or electricity.

2.17.4 Technologies

There are four technologies for bioethanol production as given below.

- Concentrated Acid Hydrolysis
- Dilute Acid Hydrolysis
- Enzymatic Hydrolysis
- Biomass Gasification and Fermentation

The first three are based on producing sugars from biomass and then fermenting the sugars to ethanol. The fourth is a very different approach involving thermal processing of biomass to gaseous hydrogen and carbon monoxide, followed by fermentation to ethanol.

2.17.4.1 Concentrated Acid Hydrolysis

This process is based on concentrated acid decrystallization of cellulose followed by dilute acid hydrolysis to sugars. Separation of acid from sugars, acid recovery, and acid reconcentration are critical unit operations. Fermentation converts sugars to ethanol.

The concentrated sulfuric acid process has been commercialized in the past, particularly in the former Soviet Union and Japan. However, these processes were only successful during times of national crisis, when economic competitiveness of ethanol production could be ignored. They cannot be economical because of the high volumes of acid required. Improvements in acid sugar separation and recovery have opened the door for commercial application. Two companies in the United States(Arkenol and Masada) are currently working with DOE and NREL to commercialize this technology

Arkenol holds a series of patents on the use of concentrated acid to produce ethanol. They are currently working with DOE to establish a commercial facility that will convert rice straw to ethanol. Arkenol plans to take advantage of opportunities for obtaining rice straw a cheap feedstock in the face of new regulations that would restrict the current practice of open field burning of rice straw. Arkenol's technology further improves the economics of raw straw conversion by allowing for the recovery and purification of silica present in the straw. NREL is working with Arkenol to develop a recombinant *Zymomonas Mobilis* strain for the project. The facility is located in Sacramento County.

Masada Resource Group holds several patents related to municipal solid waste (MSW)-to-ethanol conversion. DOE and NREL have been working with Masada to support their MSW-to-ethanol plant, which is located in Middletown, NY. The plant will process the lignocellulosic fraction of municipal solid waste into ethanol using technology based on concentrated sulfuric acid process. The robustness of this process makes it well suited to complex and highly variable feedstocks like municipal solid waste to take advantage of relatively high tipping fees available in the area for collection and disposal of municipal solid waste.

2.17.4.2 Dilute Acid Hydrolysis

Hydrolysis occurs in two stages to maximize sugar yields from the hemicellulose and cellulose fractions of biomass. The first stage is operated under milder conditions to hydrolyze hemicellulose, while the second stage is optimized to hydrolyze the more resistant cellulose fraction. Liquid hydrolyzates are recovered from each stage, neutralized, and fermented to ethanol.

There is quite a bit of industrial experience with the dilute acid process. Germany, Japan, and Russia have operated dilute acid hydrolysis percolation plants off and on over the past 50 years. However, these percolation designs would not survive in a competitive market situation. Today, companies are beginning to look at commercial opportunities for this technology, which combine recent improvements and niche opportunities to solve environmental problems.

BC International (BCI) and the DOE have formed a cost-shared partnership to develop a biomass-to-ethanol plant. The facility will initially produce 20 million gallons per year of ethanol. BCI has utilized an existing ethanol plant located in Jennings, LA. Dilute acid hydrolysis will be used to recover sugar from bagasse, the waste left over after sugar cane processing. A proprietary, genetically engineered organism will ferment the sugars from bagasse to ethanol.

Tembec and Georgia Pacific are operating sulfite pulp mills in North America, which utilize a dilute acid hydrolysis process to dissolve hemicellulose and lignin from wood, and produce specialty cellulose pulp. The hexose sugars in the spent sulfite liquor are fermented to ethanol. The lignin is either burnt to generate process steam or converted to value-added products such as dispersing agents, animal feed binders, concrete additives, drilling mud additives, and soil stabilizer.

2.17.4.3 Enzymatic Hydrolysis

The first application of enzymes to wood hydrolysis in an ethanol process was to simply replace the cellulose acid hydrolysis step with a cellulase enzyme hydrolysis step. This is called separate hydrolysis and fermentation. An important process modification made for the enzymatic hydrolysis of biomass was the introduction of simultaneous saccharification and fermentation (SSF), which has recently been improved to include the co-fermentation of multiple sugar substrates. In the SSF process, cellulase and fermenting microbes are combined. As sugars are produced, the fermentative organisms convert them to ethanol. Enzymatic hydrolysis will be used in Iogen/Petro Canada's Ottawa, Canada project and is being explored for BCI's Gridely project. The current high cost of cellulase enzymes is the key barrier to economical production of bioethanol from lignocellulosic material, research is on to achieve a tenfold reduction in the cost of these enzymes.

2.17.4.3.1 Cellulase Enzyme Research

The goal is to reduce the cost of using cellulase enzymes in the bioethanol process by employing cutting-edge and efficient biochemical technologies. The current estimate for cellulase ranges from 30 to 50 cents per gallon of ethanol produced. The objective is to reduce cellulase cost to less than 5 cents per gallon of ethanol. This requires a tenfold increase in specific activity or production efficiency or some combination thereof. Nearer-term goals include a threefold increase in cellulase-specific activity (relative to the *Trichoderma reesei* system) by FY 2005. This may be possible by genetic manipulation of microbes.

2.17.4.4 Biomass Gasification and Fermentation

Biomass can be converted to synthesis gas (consisting primarily of carbon monoxide, carbon dioxide, and hydrogen) via a high temperature gasification process. Anaerobic bacteria are then used to convert the synthesis gas into ethanol. Bioresource Engineering Inc. has developed synthesis gas fermentation technology that can be used to produce ethanol from cellulosic wastes with high yields and rates. The feasibility of the technology has been demonstrated, and plans are under way to pilot the technology as a first step toward commercialization. The conversion of a waste stream, the disposal of which is costly, into a valuable fuel adds both environmental and economic incentives. The yields can be high because all of the raw material, except the ash and metal, is converted to ethanol. BRI has developed bioreactor systems for fermentation that results in retention times of only a few minutes at atmospheric pressure and less than a minute at elevated pressure. These retention times result in very economical equipment costs. The biocatalyst is automatically regenerated by slow growth of the bacteria in the reactor.

2.17.5 Development of Microbes

Microorganisms that ferment sugars to ethanol include yeasts and bacteria. Research has focused on expanding the range and efficiency of the organisms used to convert sugar to ethanol. Breakthroughs in fermentation technology in the past decade lead to commercialization of biomass conversion technology

For most of this century, researchers assumed that many of the sugars contained in biomass were not fermentable particularly those contained in hemicellulose. This meant that as much as 25% of the sugars in biomass were out of bounds as far as ethanol production was concerned. In the 1970s and 80s, microbiologists discovered microbes that could ferment these sugars, albeit slowly and inefficiently. With the advent of new tools in the emerging field of biotechnology, researchers at DOE labs and at universities acrossUSA, have succeeded in producing several new strains of yeast and bacteria(*E. coli*, *Zymomonas*, *Saccharomyces*) that exhibit varying degrees of ability to ferment the full spectrum of available sugars to ethanol.

Today's ethanol producers are turning their attention to corn fiber—the shell of the kernel as a source of additional sugars for ethanol production. But, corn fiber, like other forms of biomass, contains sugars that are not fermentable by today's industrial fermentation organisms. Research is on to tailor new microbes that can ferment these specific sugars.

2.17.6 Raw materials for making bioethanol

Ethanol producers in the United States produce around 1.5 billion gallons of ethanol each year, mostly derived from corn. As demand for ethanol increases, other biomass resources, such as agricultural and forestry wastes, municipal solid wastes, industrial wastes, and crops grown solely for energy purposes, will be used to make ethanol. Research activities over the past 20 years have developed technology to convert these feedstocks to ethanol

Fuel ethanol is currently produced from the easily fermented sugars and starches in grain and food processing wastes. Soon, new technologies will be economically viable for converting plant fiber to ethanol. A portion of the agricultural and forestry residues (corn stover ,stalks, leaves, branches) which are presently burned or left in the field may therefore be harvested for biofuel production. There will be many benefits by connecting the established corn ethanol industry with the emerging technologies that produce ethanol from agricultural wastes and other types of biomass.

2.17.7 Meeting the Ethanol demand for blending:

The ethanol demand for blending can be calculated from the plan projection of the future growth in gasoline use. The tables below provide the figures for the tenth plan together with the avilability.

Table 2.15: Ethanol Demand And Supply For Blending In Gasoline

Year	Gasoline demand MMT	Ethanol demand Th KL	Molasses production MMT	Ethanol production			Utilisation of ethanol		
				Molasses Th KL	Cane Th KL	Total Th KL	Potable Th KL	Industry Th KL	Balance Th KL
2001-02	7.07	416.14	8.77	1775	0	1775	648	600	527
2006-07	10.07	592.72	11.36	2300	1485	3785	765	711	2309
2011-12	12.85	756.35	11.36	2300	1485	3785	887	844	2054
2016-17	16.4	965.30	11.36	2300	1485	3785	1028	1003	1754

Notes:

1. Area under cane cultivation is expected to increase from 4.36 mha in 2001-02 to 4.96 in 2006-07 which would add additional cane production of around 50 MMT.
2. About 30% of cane goes for making gur and khandsari. If there is no additional increase in khandsari demand, sugar and molasses production would increase.
3. The present distiller capacity is for 2900 Th kL of ethanol and looks to be sufficent for 5% blend till 12 th plan
4. A growth of 3% in potable use and a 3.5% in chemical and other use has been taken

As per the All India Distellers Association, the present installed capacity of alcohol production in the country is 2900 million litres. With the present availability of molasses to the tune of 9 million tonnes the alcohol production is around 1800 million litres. Out of which around 600 million litres is surplus after meeting the demand of industrial use (540 million litres) and potable use, (650 million litres). This is capable of providing a 5% blend to the gasoline. The present consumption of gasoline is estimated at 8.5 million tonnes requiring 502 million litres for 5% blend. The industry expects that the present capacity able to meet the blending requirement of the gasoline till the end of the Tenth Plan with the terminal years gasoline consumption at 11.6 million tonnes needing 682 million liters of ethanol for blending where 823 million liters will be surplus from the production of 2300 million liters of alcohol. Decision has already been taken to make it compulsory for a 5% blend of ethanol in gasoline.

Since there is a surplus production of sugar and export not giving much value addition it will not be irrational to convert sugar to alcohol or directly came to alcohol in much more proportion than being carried now. By this a 10% blend of ethanol with gasoline can be maintained for considerable period. Apart from sugarcane, other agro-products including grains can be used for fermentation. Taking the crop yield in account, sugarcane is the best choice as it is the crop having the highest efficiency of photosynthesis and provide a possibility of 1200 gallons of 99% alcohol from a acre. Potato provides the next highest yield of alcohol on unit area of land; 300 gallons per acre.

From the table it is clear that for meeting 5% blending demand, the ethanol capacity in the country is sufficient. For higher blend and till the demand stablises, the crop productivity, or use of bio-mass into converting to alcohol would be much more needed. The Government has taken the decision to make the 5% blending in gasoline as mandatory in phased manner. As stated above, the industry can easily meet the requirement if the land is not diverted from cane production.

Table 2.16 : Alcohol Production from molasses and Use

(in million litre)

Alcochol year	Molasses Prod. MMT	Production of Alcohol (mil. litre)	Industrial use (mil. litre)	Potable use (mil litre)	Other uses (mil. litre)	Surplus availability of alcohol (mil. litre)
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	877	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

Table 2.17 : Potential of ethanol production from sugarcane

Year	Area under cane	Cane prod	Cane utilization			Sugar production		Addl. Alcohol prod. (in million litre)	
			Sugar	Gur & khand	Seed & chew	Target	Revised prod.	From addl. molasses prod.	Addl. cane available for alcohol prod.
2002-03	4.36	309.9	181	92.0	37	182	192	69	475
2003-04	4.53	321.6	188	95.6	38	192	202	99	795
2004-05	4.63	333.3	195	98.3	40	199	212	128	1000
2005-06	4.79	345.1	202	102.1	41	206	223	168	1222
2006-07	4.96	356.8	209	104.8	43	213	233	198	1485

2.17.8 Economics of alcohol production:

2.17.8.1 From sugarcane:

A tonne of sugarcane, on an average, would provide 110 kg of fermentable sugar in the juice. If all the sugar juice is fermented directly, the ethanol yield will be 70 litres taking a sugar loss of 2% in spent wash and specific gravity of ethanol as 0.79. The present price of sugarcane as fixed by Centre under the *minimum statutory price* stands at Rs. 695/- per tonne *with 8.5% recovery . At* higher recovery which is the case always, the effective price comes to Rs. 900/- per tonne if State Governments does not add further cost to it. For example, the UP state has added the statutory price by Rs. 45/- per tonne on the Centre's price of Rs. 695/- . Therefore the feed stock price itself comes to Rs. 900/70 = Rs. 13/- per litre of ethanol. A minimum of Rs. 2/- per litre would be the conversion cost i.e. salary and wages of the operational staff. In other words, direct conversion of sugar juice to ethanol will cost more than Rs. 20/- per litre, if we add the capital related charges of investment, profit to the manufacturer, energy cost of making anhydrous alcohol, transport, marketing, blending etc. This may not be financially viable with present ex-factory cost of gasoline. To make it viable following options are available:-

i. Sugarcane prices are decontrolled and left for the market to decide. This may result into cane prices lower than Rs. 500/- per tonne.
ii. Combining with sugar production so that major part of cane cost is off-loaded to sugar. This is the present situation also where all the ethanol production from sugarcane is coming through molasses, a by-product in sugar production. A tonne of sugarcane produces 100 kg of sugar as well as 40 kg of molasses the latter will produce around 10 litres of ethanol. Even if sugar is sold at Rs. 10/- per kg it will be sufficient to pay all the cost of the sugarcane.
iii. Use of by-products bagasse and spent wash *very efficiently*. The spent wash which is produced in large quantity (around 15 litre for 1 lire of ethanol produced) can be subjected to *anaerobic* digestion which not only removes its BOD and COD but will also provide valuable bio-gas (60% methane) which can meet 2/3rd of energy cost of making anhydrous alcohol through conventional route. Using absorption or membrane technology of drying alcohol above 95% purity, the biogas generation would be sufficient for all its energy demand (if short by any margin, the same could be made from the bagasse based cogeneration facility). The bagasse which is left after crushing can provide electricity through efficient co-generation. As per an estimate, a cane crushing mill with 455 tph crushing capacity can generate 44 MW of power. This comes to about 97 kWh/tonne of cane crushed. At a Rs. 2/- kWh rate of power exported to grid the earning will be far sufficient to meet the cane prices even after meeting the capital rated charges of installing the power generation facility. To realise the energy efficiency as sated above, the followings would have to be set up having the magnitude of the capital investments as indicated -

- Molecular sieve costing around Rs 2-2.5 crore for 30 kld plant.
- Anaerobic bio-gas production costing Rs 4-5 crore.
- Steam and power generation plant (co-generation) costing around Rs 3 crore/MW.

Fortunately, apart from a low pay back period for return in investments, there are several sources of getting finance for setting up the facilities above (to increase efficiency)-

- Assistance from Asian Development Bank, KfW, Germany, JBIC, Japan
- Assistance from IREDA under renewable energy plan
- Carbon credit of nearly $10/te of carbon saved under CDM of the Kyoto Protocol.

2.17.8.2 From other feedstocks:

The other major source can be corn, sugrbeet, potatoes etc. Depending on the starch content's in the feedstock, the yield of ethanol would vary. Taking corn, it can be at 2.75 tonne of grains per kilolitre of ethanol. The feedstock cost at Rs. 7/- per kg itself would cost Rs. 20/- in one litre of ethanol so produced. The sale of the residue, (i.e. dried distillers grains and solubles which is produced in the quantity of 0.56 kg per litre of ethanol produced would fetch a maximum of Rs. 3.5 @ Rs. 6/- per kg of residue unless the latter is converted to more value added products. Thus the feedstock price after taking the credit of the DDGS sale would not be lower than Rs. 16.5 per litre. The spoiled grain available in large quantity (2-5 lakhs tonnes per year from FCI) would certainly make a very cheap alcohol. For others, it is the market price that will determine the economics. Generally foodgrain price will be dictated by its use for human consumption which, in turn, will be subjected to prices across other grains and alternatives.

2.17.9 R&D work

While a boundary can be drawn to limit R&D activities in the area of ethanol production from agro-crops or biomass in general, but for short term requirement , the following areas of research & development should be stressed mainly towards the compatibility of the use of blends in existing engines:-

2.17.9.1 Ethanol-gasoline blend:

a. Performance of engine and corrosion of ethanol gasoline blend at higher ethanol percentage above 10%. Because of the low water tolerance of alcohol-gasoline blends, anhydrous ethanol must be used & great care must be exercised to avoid water contamination. For 25 % alcohol blend, less than 2% of water will cause separation. Ethanol can also be used in modified engines, specifically designed and manufactured to operate on ethanol fuel, and will generally be more efficient than modified gasoline engines.

b. Most conventional vehicles on the road today can use E10 (a 10% ethanol- 90% gasoline blend also known as gasohol) without any special modifications. However, auto manufacturers are also producing vehicles that are specially modified to run on a higher percentage of ethanol. Generally, the use of ethanol blending reduces the harmful emissions like CO, CO_2 & hydrocarbons. However, additional studies are required to understand potential emissions benefits for all engine models and driving cycles. Effect on exhaust treatment devices using ethanol blending should also be established. The main mechanical differences between ethanol and gasoline vehicles lie in the engine calibration and the fuel management system. Ethanol vehicles come with a special computerized system that monitors the ethanol/gasoline ratio of the fuel, optimizes performance, and adjusts emissions control devices. Ethanol may also corrode certain materials that are commonly used in automobile parts, such as rubber and plastic. Components that come in contact with the fuel, such as piston rings, engine block, and valve seals, must be made of ethanol-compatible materials.

c. Suitable additive for ethanol gasoline blend to be used in two stroke engines. The use of ethanol in specially designed two-cycle engines has been demonstrated on a limited basis. The problem of using ethanol in these engines is that the ethanol does not blend well with lubricating oil. To get around this problem, research is under way to find lubricating oils that are not affected by ethanol engines. The study on In-use vehicle must also be considered because they are having totally different configuration compared to new generation vehicles.

d. Andehyde Emission: Aldehyde emissions from ethanol blends are generally higher than those from gasoline. Formaldehyde, the major constituent in aldehyde emissions, is a suspected carcinogen. However, the catalytic converters used vehicles reduce aldehyde emissions to near the level produced when unblended gasoline is combusted. The Royal Society of Canada has concluded that any increases are minute, and harmful effects are remote .

2.17.9.2 Ethanol-diesel blends:

e. E-diesel cannot be safely handled like conventional diesel but must be handled like gasoline. This may necessitate some modifications to storage and handling equipment, as well as vehicle fuel systems. Stability is much less of a concern for micro-emulsions as these have proven stable for extended periods. However, stability of e-diesel micro-emulsions under a range of storage conditions will need to be demonstrated. Emulsifiers are known to extend the stability of ethanol-diesel blends to lower temperatures at ethanol blending levels as high as 15% or even 20% in conventional diesel. Detailed data on the efficacy of emulsifiers as a function of temperature and fuel aromatic content do not appear to be publicly available & most manufacturers have not optimized emulsifier. A large body of test data acquired in close cooperation with the OEM's will be necessary to address this issue.Development of better emullsifier for ethanol diesel blend**.**

f. Lubricity of e-diesel: Lubricity is the ability of the fuel to lubricate metal surfaces and is relevant to wear in fuel pumps and other engine components that are lubricated by the fuel. Severely hydrotreated, ultralow sulfur diesel fuels as well as Fischer-Tropsch diesel fuels tend to have low lubricity. This can be remedied through the use of a lubricity additive or by blending with higher lubricity components. Ethanol is not expected to impart increased lubricity to diesel fuel. However, most emulsifier manufacturers claim that the emulsifier itself can impart improved lubricity. This would seem to be substantiated by data made public by PEC that shows premium lubricity properties (i.e. HFRR of less than 300 micron and SLBOCLE of more than 5200 g [jht1]). Better quantification of the effect of e-diesel on fuel lubricity for both conventional and ultra-low sulfur fuels is needed. The inclusion of lubricity in an e-diesel standard may be desirable.

g. Other problem of e-diesel: Concerns are expressed related to engine performance using e-diesel. These include the idea that the solvency effect of ethanol might loosen deposits in older vehicles causing breakdowns. Another concern is that because of e-diesel's higher volatility, there may be a greater incidence of pump and injector cavitation, leading to increased wear and hot restart problems. The lower energy content may require changes to governing strategy to prevent stalling under certain conditions such as steep grades, high temperature, and altitude. While some of these concerns may prove to be unfounded, they will require investigation.

2.17.9.3 Ethanol production from biomass:

h. Development of more energy efficient and economical process for fermenting cellulose materials into ethanol. In the coming years it is believed that cellulosic biomass will be the largest source of bioethanol. The broad category of biomass for the production of ethanol includes agricultural crops & residues and wood. Biomass resources are abundant and have multiple application potential. Among the various competing processes, bioethanol from lignocellulosic biomass appears to have near-term economic potential. The crops residues such as rice straw, bagasse etc are not currently used to derive desired economic and environmental benefits and thus they could be important resource bases for bioethanol. A major challenge is developing biocatalysts capable of fermenting lignocellulosic biomass for efficient industrial application. Some narration on the possibility would be in order which would also highlight the need of research in the area.

i. Study on gasification route to produce ethanol from biomass: Compared to enzymatic route of making alcohol, chemical catalytic route through gasification would be faster, however, technical and economic viability together with requirements of material, energy and investments needs to be established to provide accurate estimate for an industrial venture.

2.18 Conclusion:

1. Though it is technically feasible to design and run automobiles on 100% ethanol, for the reason of availability and compatibility with vehicles presently in use blending of ethanol with motor spirit needs to make a very modest beginning.
2. Five percent blending has already been introduced in some states. According to the information availability about production and demand of ethanol for all applications, production of molasses and distillery capacity, 7% blend of ethanol in gasoline is

feasible provided facilities to dehydrate alcohol are added to the required extent. The target should be to raise the blending in stages to 10% by the end of the X Plan.

3. Ethanol may be manufactured using molasses as the raw material. If the industry finds it economically feasible, it should be encouraged to produce alcohol also from sugarcane juice directly in areas where sugarcane is surplus.
4. Restrictions on movement of molasses and putting up ethanol manufacturing plants may be removed.
5. Imported ethanol should be subject to suitable duties so that domestically produced ethanol is not costlier than the imported one.
6. Ethanol diesel blending requires emulsifier and also poses certain storage and technical problems. Indian Institute of Petroleum is working on the subject. Ethanol diesel blending should await the solution of the problems.
7. Buyback arrangement with oil companies for the uptake of anhydrous alcohol should be made.
8. To reduce cost of production of ethanol, the following measures may be considered:

   - Provision of incentives for new economic sized distilleries incorporating state of art technology such as, molecular sieve technology for making anhydrous alcohol.
   - Integration of distillery with sugar plant to have multiple choice of making sugar, or direct sugarcane to ethanol.

9. The cost of ethanol produced using other raw materials such as grains, potato, sugar beet and straw is estimated to be more than the price of motor spirit and may need subsidy. Economics of ethanol production from other feedstocks as sugar beet, corn, potatoes, etc should be studied. It may be left to the industry to use these raw materials for producing ethanol as and when if it finds them economical.

10. R&D may be supported to reduce the cost of ethanol production from different feed stocks.

Chapter 3

Bio-Diesel

3.1 Introduction

Bio-diesel is fatty acid ethyl or methyl ester made from virgin or used vegetable oils (both edible & non-edible) and animal fats. The main commodity sources for bio-diesel in India can be non-edible oils obtained from plant species such as Jatropha Curcas (Ratanjyot), Pongamia Pinnata (Karanj) , Calophyllum inophyllum (Nagchampa), Hevca brasiliensis (Rubber) etc. . Bio-diesel contains no petroleum, but it can be blended at any level with petroleum diesel to create a bio-diesel blend or can be used in its pure form. Just like petroleum diesel, bio-diesel operates in compression ignition engine; which essentially require very little or no engine modifications because bio-diesel has properties similar to petroleum diesel fuels. It can be stored just like the petroleum diesel fuel and hence does not require separate infrastructure. The use of bio-diesel in conventional diesel engines results in substantial reduction of un-burnt hydrocarbons, carbon monoxide and particulate matters. Bio-diesel is considered clean fuel since it has almost no sulphur, no aromatics and has about 10 % built-in oxygen, which helps it to burn fully. Its higher cetane number improves the ignition quality even when blended in the petroleum diesel.

As mentioned in the Introduction Chapter for new vehicles (except 2 and 3 wheelers) compliance of Bharat Stage II emission norms are to be enforced in the entire country from 1.4.2005 and Euro III equivalent norms by 1.4.2010. In addition to 4 metros where Bharat Stage II norms are already in place, Bangalore, Hyderabad, Ahmedabad, Pune, Surat, Kanpur and Agra should also meet this norm from 1.4.2003. The four metros and the other seven cities should comply Euro III and Euro IV equivalent emission norms from 1.4.2005 and 1.4.2010 respectively. The 2 and 3 wheelers should conform to Bharat Stage II norms from 1.4.2005 all over the country and Bharat Stage III norms preferably from 1.4.2008 but not later than 2010. For new vehicles, a drastic reduction in sulphur content (< 350 ppm) and higher cetane number (>51) will be required in the petroleum diesel produced by Indian Refineries. Bio-diesel meets these two important specifications and would help in improving the lubricity of low sulphur diesel. The present specification of flash point for petroleum diesel is 35°C which is lower than all the countries in the world (>55°C). Bio-Diesel will help in raising the flash point , a requirement of safety.

B20 (a blend of 20 percent by volume bio-diesel with 80 percent by volume petroleum diesel) has demonstrated significant environmental benefits in US with a minimum increase in cost for fleet operations and other consumers. Bio-diesel is registered as a fuel and fuel additive with the US Environmental Protection Agency and meets clean diesel standards established by the California Air Resources Board. Neat (100 percent) bio-diesel has been designated as an alternative fuel by the Department of Energy and the Department of Transportation of US. Studies conducted with bio-diesel on engines have shown substantial reduction in Particulate matter (25 – 50%). However, a marginal increase in NO_x (1-6%) is also reported; but it can be taken care of either by optimization of engine parts or by using De-NO_x catalyst (De-NO_x catalyst will be necessary for Bharat-III / IV compliant engines). HC and CO emissions were also reported to be lower. Non-regulated emissions like PAH etc were also found to be lower.

Bio-diesel has been accepted as clean alternative fuel by US and its production presently is about 100 million Gallons. Each State has passed specific bills to promote the use of bio-diesel by reduction of taxes. Sunflower, rapeseed etc. is the raw material used in Europe whereas soyabean is used in USA. Thailand uses palm oil, Ireland uses frying oil and animal fats. Due to its favorable properties ,bio-diesel can be used as fuel for diesel engines (as either,B5-a blend of 5% bio-diesel in petro-diesel fuel,) or B20 or B100). USA uses B20 and B100 bio-diesel, France uses B5 as mandatory in all diesel fuel. It can also be used as an additive to reduce the overall sulfur content of blend and to compensate for lubricity loss due to sulfur removal from diesel fuel.

The viscosity of bio-diesel is higher (1.9 to 6.0 cSt) and is reported to result into gum formation on injector, cylinder liner etc if used in neat form. However, blends of up to 20% should not give any problem. While an engine can be designed for 100% bio-diesel use, the existing engines can use 20% bio-diesel blend without any modification and reduction in torque output. In USA, 20% bio-diesel blend is being used, while in European countries 5 -15% blends have been adopted.

3.2 Bio-Diesel as an option for Energy Security

India ranks sixth in the world in terms of energy demand accounting for 3.5% of world commercial energy demand in 2001.The energy demand is expected to grow at 4.8%. A large part of India's population, mostly in the rural areas, does not have access to it. At 479 kg of oil equivalent the per capita energy consumption is very low. Hence a programme for the development of energy from raw material which grows in the rural areas will go a long way in providing energy security to the rural people.

The growth in energy demand in all forms is expected to continue unabated owing to increasing urbanisation, standard of living and expanding population with stabilisation not before mid of the current century. The demand of Diesel (H.S.D) is projected to grow from 39.81 MMT in 2001-02 to 52.32 MMT in 2006-07 @ 5.6% per annum. Our crude oil production as per the Tenth Plan Working Group is estimated to hover around 33-34 MMT per annum even though there will be increase in gas production from 86 MMSCMD (2002-03) to 103 MMSCMD in (2006-07). Only with joint venture abroad there is a hope of oil production to increase to 41 MMT by (2016-17). The gas production would decline by this period to 73 MMSCMD. The increasing gap between demand and domestically produced petroleum is a matter of serious concern.

In other words, our dependence on import of oil will increase in the foreseeable future. The Working Group has estimated import of crude oil to go up from 85 MMT per annum to 147 MMT per annum by the end of 2006-07 correspondingly increasing the import bill from $ 13.3 billion to $ 15.7 billion

Transport sector remains the most problematic sector as no alternative to petroleum based fuel has been successful so far. Hence petro based fuels especially petroleum diesel (HSD) will continue to dominate the transport sector in the foreseeable future but their consumption can be minimized by implementation of Bio-diesel programme expeditiously.

Targets need to be set up for bio-diesel production to achieve blending ratios of 5, 10 and 20 percent in phased manner. The estimated bio-diesel requirements for blending with petro-diesel over the period of next 5 years are given in Table 3.1 :

The Biodiesel requirement for 5%, 10% and 20% blends has been discussed in the 'Introduction' Chapter. For convenience , the table is reproduced below:

Table 3.1

Year	Diesel Demand Million Ton	Bio-diesel requirement for blending **Million Ton**		
		@ 5 %	@ 10 %	@ 20 %
2001-02	39.81	1.99	3.98	7.96
2002-03	42.15	2.16	4.32	8.64
2003-04	44.51	2.28	4.56	9.12
2004-05	46.97	2.35	4.70	9.40
2005-06	49.56	2.48	4.96	9.92
2006-07	52.33	2.62	5.24	10.48

3.3 Feasibility of producing bio-diesel as diesel substitute

While the country is short of petroleum reserve, it has large arable land as well as good climatic conditions (tropical) with adequate rainfall in large parts of the area to account for large biomass production each year. For the reason of edible oil demand being higher than its domestic production, there is no possibility of diverting this oil for production of bio-diesel. Fortunately there is a large junk of degraded forest land and un-utilised public land, field boundaries and fallow lands of farmers where non-edible oil-seeds can be grown. There are many tree species which bear seeds rich in oil. Of these some promising tree species have been evaluated and it has been found that there are a number of them such as *Jatropha curcas* and *Pongamia Pinnata* ('Honge' or 'Karanja') which would be very suitable in our conditions. However, ***Jatropha curcas*** has been found most suitable for the purpose. It will use lands which are largely unproductive for the time being and are located in poverty stricken areas and in degraded forests. It will also be planted on farmers' field boundaries and fallow lands. They will also be planted in public lands such as along the railways, roads and irrigation canals.

Economics of *Jatropha bio-diesel*

US produces bio-diesel from edible oil (mainly soya oil), the 100% bio-diesel costs around $ 1.25 to $2.25 per gallon depending upon purchase volume and the delivery costs and competes with low sulfur diesel oil. However, it is costlier to normal diesel and the B20 blend costs 13 to 22 cents more per gallon than normal diesel. It takes about 7.3 pounds of soybean oil which costs about 20 cents/pound, to produce a gallon of bio-diesel. Feedstock costs alone, therefore are at least $ 1.5 per gallon of soya-diesel. Under the mustard seed program, oil can be produced today for approximately 10 cents/pound and the total cost of producing mustard bio-diesel is around $ 1 per gallon. The mustard oils, a low value product contains as much as 90% mono-saturated fatty acids which makes it perfect for bio-diesel, balancing cold flow issues with NO_x emission issues. US is planning to add 5-10 billion gallons of bio-diesel through mustard seeds having mustard meal a high value pesticide that helps keep the price of mustard oil low.

In India, it is estimated that cost of Bio-Diesel produced by trans-esterification of oil obtained from Jaropha Curcas oil-seeds shall be approximately same as that of petro-diesel. The bye products of Bio-diesel from Jatropha seed are the seed oil cake and glycerol which have good commercial value. The seed oil cake is a very good compost being rich in plant nutrients. It can also yield biogas which can be used for cooking and the residue will be used as a compost. Hence oil cake will fetch good price. Glycerol is produced as a bye product in the trans-esterification of oil. These bye-products shall reduce the cost of Bio-diesel to make it at par with petro-diesel.

The cost components of Bio-diesel are the price of seed, seed collection and oil extraction, oil trans-esterification, transport of seed and oil. As mentioned earlier, cost recovery will be through sale of oil-cake and of glycerol. Taking these elements into account, the price of Bio-diesel has been worked out assuming raw material cost of Rs. 3 per kg and varying prices of by-products. The cost of Bio-diesel varies between Rs. 9.37 per litre to Rs. 16.02 per litre depending upon the price assumed for the oil- cake and glycerol. The use of Bio-diesel is thus economically feasible.

3.4 Production of Bio-Diesel

Many developed countries have active bio-diesel programmes. Currently bio-diesel is produced mainly from field crop oils like rapeseed, sunflower etc., in Europe and soybean in US. Malaysia utilizes palm oil for bio-diesel production while in Nicaragua it is *jatropha* oil.

The production of vegetable oils globally and in India are given in Tables 3.2 and 3.3

Table 3.2 Global production of the major vegetable oils (2001)

Oil	**Production (million tonnes)**
Soybean	27.8
Rapeseed	13.7
Cottonseed	4.0
Sunflower	8.2
Peanut	5.1
Coconut	3.5
Linseed	0.6
Palm	23.4
Palm kernel	2.9
Olive	2.7
Corn	2.0
Castor	0.5
Seasame	0.8
Total	95.2

(Source: Oilworld Weekly, 2002)

Table 3.3 Vegetable oil production in India (2001)

Oil	**Production (million tonnes)**
Groundnut	1.40
Soya	0.82
Rape / Mustard	1.55
Sunflower	0.30
Sesame	0.26
Castor	0.25
Niger	0.03
Safflower	0.09
Linseed	0.10
Cottonseed	0.44
Coconut	0.55
Rice Bran	0.55
Oils from expelled cakes	0.28
Minor oilseeds	0.05
Total	**6.67**

Source: Solvent Extractors' Association of India

3.4.1 Derivatives of triglycerides (vegetable oils) as diesel fuels:

The alternative diesel fuels must be technically and environmentally acceptable, and economically competitive. From the viewpoint of these requirements, triglycerides (vegetable oils/animal fats) and their derivatives may be considered as viable alternatives for diesel fuels.

The problems with substituting triglycerides for diesel fuels are mostly associated with their high viscosities, low volatilities and polyunsaturated character. The problems have been mitigated by developing vegetable oil derivatives that approximate the properties and performance and make them compatible with the hydrocarbon-based diesel fuels through:

- pyrolysis;
- microemulsification;
- dilution; and
- transesterification.

3.4.1.1 Pyrolysis

Pyrolysis refers to a chemical change caused by the application of thermal energy in the absence of air or nitrogen. The liquid fractions of the thermally decomposed vegetable oil are likely to approach diesel fuels. The pyrolyzate had lower viscosity, flash point, and pour point than diesel fuel and equivalent calorific values. The cetane number of the pyrolyzate was lower. The pyrolysed vegetable oils contain acceptable amounts of sulphur, water and sediment and give acceptable copper corrosion values but unacceptable ash, carbon residue and pour point.

3.4.1.2 Micro-emulsification

The formation of microemulsions (co-solvency) is one of the potential solutions for solving the problem of vegetable oil viscosity. Micro-emulsions are defined as transparent, thermodynamically stable colloidal dispersions. The droplet diameters in micro-emulsions range from 100 to 1000 Å. A micro-emulsion can be made of vegetable oils with an ester and dispersant (co-solvent), or of vegetable oils, an alcohol and a surfactant and a cetane improver, with or without diesel fuels. Water (from aqueous ethanol) may also be present in order to use lower-proof ethanol, thus increasing water tolerance of the micro-emulsions.

3.4.1.3 Dilution

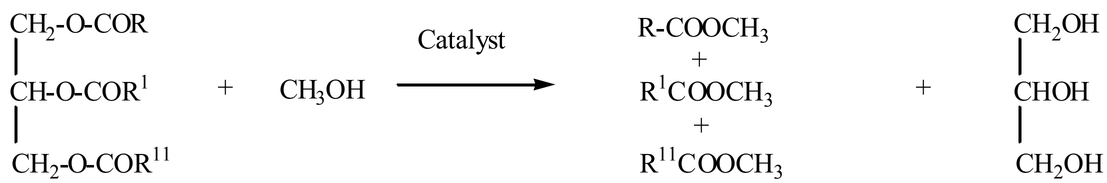
Dilution of vegetable oils can be accomplished with such materials as diesel fuels, solvent or ethanol.

3.4.1.4 Transesterification

Transesterification also called alcoholysis, is the displacement of alcohol from an ester by another alcohol in a process similar to hydrolysis. This process has been widely used to reduce the viscosity of triglycerides. The transesterification reaction is represented by the general equation

$$RCOOR' + R'' \longrightarrow RCOOR'' + R'OH$$

If methanol is used in the above reaction, it is termed methanolysis. The reaction of triglyceride with methanol is represented by the general equation:



Triglyceride **Methanol** **Fatty acid methyl ester** **Glycerol**

Triglycerides are readily trans-esterified in the presence of alkaline catalyst at atmospheric pressure and at a temperature of approximately 60 to 70°C with an excess of methanol. The mixture at the end of reaction is allowed to settle. The lower glycerol layer is drawn off while the upper methyl ester layer is washed to remove entrained glycerol and is then processed further. The excess methanol is recovered by distillation and sent to a rectifying column for purification and recycled.

The transesterification works well when the starting oil is of high quality. However, quite often low quality oils are used as raw materials for bio-diesel preparation. In cases where the free fatty acid content of the oil is above 1%, difficulties arise due to the formation of soap which promote emulsification during the water washing stage and at an FFA content above 2% the process becomes unworkable.

3.4.2 Process variables in transesterification

The most important variables that influence transesterification reaction time and conversion are:

- oil temperature
- reaction temperature;
- ratio of alcohol to oil;
- catalyst type and concentration;
- mixing intensity;
- purity of reactants.

3.4.2.1 Oil Temperature

The temperature to which oil is heated before mixing with catalyst and methanol, affects the reaction. It was observed that increase in oil temperature marginally increases the percentage oil to bio-diesel conversion as well as the bio-diesel recovery. However, the tests were conducted up-to only 60°C as higher temperatures may result in methanol loss in the batch process.

3.4.2.2 Reaction temperature

The rate of reaction is strongly influenced by the reaction temperature. Generally, the reaction is conducted close to the boiling point of methanol (60 to 70°C) at atmospheric pressure. The maximum yield of esters occurs at temperatures ranging from 60 to 80°C at a molar ratio (alcohol to oil) of 6:1. Further increase in temperature is reported to have a negative effect on the conversion. Studies have indicated that given enough time, transesterification can proceed satisfactorily at ambient temperatures in the case of the alkaline catalyst.

It was observed that bio-diesel recovery was affected at very low temperatures (just like low ambient temperatures in cold weather) but conversion was almost unaffected.

3.4.2.3 Ratio of alcohol to oil

Another important variable affecting the yield of ester is the molar ratio of alcohol to vegetable oil. A molar ratio of 6:1 is normally used in industrial processes to obtain methyl ester yields higher than 98% by weight. Higher molar ratio of alcohol to vegetable oil interferes in the separation of glycerol.

It was observed that lower molar ratios required more reaction time. With higher molar ratios, conversion increased but recovery decreased due to poor separation of glycerol. It was found that optimum molar ratios depend upon type & quality of oil.

3.4.2.4 Catalyst type and concentration

Alkali metal alkoxides are the most effective transesterification catalyst compared to the acidic catalyst. Sodium alkoxides are among the most efficient catalysts used for this purpose, although potassium hydroxide and sodium hydroxide can also be used. Transmethylations occur many folds faster in the presence of an alkaline catalyst than those catalysed by the same amount of acidic catalyst. Most commercial transesterifications are conducted with alkaline catalysts. The alkaline catalyst concentration in the range of 0.5 to 1% by weight yields 94 to 99% conversion of vegetable oil into esters. Further, increase in catalyst concentration does not increase the conversion and it adds to extra costs because it is necessary to remove it from the reaction medium at the end.

It was observed that higher amounts of sodium hydroxide catalyst were required for higher FFA oil. Otherwise higher amount of sodium hydroxide resulted in reduced recovery.

3.4.2.5 Mixing intensity

The mixing effect is most significant during the slow rate region of the transesterification reaction. As the single phase is established, mixing becomes insignificant. The understanding of the mixing effects on the kinetics of the transesterification process is a valuable tool in the process scale-up and design. It was observed that after adding methanol & catalyst to the oil, 5-10 minutes stirring helps in higher rate of conversion and recovery.

3.4.2.6 Purity of reactants

Impurities present in the oil also affect conversion levels. Under the same conditions, 67 to 84% conversion into esters using crude vegetable oils can be obtained, compared with 94 to 97% when using refined oils. The free fatty acids in the original oils interfere with the catalyst. However, under conditions of high temperature and pressure this problem can be overcome.

It was observed that crude oils were equally good compared to refined oils for production of bio-diesel. However, the oils should be properly filtered. Oil quality is very important in this regard. The oil settled at the bottom during storage may give lesser bio-diesel recovery because of accumulation of impurities like wax etc.

3.4.3 Raw material and its quality for the production of bio-diesel

3.4.3.1 Vegetable Oil : Any sediment would collect at the bottom of the reaction vessel during glycerol settling and at the liquid interface during washing. This would interfere with the separation of the phases and may tend to promote emulsion formation. The oil must be moisture-free because every molecule of water destroys a molecule of the catalyst thus decreasing its concentration. The free fatty acid content should be less than 1%.

It was observed that lesser the FFA in oil better is the bio-diesel recovery . Higher FFA oil can also be used but the bio-diesel recovery will depend upon oil type and amount of sodium hydroxide used.

3.4.3.2 Alcohol: Methanol or ethanol, as near to absolute as possible. As with the oil, the water affects the extent of conversion enough to prevent the separation of glycerol from the reaction mixture.

3.4.3.3 Catalyst: Sodium or potassium hydroxide, preferably the latter. The corresponding alkoxide also can be used, but prohibitively expensive. Best if it has ≥ 85% potassium hydroxide. Even best grades of potassium hydroxide have 14-15% water which can not be removed. It should be low in carbonate, because the carbonate is not an efficient catalyst and may cause cloudiness in the final ester. Sodium hydroxide pellets have given very good results. Because quantity of catalyst used is quite less, good quality catalyst (in-spite of high cost) can be used.

3.4.3.4 Animal fats: The most prominent animal fat to be studied for potential bio-diesel use is tallow. Tallow contains a high amount of saturated fatty acids, and it has therefore a melting point above ambient temperature.

3.4.3.5 Waste vegetable oils: Every year many millions of tonnes of waste cooking oils are collected and used in a variety of ways throughout the world. This is a virtually inexhaustible source of energy, which might also prove an additional line of production for "green" companies. These oils contain some degradation products of vegetable oils and foreign material. However, analyses of used vegetable oils indicate that the differences between used and unused fats are not very great and in most cases simple heating and removal by filtration of solid particles suffices for subsequent transesterification. The cetane number of a used frying oil methyl ester was given as 49, thus comparing well with other materials,

3.4.3.6 Esters of vegetable oil: they make good biomass fuels as diesel substitutes, provided the following factors receive special attention:

- The yield of transesterified product should be >90%.
- The fuel should be as neutral as possible (pH 6.5-8.0)
- The fuel should be centrifuged at a temperature below the expected ambient operating temperature. Winterization has been suggested as the ideal solution.
- The neutralizing agent should form fuel in soluble salts, free from carbonate groups.
- Ash content should be 0.01%. The fuel should be free from alcohol.

3.4.4 Storability of bio-diesel

It was observed that when the bio-diesels of different oils were stored, their FFA as well as viscosity increased. However, FFA remained below 1% even after one and a half years of storage. Minimum increase was observed in *Jatropha curcas* oil bio-diesel followed by rice bran, sun flower and linseed oil bio-diesel. During storage, the bio-diesels also gained some weight. It may be mainly due to reaction with oxygen in the air.

3.4.5 Plants in operation/ under construction

Different technologies are currently available and used in the industrial production of bio-diesel, which is sold under different trademarks. For example, there are the Italian processes Novamont, and the French IFP as given in Table 3.4.

A number of units are manufacturing bio-diesel worldwide. These units are using sunflower oil, soyabean oil, rapeseed oil, used-frying oil, jatropha oil, etc. as a source of triglycerides as given in Table 3.5 & Table 3.6

A total of 85 plants were identified including a few pilot plants, over 30 small capacity plants (500-3000 tons) mostly with farmers' co-operative as owner and several big plants in the capacity range of 10,000 to 120,000 tons. Of these, 44 plants were in Western Europe with Italy as the leading country with 11 plants, 29 plants in Eastern Europe with Czechia being the leading country with 16 plants, 8 plants in North America and 4 plants in the rest of the world. Overall capacity grew from 111,000 tons in 1991 to 1,286,000 in 1997. USA is the fastest growing newcomer and a number of companies are emerging there. Additional capacities are expected in Japan and the palm oil producing countries, Indonesia and Malaysia. Actual production grew from 10,000 tons in 1991 to 661,000 tons in 1997. France is the leading producer with 227,000 tons (in 1996). Table 3.5 gives country wise number of plants, production capacity and feedstock oil used. Details about few plants are given in Table 3.6.

Table 3.4: Available bio-diesel production technologies

Company	**Reaction conditions**			
	P (atm)	**T (^oC)**	**Catalyst**	**Mode of operation**
Transesterification				
Comprimo/Vogel and Noot	1	Ambient	KOH	Batch
Idaho University	1	Ambient	KOH	Batch
Novamont/ Technimont	1	>Ambient	Organic	Batch
Conneman/Feld and Hahn	1	60-70	NaOH	Continuous
Lurgi	1	60-70	Alkaline	Continuous
IFP/sofiproteal	1	50-130	Alkaline/acid	Batch
Gratech	3.5	95		Continuous
Desmet	50	200	Nonalkaline	Continuous
Others:Oleofina. Procter & Gamble, MEKFT				
Indian Institute of Chemical Technology, Hyderabad, India			Catalyst free	Batch
Indian institute of Petroleum, Dehradun, India			(a)Base catalyst, (b) acid catalyst	Batch
Punjab Agricultural University, Ludhiana, India	1	55-60^oC	NaOH pellets	Batch

(Source: Tadashi Murayama)

Table 3.5 : Country wise capacity of the bio-diesel plants

Country	Number of plants	Location	Total annual capacity, tonnes	Oils used
Austria	11(1)	Aschach, Bruck, Pischelsdorf	56,200-60,000	Used Frying Oil
Belgium	3	Feluy, Seneffe	241,000	-
Canada	1	Saskatoon	-	-
Czechoslovakia	17(1)	Mydlovary, Olomouc	42,500-45,000	Used Frying Oil
Denmark	3	Otterup, Jutland	32,000	-
France	7(1)	Rouen, Compiegne, Boussens, Peronne, Verdun, Nogentsurseine	38,100	-
Germany	8(4)	Leer, Dusseldorf, Kiel, Barby, Germunden, Thuringia	207,000	-
Hungary	17(6)	Visnye, Gyor	18,880	-
Ireland	1	-	5000	Used Frying Oil
Italy	9(4)	Livomo, Cittadi, Casleto, Milano, Solbiate, Napoli, Bari, Ancona, Brescia	779,000	Sunflower Oil
Nicaragua	1	-	-	Jatropha oil
Slovak Republic	10(1)	-	50,500-51,500	-
Spain	1	Bilbao	500	-
Sweden	3(1)	Gothenborg, Skane, Orebro	75,000	-
Switzerland	1	Geneva	2000	-
U.K.	1	East Dusham	-	-
U.S.A.	40(3)	Midwest, Chicago, Quincy	190,000	Used frying oil
Yugoslavia	2	-	5000	-

*figure within parenthesis indicate the number of plants under construction.
(Source: Anjana Srivastava and Ramprasad)

Table 3.6 : Details about few plants

Plant Location	Operational since	BioDiesel prodn. per year	Feedstock	By Products
MURECK/AUSTRIA Turnkey plant	1991	1,000 t (0.3)	rapeseed, crude rapeseed oil	Glycerol phase
First industrial facility worldwide to produce BioDiesel from 100% waste cooking oil	1994		Waste cooking oil	
Capacity extension	1995	2,750t (0.83)		
Adjustment of plant to meet DIN standard	1998			
Capacity extension	2000	3,500t (1.05)		
GUSSING/AUSTRIA Turnkey plant	1991	1,000t (0.3)	Rapeseed,crude rapeseed oil	Glycerol phase
BRUCK a.d. LEITHA/AUSTRIA Turnkey plant and production of pharmaceutical glycerol	1992	15,000 t (4.5)	Rapeseed oil top degummed	Pharmaceutical (grade) glycerol + solid fertilizer
Increase in yearly output Installation of esterification process for which a worldwide patent has been taken out	1995	20,000t (6Mio)		
OLOMOUC/CZECH REPUBLIC Overall planning and delivery of esterification facility	1994	30,000t (9)	Rapeseed oil (water degummed)	Crude glycerol 60%, free fatty acids
BUTLER, KENTUCKY/USA Overall planning and delivery of esterification facility including Glycerol processing	Oct 1998	5,000t(1.5l)	WCO and/or animal fats	Crude glycerol 50%, solid fertilizer
MALCHIN/GERMANY Overall planning and delivery of esterification facility including Glycerol processing	Under construction	12,000t (3.6)	Crude Rape seed oil + Tallow + WCO	Crude glycerol 80%, solid fertilizer
BARCELONA/SPAIN Overall planning and delivery of esterification facility including Glycerol processing	Under construction	16,000t (5.4)	Tallow WCO	Crude glycerol 80%, solid fertilizer
NIEDERPOELLNITZ/GERMANY Overall planning and delivery of esterification facility including Glycerol processing	Under construction	50,000t (15)	Rape seed oil Top degummed + tallow	Crude glycerol 80%, solid fertilizer

Note: Figures in bracket indicate million US gallons (Source: Austrian Biofuels Institute)

3.4.6 Work-done in India

In India, attempts are being made for using non-edible and under-exploited oils for production of esters. The non-traditional seed oils available in the country, which can be exploited for this purpose, are *Madhuca indica, Shorea robusta, Pongamia glabra, Mesua ferra* (Linn), *Mallotus philippines, Garcinia indica, Jatropha curcas* and *Salvadora.*

3.4.6.1 Punjab Agricultural University is actively involved in R&D work on plant oils and their esters (bio-diesel) as alternate fuel for diesel engines since early eighties. Firstly a number of plant oils were used in blend with HSD (high speed diesel) fuel and kerosene oil in the existing diesel engine. Then a simple bio-diesel production process was standardised in the laboratory. Based on that a 12 liter batch reactor was developed and used for bulk production of bio-diesel which was later scaled up to 60 liters. Biodiesel has been prepared from a number of plant oils (edible as well as non-edible) and used successfully in existing diesel engines.

3.4.6.2 Indian Institute of Petroleum (IIP) is actively pursuing the utilization of non-edible oils for the production of bio-diesel, additives for lubricating oils, saturated and unsaturated alcohols and fatty acids and many other value added products. The results obtained so far are encouraging and need further investigations for commercial exploitation of these products. Some of the products used as lube additives are being produced commercially from non-edible oils based on IIP's technologies.

IIP is pursuing programme sponsored by DBT on "Liquid fuels form Renewable Resources". The project has two parts :

Part – A deals with the indigenous technology development for bio-diesel production using *Jatropha Curcas,* Karanj Oil, Mahua Oil and *Salvadora* Oil, as a net working project alongwith CSMCRI, Bhavnagar and NBRI Lucknow.

Part – B deals with the recovery of Hydrocarbons from biomass and their conversion to liquid fuel with Rajasthan University Jaipur as a networking partner. Rajasthan University will be supplying the biomass to IIP for its extraction and conversion to liquid fuels.

Under this programme bulk sample of bio-diesel will be prepared using the 30 litre capacity batch pilot plant available at IIP**.**

3.4.6.3 Indian Institute of Chemical Technology extracted oil from *Jatropha curcas.* The oil extraction was based on cooking of *jatropha* seeds with water followed by drying and expelling of oil. A catalyst-free process (Indian patent filed, US Patent being filed) that is insensitive to moisture or high FFA content has been developed at IICT, and an oil of any FFA content can be converted to the alkyl ester. Active work is also going on at IICT for the preparation of fatty acid esters from low and high FFA vegetable oils using enzymes and solid catalysts.

3.4.6.4 Besides, preliminary studies on the utilization of non-edible oils such as Neem, Mahua, Linseed etc. as fuel are being carried out at IIT, Delhi and IIT, Madras. IOC R&D is also doing some work on the transesterification of vegetable oils. IOC (R&D) has already set up a biodiesel production facility of 60 kg/day at Faridabad. Mahindra & Mahindra Ltd has a pilot plant utilizing Karanj for bio-diesel production in Mumbai. This plant has carried out successful trails on tractors using this fuel. Parameters such as power, torque, fuel consumption, emissions, etc. have been found quite satisfactory on tractors operating on this bio-diesel. Field trials for about 30000 kms have also been carried out on the tractors. In India most of the trials were done using bio-diesel from feedstock like Karanj and Jatropha. Bio-diesel from different feed-stocks even after meeting ASTM standards may vary in composition, lubricity, oxidation stability, etc. It is desirable to carry out tests on bio-diesel from all possible feed-stocks available in India and generate comparative data on fuel composition

3.5 Blending of Esters & Diesel

Blending conventional Diesel Fuel (DF) with esters (usually methyl esters) of vegetable oils is presently the most common form of bio-diesel. The most common ratio is 80% conventional diesel fuel and 20% vegetable oil ester, also termed "B20," indicating the 20% level of bio-diesel; There have been numerous reports that significant emission reductions are achieved with these blends.

No engine problems were reported in larger-scale tests with, for example, urban bus fleets running on B20. Fuel economy was comparable to DF2, with the consumption of bio-diesel blend being only 2-5% higher than that of conventional DF. Another advantage of bio-diesel blends is the simplicity of fuel preparation, which only requires mixing of the components.

Ester blends have been reported to be stable, for example, a blend of 20% peanut oil with 80% DF did not separate at room temperature over a period of 3 months. A 50:50 blends of peanut oil with DF was also found quite stable.

Several studies have shown that diesel/bio-diesel blends reduce smoke opacity, particulates, un-burnt hydrocarbons, carbon dioxide and carbon monoxide emissions, but nitrous monoxide emissions are slightly increased. One limitation to the use of bio-diesel is its tendency to crystallize at low temperatures below 0°C. Methyl and ethyl esters of vegetable oils will crystallize and separate from diesel at temperatures often experienced in winter time operation. Such crystals can plug fuel lines and filters, causing problems in fuel pumping and engine operation. One solution to this problem may be the use of branched-chain esters, such as isopropyl esters. The isopropyl esters of soyabean oil crystallize 7 to 11°C lower than the corresponding methyl esters. Another method to improve the cold flow properties of vegetable oil esters is to remove high-melting saturated esters by inducing crystallization with cooling, a process known as winterization.

3.6 Storage of Bio-Diesel:

Pure plant oils are completely harmless to the environment, especially the groundwater. However, esterification of vegetable oil increases its water hazard. As per German EPA classifies waste vegetable oil as a toxic waste.

As a general rule blends of bio-diesel and petroleum diesel should be treated like petroleum diesel. It is recommended to store bio-diesel in clean, dry and approved tanks. Though the flash point of bio-diesel is high, still storage precautions somewhat like that in storing the diesel fuel need to be taken

Bio-diesel can be stored for long periods in closed containers with little headroom but the container must be protected from direct sunlight, low temperature and weather. Underground storage is preferred in cold climates but is stored in open proper insulation, heating and other equipment should be installed. B 20 fuel can be stored in above ground tanks depending on the pour point and cloud points of the blend

Low temperature can cause bio-diesel to gel. Additives can be used for low temperature storage and pumping. The bio-diesel / its blends should be stored at temperatures at least higher by 15 deg C that the pour point of the fuel. While splash blending the bio-diesel, care should be taken to avoid very low fuel temperatures as the saturated compounds can crystallize and separate out to cause plugging of fuel lines and filters. Condensation of water in the tank should be avoided as hydrocarbon-degrading bacteria and mold can grow and use bio-diesel as food.

Bio-diesel and its blends are susceptible to growing microbes when water is present in fuel. Biocides, chemical that kill bacteria and molds growing in fuel tank , in small concentration .Biocides does not remove sediments. Moreover, storage of bio-diesel in old tanks can release accumulated deposits and slime and can cause very severe filter and pump blockage problem.

For long term Storage stability of Bio-diesel and blends adequate data are not available. Based on experience so far it is recommended that bio-diesel can be store up to a maximum period of 6 months Some anti-oxidant additives are also used for longer periods of storage. Similarly periods are applicable for storage of bio-diesel and its blends in vehicle fuel tank. Due to being a mild solvent, bio-diesel has a tendency to dissolve the sediments normally encountered in old tanks used for diesel fuel and cause filter blockage, injector failures in addition to clogging of fuel lines. Brass, copper, zinc etc oxidizes diesel and bio-diesel fuels and create sediments. The fuel and fitting will start changing color as the sediments are formed. Storage tank made of aluminum, steel etc should be used,

3.7 Handling of Bio-Diesel :

As a general rule blends of bio-diesel and petroleum diesel should be treated like petroleum diesel. Bio-diesel vegetable methyl esters contain no volatile organic compounds that can give rise to poisonous or noxious fumes**.** There is no aromatic hydrocarbon (benzene, toluene, zylene) or chlorinated hydrocarbons. There is no lead or sulfur to react and release any harmful or corrosive gases. However, in case of bio-diesel blends significant fumes released by benzene and other aromatics present in the base diesel fuel can continue. On eye contact bio-diesel may cause eye irritation. Safety glasses or face shields should be used to avoid mist or splash on face and eyes. Fire fighting measures to be followed as per its fire hazard classification. Hot fuel may cause burn. Bio-diesel should be handled with gloves as it may cause soft skin. Mild irritation on skin can occur.

German Regulations on water hazard classification classify products either as NWG (non hazardous to water) or WGK 1, WGK 2 and WGK 3 with increasing water hazard . Both bio-diesel and methanol are classifies as WGK 1. The glycerin also falls under same classification. There is no risk of explosions from vapor in bio-diesel as the flash point is high and the vapor pressure is less than 1 mm Hg. Large bio-diesel spills can be harmful. Bio-diesel, while not completely harmless to the larvae of crustacea and fish, is less harmful than petroleum diesel fuel.

Bio-diesel methyl esters have very low solubility in water (saturation concentration of 7ppm in sea water and 14 ppm in fresh water at 17 deg. C) compared to petroleum diesel that contain benzene, toluene, zylene and other more water soluble, highly toxic compounds. However, when the bio-diesel is vigorously blended into water, the methyl esters form a temporary emulsion of tiny droplets that appear to be harmful to the swimming larvae. The half-life for biodegradation of vegetable methyl ester is about 4 days at 17 deg, C about twice fast as petroleum diesel. In the laboratory tests, rapeseed methyl eater degraded by 95% while the diesel fuel degraded only 40% at the end of 23 days.

Any accidental discharge/ spill of small amounts of bio-diesel should have little impact on the environment compared to petroleum diesel, which contain more toxic and more water-soluble aromatics. Nonetheless, the methyl esters could still cause harm. EPA still considers spills of vegetable oils and animal fats as harmful to the environment. Spilling bio-diesel in water is as illegal as spilling petroleum. Bio-diesel need to be handled like any other petroleum fuels and laws should be reviewed to ensure that bio-diesel is covered in the same class, if not included already. When biocides are used in the fuel tank to kill bacteria, suitable handling precautions like use of gloves and eye protection is must.

One must check if the laws on disposal of petroleum products are applicable to bio-diesel also. Similarly check if Laws for spill prevention and containment action for those who produce or store bio-diesel exists. Discharge of animal fats and vegetable oil are order of magnitude less toxic than petroleum discharge, do not create carcinogenic compounds and, are really biodegradable by bacteria thus minimizing physical impact on environment.

Nevertheless, extreme discharges of animal fats, vegetable oils and bio-diesel can cause negative impact on aquatic life. Bio-diesel spills compare more favorably to petroleum oil spills. Moreover, likelihood of an vegetable oil or bio-diesel oil spill being comparable in magnitude to a petroleum spill is also very small due to differences in volumes in the two industries. Petroleum tankers exceed 250,000-ton capacity whereas vegetable oils are carried in parcel tankers with 3500-ton capacity.

There is a need to differentiate between the vegetable oils and petroleum oil through the creation of separate classes for animal fats and vegetable oils from petroleum oils, and apply separate standards based on the differences in physical characteristics between the classes. Bio-diesel is currently controlled in the same manner as animal fats, vegetable oils and petroleum oils are controlled under oil spill laws and regulations, bio-diesel facilities and tanker vessels transporting bio-diesel remain controlled in the same manner as if they were petroleum oil facilities or tanker vessels transporting petroleum oil.

3.8 Analysis of technologies with reference to Indian resources & requirements

3.8.1 India has rich and abundant forest resources with a wide range of plants and oilseeds. The production of these oilseeds can be stepped up many folds if the government takes the decision to use them for producing diesel fuels. Economical feasibility of bio-diesel depends on the price of the crude petroleum and the cost of transporting diesel to long distances to remote markets in India. Further, the strict regulations on the aromatics and sulphur contents in diesel fuels will result in higher cost of production of conventional diesel fuels.

3.8.2 The production of ethyl esters from edible oils is currently much more expensive than hydrocarbon-based diesel fuels due to the relatively high costs of vegetable oils. The cost of bio-diesel can be reduced if we consider non-edible oils, and used frying oils instead of edible oils. Non-edible oils such as neem, mahua, karanja, babassu, Jatropha, etc. are easily available in many parts of the world including India, and are very cheap compared to edible oils. The potential availability of some non-edible oils in India is given in Table 3.7.

Table 3.7 Non-edible oil sources of India

Oil	Botanical	Potential (million tonnes)	Utilised (million tonnes)	Percent Utilisation
Rice bran	Oryza Sativa	474,000	101,000	21
Sal	*Shorea robusta*	720,000	23,000	3
Neem	*Melia azadirachta*	400,000	20,000	6
Karanja	*Pongamia glabra*	135,000	8,000	6

(Source: Anjana Srivastava and Ramprasad)

3.8.3 The processing of oilseeds for the production of edible vegetable oils generates by-product streams containing triglycerides, phospholipids and free fatty acids. In many cases these streams are of considerably lower value than the finished oil. Successful development of a scheme for ester synthesis from low-value lipids could address the economic barriers to a wider adoption of bio-diesel.

3.8.4 Fatty acid methyl ester could be produced from tall oil, a by-product in the manufacture of pulp by the Kraft process. Tall oil consists of free C_{18} unsaturated fatty acids, resin acids and relatively small amounts of unsaponifiables. The fatty acid fraction of tall oil contains mainly oleic acid, linoleic acid and its isomers.

3.8.5 With the mushrooming of fast food centres and restaurants in India, it is expected that considerable amounts of used-frying oils will be discarded into the drains. These can be used for making bio-diesel, thus helping to reduce the cost of water treatment in the sewerage system and assisting in the recycling of resources.

3.8.6 Acid oil, which is cheaper than both raw and refined oils, is a major by-product of the alkali refining industries and is a potential raw material for making bio-diesel.

3.8.7 It is also possible to use vegetable oils directly blended with diesel oil. With about 25% diesel oil mixed with vegetable oil, it is possible to achieve improved thermal efficiency and lower smoke emissions

3.8.8 Heating the fuel to lower the viscosity and then using vegetable oils directly as fuels is also an option.

3.8.9 Thermal and catalytic decomposition of vegetable oils to produce gasoline and diesel fuel has been studied by a number of scientists using various methods with the objective of finding a gasoline replacement, but the fuel obtained possessed an inferior octane number. At the present, a hydrocarbon fuel with a similar volatility and molecular weight as diesel fuel can be produced with an approximate volume yield of 50% from the decomposition of vegetable oils. The method that appears most promising is pre-hydrogenation followed by thermal or catalytic decomposition of vegetable oils.

3.8.10 Biodiesel can be used as a pure fuel or blend with petroleum diesel depending on the economics and emissions.

3.8.11 The Indian Scenario is different from Europe and USA where refined vegetable oils, waste frying oils and tallow are used to produce bio-diesel. In India, non-edible oils are likely the preferred feedstock. The transesterification of non-edible oils has not been studied extensively with a view to produce bio-diesel. Data on oil characteristics, their behavior in transesterification and quality of bio-diesel produced from each oil are needed for application of this process such as: catalysts (basic, acidic, homogeneous/ heterogeneous); continuous/ batch operation; scale of operation; by products valuation and utilization.

3.9 Engine Development & Modifications

Studies conducted with bio-diesel on engines have shown substantial reduction in Particulate matter (25 – 50%). However, a marginal increase in NO_x (1-6%) is also reported. It may be noted that the marginal increase in NO_x can be taken care of either by optimization of engine parts or by using De-NO_x catalyst. HC and CO emissions were also reported to be lower. Non-regulated emissions like PAH etc were also found to be lower.

Although, bio-diesel is reported to have superior lubricity, its effect on lubricity of FIP needs to be quantified for typical Indian feed stocks. Flash point of biodiesel is high (> 100^o C). Its blending with diesel fuel can be utilized to increase the flash point of diesel particularly in India where flash point is 35^o C well below the world average of 55^o C. This is important from the safety point of view. Most of the studies reported had used methyl ester. However, ethyl ester can also be expected to give similar results.

The viscosity of biodiesel is higher (1.9 to 6.0 cSt) and reported to result into gum formation on injector, cylinder liner etc. This needs to be studied on various engine designs. 5-10% bio-diesel can be used with HSD without any engine modifications.

The Emission norms of diesel cars and heavy-duty vehicles are given in Table-3.8 and Table-3.9 respectively. Indian and European diesel fuel specifications are tabulated in Table-3.10. It may be noted that increasing demand on improving fuel quality with time due to stringent emission norms requires heavy cost in terms of better vehicle technology and refineries up-gradation. Therefore, use of clean fuels like bio-diesel becomes more relevant in the present context.

Biodiesel can be derived from many vegetable oils, restaurant greases and fats such as corn, cashew, oat, palm, lupine, rubber seed, coffee, linseed, hazelnut, euphobia, pumpkin seed, sesame, kenaf, calendula, cotton, hemp, soybean, rapeseed, olive tree, castor bean, jojoba, pecan, oil palm, safflower, rice, sunflower, peanut, tung oil tree, jatropha, macadamia nut, brazil nut, avocado, coconut, macuba palm karanja etc. Vegetable oils can be used as a fuel in diesel engines. The use of unrefined vegetable oil leads to poor fuel atomization due to high viscosity resulting in poor combustion and also more gum formation in fuel injector, liner etc. The results of emissions of using unrefined vegetable oils were unfavorable and were also accompanied by deposit formation . Therefore, it is necessary to esterify the vegetable oil for use in engines. Most of the studies presented below are focussed on use of methyl ester and its blends in engines. Methyl esters have high cetane number leading to low engine operating noise and good starting characteristics. Some of the properties of Methyl esters are shown in Table 3.11.

Christopher A. Sharp conducted detailed experiments with biodiesel. He conducted the experiments with three engines (1997 Cummins N14, 1997 DDC Series 50, 1995 Cummins B5.9) with neat biodiesel (B100) and biodiesel-diesel blend (B20). The results of the engine (DDC Series 50) are shown in Table 3.12. He investigated the effects of biodiesel on engine performance and exhaust emissions with and without catalyst. The results show a significant reduction in exhaust emissions. CO and HC emissions were significantly lower than diesel operation. However, NOx emissions increased marginally. The particulate emissions were generally lower (about 25 to 50%) due to higher oxygen content in biodiesel. The non- regulated emissions like PAH and nPAH also decreased significantly.

Apart from benefit in terms of emissions, the use of biodiesel is also reported to give excess carbon deposit on injector, liner etc and the results in various studies had also confirmed this problem. However, these problems can be addressed by use of a suitable additives package.

Engine oil dilution is a potential problem with biodiesel since it is more prone to oxidation and polymerization than diesel fuel. The presence of biodiesel in engine could cause thick sludge to occur with the consequence that the oil becomes too thick to pump . Engine oil formulations need to be studied to minimize the effect of dilution with biodiesel.

The manufacture of Caterpillar engine has recommended various suggestions to the users on the use of biodiesel in their engines . The salient features of recommendations are;

- Biodiesel provides approximately 5 - 7% less energy than distillate fuels. One should not change the engine rating to compensate for the power loss in order to avoid engine problems.
- At low ambient temperatures, the fuel system may require heated fuel lines, filters and tanks. Biodiesel has poor oxidation stability, which may accelerate fuel oxidation in the fuel system. Oxidation stability additive has to be used to avoid long term storage problem.
- They have set the Caterpiller biodiesel specification standards. In that, they mentioned the fuel quality on use in Caterpiller engine should be sulfur content maximum of 0.01% by weight, cetane number minimum of 45, flash point minimum of 100 ^{o} C etc.

Use of bio-fuels and their effect on greenhouse gas (GHG) emissions to atmosphere is well updated in a Concave report . They studied the effects with ethanol and Rapeseed Methyl Ester (RME). They considered to calculate net greenhouse gas in view of emissions from bio-fuels production process and burning and these were compared with fossil fuel at same energy content. They reported that the CO_2 emitted during combustion of the bio-fuel does not enter into the balance, because it was absorbed from the atmosphere by the growing crop. This point is well debated and concluded in the concave report. The gain in terms of GHG for the use of biodiesel is not well established as lot of uncertainties need to be cleared in estimating GHG.

It must be noted that the light duty diesel engines are sufficiently different from heavy duty diesel engines in may aspects and one should not expect that the emission behavior of the two types of engines would be same. This fact should be kept in mind while transferring conclusions of studies done on one type of engine to other type of engines

Table-3.8

Indian & European Vehicle Emission Norms
Diesel Cars

Emissions	**Euro-I (1993)** India 2000	**Euro-II (1996) Bharat Stage-II *(2000)**	**Euro-III (2000) Bharat Stage-III **(2005)**	**Euro-IV**
CO (g/km)	**2.72**	**1.0**	**0.64**	**0.50**
HC+Nox (g/km)	**0.97**	**0.7 (IDI)** 0.9 (DI)	**0.56**	**0.30**
PM (g/km)	**0.14**	**0.08**	**0.05**	**0.025**

Table-3.9

Indian & European Vehicle Emission Norms
Diesel Heavy Duty vehicles

Emissions	**Euro-I (1993)** India (2000)	**Euro-II (1996) Bharat Stage-II *(2001)**	**Euro-III (2000) Bharat Stage-III **(2005)**	**Euro-IV**
CO (g/kWh)	**4.5**	**4**	**2.1**	**1.50**
HC (g/kWh)	**1.1**	1.1	**0.66**	**0.02**
Nox (g/kWh)	8.0	**7.0**	**5.0**	**3.5**
PM (g/kWh)	**0.36**	**0.15**	**0.10**	**0.025**

* Implemented only in metros.
** To be implemented in metro from 2005

Table-3.10
Comparison of Indian & European Diesel specifications

Characteristics	India-2000	Bharat Stage-II	Bharat Stage –III	Euro-II1993	Euro-III 2000	Euro-IV 2005
Cetane No.,Min.	48	48	51	49	51	-
Cetane index, Min.	-	46	46	46	46	-
Sulphur,ppm	2500	500	350	500	350	50
PAH,wt.-%,max	-	-	11-	11	-	
Viscosity@400c	2-5	2-5	2-4.5	2-4.5	2-4.5	-
Density,kg/m3,max	860	860	845	860	845	-
T_{85}, ^{0}c	350	350	-	350	-	-
T_{95}, ^{0}c	370	370	360	370	360	-

TABLE - 3.11

Properties of different Methyl esters compared to diesel fuel

Fuel Property	**Soybean Methyl Ester**	**Rapeseed Methyl Ester**	**No. 2 Diesel Fuel**
Formula	**C18 to C19**	C18 to C19	C8 to C25
Carbon (% wt)	78	81	84-87
Hydrogen (% wt)	11	12	13-16
Oxygen	11	7	0
Specific gravity	0.87	0.88	0.81
Pour point (^{0} C)	-3	-15	-23
Viscosity mPa-s at 20^0 C	3.6	3.6	2.6 – 4.1
Lower Heating Value kJ/L	32	37	35-37
Flash Point (^{0} C)	--	179	74
Cetane Number	52	62	40 – 55

TABLE – 3.12

Tests result for DDC series 50 engine at transient conditions are

Test fuel	**HC** (g/hp-hr)	**CO** (g/hp-hr)	**NOx** (g/hp-hr)	**PM** (g/hp-hr)
2D	0.06	1.49	4.5	0.102
B20	0.06	1.38	4.66	0.088
B100	0.01	0.92	5.01	0.052
B100 with catalyst	0.02	0.76	4.9	0.03

3.10 Environmental and Health Effects of Bio-diesel

The use of bio-diesel in a conventional diesel engine results in substantial reduction of unburned hydrocarbons, carbon monoxide and particulate matter. However, Emissions of nitrogen dioxides are either slightly reduced or slightly increased depending on the duty cycle and testing methods. The use of bio-diesel decreases the solid carbon fraction of particulate matter (since the oxygen in bio-diesel enables more complete combustion to CO_2), eliminates the sulphur fraction (as there is no sulphur in the fuel), while the soluble or hydrogen fraction stays the same or is increased. Therefore, bio-diesel works well with new technologies such as oxidation catalysts.

As per U.S.EPA bio-diesel has been comprehensively evaluated in terms of emissions and potential health effects under the Clean Air Act Section 211(b). These programmes include stringent emissions testing protocols required by EPA for certification of fuels in the U.S. The data gathered through these tests include thorough inventory of the environmental and human health effects attributes that current technology will allow. The results of the emissions tests for pure biodiesel (B100) and mixed biodiesel (B20-20% biodiesel and 80% petrodiesel) compared to conventional diesel are given in Table-3.13 & 3.14

Table 3.13 : Bio-diesel Emissions Compared to Conventional Diesel

Emissions	B100	B20
Regulated Emissions		
Total Unburned Hydrocarbons	-93%	-30%
Carbon Monoxide	-50%	-20%
Particulate Matter	-30%	-22%
Nox	+13%	+2%
Non-Regulated Emissions		
Sulphates	-100%	-20%*
Polyciclic Aromatic Hydrocarbons (PAH)**	-80%	-13%
NPAH (Nitrated PAHs)**	-90%	-50%***
Ozone Potential of Speciated HC	-50%	-10%
Life-Cycle Emissions		
Carbon Dioxide (LCA)	-80%	
Sulphur Dioxide (LCA)	-100%	

***Estimated from B100 results. **Average reduction across all compounds measured. ***2-nitroflourine results were within test method variability.**

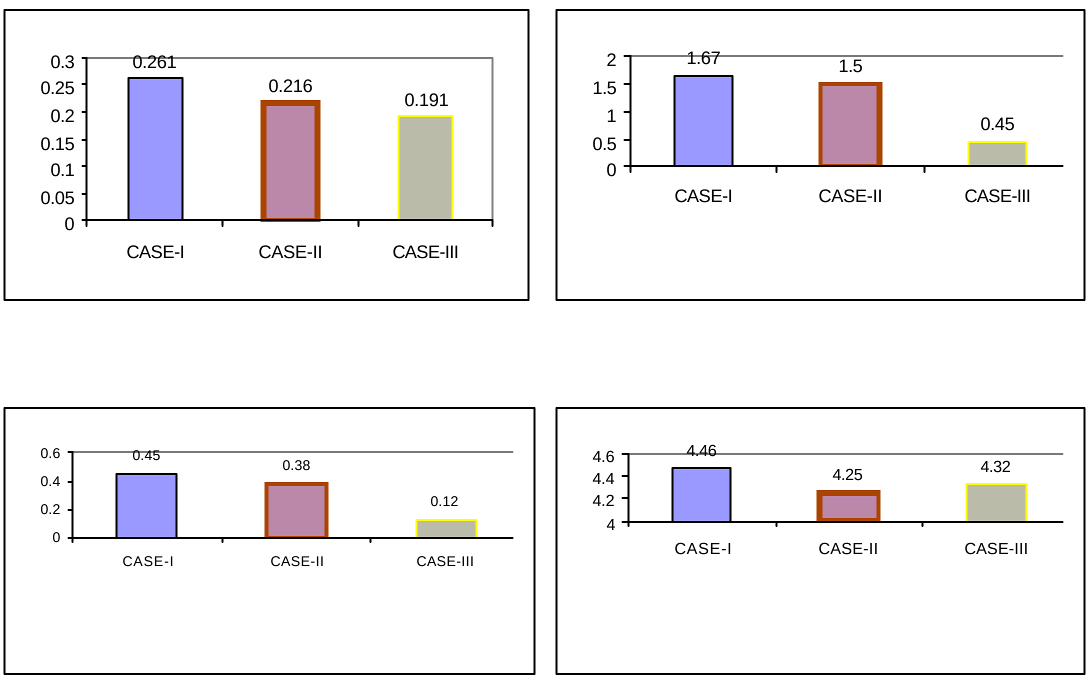
Test Cycle : EEC+EUDC90kmph Cold Start.

All in g/km

	CO	HC	NOX	HC+NOX	PM
BS-II Limit	**1.5**			**1.2**	**0.17**
Base Line	0.77	0.37	0.79	1.16	0.129
With 10 % Blend	0.65	0.22	0.83	1.04	0.093
With 15 % Blend	0.62	0.16	0.89	1.05	0.080
% Improvement with respect to the base line					
10 % Blend	15%	41 %	-4 %	10%	28%
15 % Blend	20%	50%	-12%	10%	38 %

Table 3.14 : Emission results of Biodiesel and blends tests on IDI diesel engine
(Source: Mahindra & Mahindra)

The life-cycle production and use of biodiesel produces approximately 80% less carbon dioxide and almost 100% less sulphur dioxide compared to conventional diesel. Comparative emissions of petrodiesel, biodiesel and biodiesel blends are shown in Figure 3.1



CASE-I: Petrodiesel with o.o5% sulphur. CASE-II: 20% biodiesel with 3-degree injection timing adjustment. CASE-III: CASE-II + Catalytic Converter

Fig-3.1 : Comparative Emissions from petrodiesel & biodiesel

Bio-diesel emissions are nontoxic. From Table 3.15, it is clear that biodiesel gives a distinct emission benefit almost for all regulated and non-regulated pollutants when compared to conventional diesel fuel but emissions of NOx appear to increase from biodiesel. NOx increases with the increase in concentration of biodiesel in the mixture of biodiesel and petrodiesel. This increase in NOx emissions may be neutralized by the efficient use of Nox control technologies, which fits better with almost nil sulphur biodiesel then conventional diesel containing sulphur. It may also be noted that emission of NOx also varies with the different family of feedstocks for bio-diesel. Moreover, the problem of increased NOx emission can be effectively tackled by retarding the fuel injection timing.

3.10.1 Comparison of particulate composition-Diesel Vs. Biodiesel (Rapeseed Methyl Esters, RSME):

When the engine is operated on RSME, soot emissions (insolubles) are dramatically reduced, but the proportion of emissions composed of fuel derived hydrocarbons (fuel solubles), condensed on the soot, is much higher. This implies that the RSME may not burn to completion as readily as diesel fuel. It should, however, be noted that gaseous HC emissions were reduced with RSME in the above tests. Since concern over particulates arises partly from the potential harmful effects of the soluble fraction, it might be suspected that emissions from RSME would be more harmful however data shows no tendency for the mutagenicity of exhaust gas to increase for a vehicle running on 20% RSME and 80% diesel blends.

Table 3.15

Test	Fuel	Total PM (g/mile)	Insolubles (g/mile)	Fuel Solubles (g/mile)	Lube Solubles (g/mile)	Soluble Inorganic Fraction %
Cold FTP Difference %	Diesel RSME	0.311 0.258 -17%	0.259 0.118 -54%	0.021 0.104 +491%	0.031 0.036 +16%	17 54 +318%
Hot FTP Difference %	Diesel RSME	0.239 0.190 -21%	0.206 0.101 -51%	0.012 0.068 +567	0.021 0.021 0%	14 47 +335

3.10.2 Toxicity & Safety issues

Biodiesel is non-toxic. The acute oral LD50 (lethal dose) is greater than 17.4-g/Kg-body weight. It causes very mild human skin irritation which is less than the irritation produced by 4% soap and water solution. It is bio-degradable. There is no tendency for the mutagenicity of exhaust gas to increase for a vehicle running on bio-diesel (20%RSME80% diesel). Bio-diesel is considered as fairly safer fuel. Bio-diesel has a flash point of about 300 F well above conventional diesel fuel. The National Institute for Occupational Safety and Health (NIOSH), USA lists its aquatic toxicity as "insignificant" in its Registry of the Toxic Effects of Chemical Substances. EPA rates bio-diesel to have the same safety concerns to that associated with conventional fuels. This product (bio-diesel) is not "hazardous" under the criteria of the Federal OSHA Hazard Communication Standard 29 CFR 1910.1200. As per the California Proposition 65- this product contains no chemicals known to the state of California to cause cancer. This fuel is registered under Fuel and Fuel additives at 40 CFR79 of US-EPA.

3.11 Research & Development

In India research on bio-diesel is in infant stage, there is a dire need to adopt vigorous programs on the technological development for its production, utilization of by products and evaluation in engine with respect to shortcomings, emissions, additive response etc. For efficient production of bio-diesel concerted R&D effort is needed to produce high quality feedstock material and to develop an improved, cost effective and efficient bio-diesel production system. Biodiesel from different feedstocks may vary in composition, lubricity, oxidation stability, etc. It is desirable to carry out tests on biodiesel from all possible feedstocks available in India and generate comparative data on fuel composition emissions and materials compatibility, etc. Toxicological study is a pre-requisite for introduction of any fuel. It is recommended that such studies in India should be initiated through concerned R&D centers. Procedure for detecting percentage of biodiesel in the blended fuel and to check adulteration of the fuel should also be developed. Emission norms for biodiesel vehicles may be similar to that of the conventional diesel vehicles

Research and Development needs in broadly three areas viz. Raw Material, Production Technology and Utilization of bio-diesel as fuel have been considered. The major raw materials used for the production of bio-diesel are vegetable oil and alcohol. In India vegetable oils are costly and are in short supply therefore, non-edible oils such as *Jatropha curcas. Pongaima, Salvodra, Acacia, Madhuca latifolia, Saliciornia* etc. are preferred feed stock for bio-diesel production. The potential of total non-edible oils in India is around 0.1 MMT/ annum. There is a need to increase the production of non-edible oil even to achieve a humble target of 5.0% replacement of diesel with bio-diesel. The other R&D issues which need attention are seed resource assessment, collection and their cryo-preservation, increasing availability of seed, seed setting, inter-cropping with TBOS, selection of high yielding crops, developing agro-technologies for different agro climatic regions, oil quality, bio-diesel production technology using new catalyst systems like heterogeneous catalysts, lipase catalyst and supported catalysts on smart polymers, utilization of by-products apart from issues related to utilization of bio-diesel as fuel including compatibility with additives and elastomers, engine performance, toxicity adulteration etc.

3.11.1 Raw Material

3.11.1.1. Production of improved feedstock / raw-material

The major raw materials used for the production of bio-diesel are (a) vegetable oil (b) alcohols (methanol, ethanol etc.). Total vegetable oil production in India (2001-02) is 6.67 mmt *(Source: Solvent Extraction Association of India)* while ethanol production is around 1.3 billion liters *(Source: CBMD souvenir on Ethanol and Bio-diesel, Sept. 2002).*

The studies all over the world on vegetable oils as the alternative fuels are mainly concentrated on field crops like rapeseed oil, sunflower oil, soybean oil, Canola oil, used fried oil etc. In India these oils are costly and are in short supply. For India it appears that non-edible oils may be the choice feed stock for bio-diesel production.

At present the most widely used raw material for biodiesel in India is *Jatropha curcas and Pongaima* However, other species such as*, Salvodra, Acacia, Madhuca latifolia, Saliciornia* etc. also offer enormous potential.

The potential of total non-edible oils in India is around 0.1 mmt/ annum *(Source: Report on Role of NGOs, and Inform, vol. 13, 151-157, Feb. 2002*). This quantity is not even sufficient for 0.25 % replacement of diesel need of India There is a need to increase the production of non-edible oil even to achieve a moderate target of 5.0% replacement of diesel with bio-diesel.

There is need to increase the area under utilization of genetically improved tree species which can produce better quality and quantity of oil. This would require systematic efforts towards tree improvement program, identification of Candidate Plus Tree (CPTs), standardization of nursery raising techniques (i.e. Vegetative/seed/tissue culture) so that high yielding genotypes could be produced for further plantation programs, which in turn could yield better quality and quantity of oil.

NOVOD, NBRI Lucknow, CSMCRI, Bhavnagar leading universities and other R&D institutions working in the similar field can play a leading role in developing high yielding varieties of CPTS specially Jatropha Curcas.

The other reachable issues, which need attention, are seed resource assessment, collection and their cryo preservation, increasing availability of seed, seed setting, inter-cropping with TBOS (Tree Borne oil Seeds).

3.11.1.2 Selection of the crop for production of Biodiesel

This is perhaps the most important and also the most neglected issue. As mentioned earlier for India it appears that non-edible oils is the choice feed stock for Bio-diesel production.

There is a need to collect scientific data to get the realistic figures on the yield pattern and on the oil content/ quality. Presently, most of such figures are just based on preliminary studies and we have no pilot projects to support the data. To begin with Jatropha Curcas seems to be the most potential candidate considering its favorable properties. Some reports indicate that *Jatropha* gives yields varying from 1.5 tons/ hectare to as high as 12 tones/ hectares. However, the types of genetic species, which give high yield, are not classified. There are enormous possibilities for selecting and breeding crops with higher yields of suitable oil.

Biotechnology tools can be applied for producing high quality elite planting material. Tissue Culture technologies help in mass-producing the elite identified clones. Techniques of genetic engineering also offer a possibility of producing desirable material. Research effort should continue for identifying new and potential sources of raw material. NOVOD can help in this regard.

3.11.1.3 Developing agro-technologies for different agro-climatic regions

For maximum yield proper agro-technologies are essential, research studies on standardizing nursery practices need to be further strengthened. There is enormous waste and marginal land available and technologies for utilizing this effectively are required to be standardized for different potential crops to be grown in various ecosystems. Proper scientific data is essential for planting density, fertilization practices, planting procedure etc. Research being supported for developing complete agro-technologies for potential crops for different agro-ecosystems, needs to be strengthened. Demonstrations should be laid out pilot scale data collected. Complete technology packages should be prepared for adoption at grass root level. This area requires complete peoples participation. CSMCRI Bhavnagar, NBRI Lucknow NOVOD, leading universities and other R&D institutions working in this area can take up this work.

3.11.1.4 Oil Quality

The oil quality has a direct relationship with the technology of transesterification a basic reaction in biodiesel production. Oils having high free fatty acids (FFA) need a different treatment of the oil from that of low FFA oils. Therefore, chemical analysis of the oil, with respect to unsaponifiable matter, free fatty acids and composition of fatty acids becomes very important. There is a need for total chemical analysis of all potential non-edible oils with special reference to Jatropha Curcas Oil for biodiesel production prior to carrying out transesterification studies. Various aspects like, characterization of the oil and pretreatment studies also require to be looked into.

The oils on storage for longer period get deteriorated so information is needed on their storage stabilities especially with respect to the increased FFA content and sediments. Improved storage practices should be developed.

OTRI may be helpful in providing these information.

3.11.2 Production Technology

3.11.2.1 Bio-diesel production

Plant based oils can be converted to Bio-diesel by processing of the oil so as to convert triglyceride to fatty acid esters. This trans-esterification reaction is simple, however, improved technologies would result in higher yield and better quality. Research efforts for perfecting an efficient chemical/ catalyst conversion process are ongoing and need to be pursued further. Methyl as well ethyl esters can be used in the diesel engine.. It may be interesting to do studies to assess effect of type of esterification on the final properties of the fuel using the same base feedstock. Indian Oil should be requested to generate some data on this aspect.

Even if India opt for foreign technology for the production of bio-diesel from non-edible oils their will be a need of R&D to fine tune the foreign technology to suits the oils produced in India.

3.11.2.2 Biocatalyst

Conventionally bio-diesel is produced through trans-esterification of oils with a short chain alcohol in the presence of a homogenous catalyst. With this catalyst, water treatment or neutralization is required. New tools/ techniques can be applied using heterogeneous catalysts, which will eliminate the pollution and handling problems. Heterogeneous slurry catalysts are filterable from the oil. Fixed-bed system avoids the catalysts removal step and also the catalyst could be potentially regenerated in-situ.

Research efforts have also been initiated for optimizing lipase catalyzed trans-esterification conditions. This includes study on identifying the appropriate lipase, purification of the enzyme through modern efficient techniques like expanded bed chromatography, affinity precipitation and three phase partitioning. Lipase catalyzed esterification / trans-esterification is reported to be a more efficient process than the chemical/ catalytic process. The data/ conditions optimized for lipase production from different microorganisms, culture conditions, fermentation, lipase assay, immobilized enzyme reaction etc. would be useful for efficient conversion.

3.11.2.3 Heterogeneous Catalyst

An emerging alternative technology is to use smart polymers. These are basically soluble polymers whose solubility can be altered in a reversible fashion by the use of a command. The command can be a change in pH, ionic strength, temperature or even addition of an ion or chemical. Thus enzymes immobilized on such supports can be used in soluble form with plant material, cellulosic material and recovered after the reaction by altering the conditions i.e. using a suitable command.

The trans-esterification reaction requires low water conditions otherwise product esters will be hydrolyzed back. The protocols for such reactions are available but optimization in terms of best enzyme, best immobilization form, best solvent etc are required with each individual system. A number of lipase are commercially available and can be used after limited purification.

A number of strategies have been worked out for enhancing enzymes activity under anhydrous conditions. These involve pH tuning, salt activation and choosing the right support for immobilization. All these need to be tried for maximizing bio-diesel yield.

Indian Institute of Petroleum, IOC R&D Faridabad, IICT Hyderabad, Punjab Agriculture University, IIT Delhi and some other research organizations which are already working on this aspect are capable of completing this work in a reasonable time frame.

3.11.2.4 Utilization of by-products

The cost of bio-diesel production can be reduced by proper utilization of by-products such as glycerol and meal cake apart from improving trans-esterification process.

Glycerol from bio-diesel contain some peculiar impurities and may not be suitable to process according to the usual technologies to produce pharmaceutical or top grade product.

There is a need not only to develop purification technology for glycerol but also for its utilization as a raw material for the production of other chemicals as large quantity (0.2 MMT/A) of the glycerol will be available even if 5 % diesel is targeted to be replaced by bio-diesel against the present glycerol demand in Indian which is the tune of 0.04 MMT/A.

There is a need to find the use of meal cake which will be available in large quantities to reduce the cost of bio-diesel. Meal cake may be used as fertilizer, as cattle feed after de-toxification, etc.

CSMCRI, NBRI Universities and NOVOD may be approached for R&D requirements.

3.11.3 Utilization as Fuel

3.11.3.1 Bio-diesel Characterization

In India most of the trials has been carried out using bio-diesel from feed stocks like *Jatropha Curcas and Karanj oils*. Bio-diesel from different feedstocks even after meeting ASTM standards may very in composition, lubricity, oxidation stability etc. It is desirable to carry out tests on bio-diesel from all possible feed stocks available in India and generate comparative data on fuel composition.

3.11.3.2 Compatibility with additives

Bio-diesel may have different response with present day additives. There is a need to study in detail the response of different available additives, their dosages on the bio-diesel e.g.

a) Bio-diesel thickens at low temperature so it needs cold flow improver additives with acceptable CFPP
b) Pour point depressants commonly used for diesel may not work for bio-diesel.
c) Poor oxidation stability of bio-diesel may require increased amount of stabilizer

d) To avoid growth of algae in presence of water, some biocide may be needed.
Some newer additives may have to be developed / required for bio-diesel.

3.11.3.3 Compatibility with elastomers

Though bio-diesel (B_{100}) can be used as a replacement of petroleum diesel, further study is needed to study the effect of bio-diesel on elastomers, additive response, corrosion etc. Minor modifications in the engine may also be required.

3.11.3.4 Stability of Bio diesel

Bio-diesel ages more quickly than fossil diesel fuel due to the chemical structure of fatty acid esters present in bio-diesel.

There are three types of stability criteria, which need to be studied:

(a) Oxidation stability (b) Thermal Stability and (c) Storage Stability

Poor oxidation and thermal stability can cause fuel thickening, formation of gum and sediments and may also affect engine oil due to dilution. Current knowledge and database is still inadequate. It is desirable to carry out tests on bio-diesel from different feedstocks available in India and generate data in relation to fuel composition.

Very little data is available on the long-term storage stability of bio-diesel. Effect of presence of water, sediments, and additives on storage stability needs to be investigated in detail.

3.11.3.5 Engine Performance

No or very little data on effect of bio-diesel from *Jatropha and Karanj Oil* on emission and engine performance using various proportion of bio-diesel is available. This needs validation on test engine beds.

Apart from the study on engine performance on different capacities of engines/ vehicles the following aspects need to be studied further

a. Endurance tests for finding out wear on engine components like cylinder liner, piston rings etc., analysis for carbon deposit on piston, value, injectors etc.
b. Analysis of crankcase lubricating oil for assessing the deterioration or contamination due to blow by leakage.
c. Effect of additives to prevent gum formation need to be evaluated.

Indian Institute of Petroleum & IOC, Faridabad are the best R&D institution having all facilities and expertise to take up R&D activity on all the aspects related to the utilization of bio-diesel as alternative fuel and potential blending component for diesel.

3.11.3.6 Toxicological Studies

Toxicological study is a pre-requisite for introduction of any fuel. It is recommended that such studies in India should be initiated through concerned R&D centers such as ITRC, Lucknow.

3.11.3.7 Adulteration

(1) Procedure for detecting percentage of bio-diesel in the blended fuel and to check adulteration of the fuel should be developed. FTL may be approached to develop the procedure for checking the adulteration.
(2) Adulteration of Jatropha Curcas Oil in edible oils will be a very serious problem after the start of this ambitious programme of producing bio-diesel from Jatropha curcas oil as Jatropha Curcas oil will be available to common people in large quantities at a very low price.

Plans should be chalked out to check this adulteration.

3.12 Properties of Bio-diesel :

A general understanding of the various properties of bio-diesel is essential to study their implications in engine use, storage, handling and safety.

3.12.1 Density/ Specific Gravity:

Bio-diesel is slightly heavier than conventional diesel fuel (specific gravity 0.88 compared to 0.84 for diesel fuel). This allows use of splash blending by adding bio-diesel on top of diesel fuel for making bio-diesel blends. Bio-diesel should always be blended at top of diesel fuel. If bio-diesel is first put at the bottom and then diesel fuel is added, it will not mix. Density control is specified in European specifications but not in ASTM specification. But for India it is proposed to keep density specifications to check for contamination/adulteration.

3.12.2 Cetane Number:

Cetane number of a diesel engine fuel is indicative of its ignition characteristics. Higher the cetane number better it is in its ignition properties. Cetane number affects a number of engine performance parameters like combustion, stability, driveability, white smoke, noise and emissions of CO and HC. Bio-diesel has higher cetane number than conventional diesel fuel. This results in higher combustion efficiency and smoother combustion. No correlation was found between the specific gravity and the cetane number of various biodiesel. It is important to note that Cetane Index, commonly used to indicate the ignition characteristics of diesel fuels, does not give correct results for bio-diesel. Hence Cetane Index is not specified and a cetane number test is necessary. Even for a biodiesel blend, cetane index is not applicable as it does give a correct approximation of cetane number of the blend.

3.12.3 Viscosity:

In addition of lubrication of fuel injection system components, Fuel viscosity controls the characteristics of the injection from the diesel injector (droplet size, spray characteristics etc.) . The viscosity of methyl esters can go to very high levels and hence, it is important to control it within an acceptable level to avoid negative impact on fuel injection system performance. Therefore, the viscosity specifications proposed are same as that of the diesel fuel.

3.12.4 Distillation characteristics:

The distillation characteristics of bio-diesel are quite different from that of diesel fuel. Bio-diesel does not contain any highly volatile components, the fuel evaporates only at higher temperature. This is the reason that sometimes sump lubrication oil dilution observed in many tests. The methyl esters present in bio-diesel generally have molecular chains of 16- 18 carbons which have very close boiling points. In other words, rather than showing a distillation characteristics, bio-diesel exhibits a boiling point. Boiling point of bio-diesel generally range between 330 to 357 deg. C. The limit of 360 deg . C is specified mainly to ensure that high boiling point components are not present in bio-diesel as adulterants/ contaminants.

3.12.5 Flash point:

Flash point of a fuel is defined as the temperature at which it will ignite when exposed to a flame or spark. The flashpoint of bio-diesel is higher than the petroleum based diesel fuel. Flashpoint of bio-diesel blends is dependent on the flashpoint of the base diesel fuel used, and increase with percentage of bio-diesel in the blend. Thus in storage, biodiesel and its blends are safer than conventional diesel. The flashpoint of bio-diesel is around 160 deg. C , but it can reduce drastically if the alcohol used in manufacture of bio-diesel is not removed properly. Residual alcohol in the bio-diesel reduces its flashpoint drastically and is harmful to fuel pump, seals, elastomers etc. It also reduces the combustion quality.

A minimum flashpoint for biodiesel is specified more from the point of view of restricting the alcohol content rather than a fire hazard. A minimum flashpoint of 100 ºC is specified to ensure that excess methanol used for the esterification is removed. Another important consideration is that the test method used to find out flashpoint (ASTM D 93) gives high scatter in results at the flashpoint nears 100 deg C. Due to this reason, the ASTM D 6751 standard issued in Feb, 2002 calls for a flashpoint of min. 130 deg C though the intent is to get a min. value of 100 deg. C (as specified in 1999 Draft standard PS 121)

3.12.6 Cold Filter Plugging Point (CFPP):

At low operating temperature fuel may thicken and not flow properly affecting the performance of fuel lines, fuel pumps and injectors. Cold filter plugging point of biodiesel reflects its cold weather performance. . It defines the fuels limit of filterability. CFPP has better correlation than cloud point for bio-diesel as well as diesel fuel. Bio-diesel thicken at low temperatures so need cold flow improver additives to have acceptable CFPP.

3.12.7 Pour Point:

Normally either pour point or CFPP are specified. French and Italian bio-diesel specifications specify pour point whereas others specify CFFP. Since CFFP reflects more accurately the cold weather operation of fuel, it is proposed not to specify pour point for bio-diesel. Pour point depressants commonly used for diesel fuel do not work for bio-diesel.

3.12.8 Cloud Point:

Cloud point is the temperature at which a cloud or haze of crystals appear in the fuel under test conditions and thus becomes important for low temperature operations. Bio-diesel generally has higher cloud point than diesel fuel. Cloud point limit is not specified but ASTM D 6751 calls for reporting of the cloud point to alert the user of possible problem under cold climatic conditions.

3.12.9 Aromatics:

Bio-diesel does not contain any aromatics so aromatic limits are not specified. It may be noted that conventional aromatic determination tests used for petroleum fuels does not give correct results for bio-diesel, hence aromatics in a bio-diesel blend can be determined only by testing the base diesel fuel before blending.

3.12.10 Stability:

Bio-diesel age more quickly than fossil diesel fuel due to the chemical structure of fatty acids and methyl esters present in bio-diesel. Typically there are up to 14 types of fatty acid methyl esters in the bio-diesel. The individual proportion of presence of these esters in the fuel affects the final properties of bio-diesel. Saturated fatty acid methyl esters (C14: 0, C16: 0,C16: 0) increase cloud point, cetane number and improve stability whereas more polyunsaturates (C18: 2,C18: 3) reduce cloud point, cetane number and stability.

There are three types of stability criteria, which need to be studied:

- Oxidation stability – more related to engine operation as engine components attain high temperatures during operation.
- Storage stability
- Thermal stability

3.12.10.1 Oxidation Stability: Poor oxidation stability can cause fuel thickening, formation of gums and sediments, which, in turn, can cause filter clogging and injector fouling. Iodine number indicates the tendency of a fuel to be unstable as it measures the presence of C=C bonds that are prone to oxidation. Generally instability increase by a factor of 1 for every C=C bond on the fatty acid chain. Thus, C18: 3 are three times more unstable than C18: 0 fatty acids

Oxidation stability of bio-diesel varies greatly depending upon the feedstock used. In one study of 22 bio-diesel samples taken from 7 European production sites, the induction period was found to vary from 1 hrs to 10 hrs.

3.12.10.2 Thermal Stability: Current knowledge and database is still inadequate. More information is needed in this area.

3.12.10.3 Storage Stability: Very little data is available on the long-term storage stability of bio-diesel. Effect of presence of water, sediments, and additives on storage stability need to be investigated more. Based on the data available so far it is recommended that bio-diesel and its blends should not be stored in a storage tank or vehicle tank for more than 6 months. Depending upon the storage temperature and other conditions use of an appropriate antioxidants (e.g. Tenox 21, t-butylhydroquinone etc.) is suggested. The antioxidants must be properly mixed with the fuel for good effectiveness. To avoid growth of algae in fuel, water contamination need to be minimized and if necessary some biocide should be used.

Currently not all of the bio-diesel standards issued mention oxidation stability. Iodine number, viscosity and neutralization number indirectly assesses it. Higher values are indicative of poor oxidation stability. Iodine number test does not pick up the stability additives if used. There is need to develop appropriate test methods for oxidation and storage stability of bio-diesel. ASTM D 2274 is a good candidate test method.

3.12.11 Iodine Number and polyunsaturated methyl ester(C 18:3+):

In diesel engines, Methyl esters have been known to cause engine oil dilution by the fuel. A high content of unsaturated fatty acids in the ester (indicated by high Iodine number) increases the danger of polymerization in the engine oil. Oil dilution decreases oil viscosity. Sudden increase in oil viscosity, as encountered in several engine tests, is attributed to oxidation and polymerization of unsaturated fuel parts entering into oil through dilution. In saturated fatty acids all the carbon is bound to two hydrogen atoms by double bonds. More the double bonds the lower is the cloud point of oil. The tendency of the fuel to be unstable can be predicted by Iodine number. Different bio-diesel have different stability performance.

When iodine is introduced in the oil, the iodine attaches itself over a single bond to form a double bond. Thus iodine number refer to the amount of iodine required to convert unsaturated oil into saturated oil. It does not refer to the amount of iodine in the oil but to the presence of unsaturated fatty acids in the fuel.. ASTM D 1520 method for measurement of Iodine number does not recognize the presence of stability additive . Iodine number is not well suited to indicate the influence of methyl ester on engine. One value of iodine number can be obtained by using several grades of unsaturated acids. SO an additional parameter, linolenic acid (C18: 3) content is specified and limited to 15% in Austrian Standard ON C 1191

3.12.12 Free and Total glycerol:

The degree of conversion completeness of the vegetable oil is indicated by the amount of free and total glycerol present in the bio-diesel. If the actual number is higher than the specified values, engine fouling, filter-clogging etc can occur. Manufacturing process controls are necessary to ensure low free and total glycerine. Free glycerol if present can build up at the bottom of the storage and vehicle fuel tanks.

3.12.13 Mono-, Di-, and Triglycerides:

Most of the bio-diesel standards, except Austrian and ASTM, specify a max. limit of 0,08 for Mono-glyceride. Draft EU standard calls for same limit. Di-and Triglycerides are also controlled in most of the standards. High levels of these glycerides can cause injector fouling, filter clogging etc.

3.12.14 Ester content:

France (96.5%), Italy (98) and Sweden (98) specify a minimum eater content whereas Austrian and ASTM Standards do not specify any limit**.**

3.12.15 Alkaline matter (Na, K) :

Alkaline matter is controlled mainly to ensure that the catalysts used in the esterification process are properly removed.

3.12.16 Total contamination:

Left over impurities at the time of manufacture (such as free proteins) may form solid particles and clog the fuel lines. Filtration and washing treatments at manufacturing level need to be robust.

3.12.17 Sulfur content:

Biodiesel generally contain less than 15ppp sulfur. ASTM D 5453 test is a suitable test for such low level of sulfur. ASTM D 2622 used for sulfur determination of diesel fuels gives falsely high results when used for biodiesel. More work need to done to assess suitability of ASTM D 2622 application to B20 biodiesel blend. The increase in oxygen content of the fuel affects precision of this test method.

3.12.18 Lubricity:

Wear due to excessive friction resulting in shortened life of diesel fuel pumps and injectors, has some times ascribed to lack of lubricity in the fuel. Numerous premature breakdown and in some cases, catastrophic failures, have occurred failures. All diesel fuel injection equipment (fuel pump and injector) of the diesel engine have reliance on diesel fuels for its lubrication, especially the Rotary (Distributor) and Common Rail type systems. The lubrication of the pump is not provided by viscosity alone but also by the lubricity property of the fuel. Even when the viscosity of the fuel is correct, several parts of the pump can wear out due to lack of lubricity. The lubricity of the fuel depends on the crude source, refining process to reduce sulfur content and the type of additives used.

BOCLE(Ball on Cylinder Lubricity Evaluator) and HFFR(High Frequency Reciprocating Rig) are commonly used for evaluating the lubricity of the fuel. BOCLE is normally used for finding the lubricity fuel without additive, as it does not properly characterize the lubricity of fuels with lubricity additives. HFFR method has been adopted by Fuel Injection Manufactures for lubricity evaluation of diesel fuels and they recommend a limit of 460 microns wear scar diameter (WSD). Lower the WSD better is the lubricity of fuel. In case of BOCLE method a higher value is better. Even with 2% biodiesel mixed in diesel fuel, the WSD values comes down to around 325 micron and is sufficient to meet the lubricity requirements of the fuel injection pump(460 micron max.).. B100 performs still better, with a WSD of about 314 micron. With further reduction of sulfur content is diesel for Euro II and Euro IV fuels, the lubricity loss due to sulfur removal can easily be compensated by the addition of appropriate amount of biodiesel in diesel fuel.

2% inclusion into any conventional diesel fuel is sufficient to address the lubricity problem. It also eliminates the inherent variability associated with use of other additives to make fuel fully lubricious. Second the biodiesel is a fuel component itself- any addition of it does cause any adverse consequences. Since pure biodiesel has high lubricity, it is not specified in the specification. When biodiesel is used as lubricity blend (B2) or diesel fuel extender (B20), its lubricity characteristics has to meet the specification for the base fuel

3.12.19 Sulfated Ash:

Sulfated ash is controlled to ensure that all the catalysts used in the transesterification process are removed. Presence of ash can cause filter plugging and or injector deposits. Soluble metallic soap , un-removed catalysts and other solids are possible sources of sulfated ash in the fuel.

3.12.20 Acid number/Neutralization number:

Acid number/Neutralization number is specified to ensure proper ageing properties of the fuel and/ or a good manufacturing process. Acid number reflects the presence of free fatty acids or acids used in manufacture of biodiesel. It also reflects the degradation of biodiesel due to thermal effects. For example, during the injection process several times more fuel returns from the injector than that injected into the combustion chamber of the engine. The temperature of this return fuel can , sometimes, be as high as 90 deg. C and thus accelerate the degradation of biodiesel. The resultant high acid number can cause damage to injector and also result in
deposits in fuel system and affect life of pumps and filters. Sodium hydro peroxide and sulfuric acids are highly corrosive and can cause serious, many times permanent, injuries**.**

3.12.21 Water Content:

Biodiesel and its blends are susceptible to growing microbes when water is present in fuel. The solvency properties of the biodiesel can cause microbial slime to detach and clog fuel filters**.**

3.12.22 Phosphorous Content:

Phosphorous can come as impurity and can affect oxidation catalyst and cause injector fouling. As more and more OEMs are going to use catalytic converters in diesel engines, it is necessary to keep the level of phosphorous in fuel low. Usually biodiesel have less than 1ppm phosphorus. The specification of min. 10-ppm phosphorous content is intended to ensure compatibility with catalytic converters irrespective of the source of biodiesel.

3.12.23 Methanol/ethanol content:

High levels of free alcohol in biodiesel cause accelerated deterioration of natural rubber seals and gaskets. Damage to fuel pumps and injectors which have natural rubber diaphragms has been very common type of failure Methanol is membrane-permeable and can cause nerve damage. Therefore control of alcohol content is required.

3.12.24 Conradson Carbon Residue (CCR):

Carbon residue of the fuel is indicative of carbon depositing tendencies of the fuel. Conradson Carbon Residue (CCR) for biodiesel is more important than that in diesel fuel because it show a high correlation with presence of free fatty acids, glycerides, soaps, polymers, higher unsaturated fatty acids, inorganic impurities and even on the additives used for pour point depression. Two methods are used to measure carbon residue:

100 % residual
10 % residual

Since most of the biodiesel boils at almost the same temperature it is difficult to get a 10% residual upon distillation. Though the 10 % CCR test is easier to do , more work need to be done before we use it in Indian specifications for biodiesel.

3.13 Specifications and Quality Standards

Standards are of vital importance for the producers, suppliers and users of bio-fuels. Government Authorities need approval standards for the evaluation of safety, risks and environmental protection. Standards are necessary for the approval and warrantee commitment for vehicles operated with bio-fuels and are therefore, a pre-requisite for the market introduction and commercialization of bio-fuels. Creation of standards shall help expand the market for renewable sources of energy in India.

Conventionally Standards and codes for products have been developed, largely by examining the existing standards and codes in different countries and then writing standards for own country. With the formation of WTO, which seeks to eliminate discrimination of products based on national origin, and the realization that, in future, bio-fuels like ethanol and bio-diesel, can become internationally traded commodities like petroleum, it is essential that a worldwide view is taken while preparing a new national standard. But at the same time, the local imperatives (such as type of raw materials etc.) must be given due consideration.

In Europe bio-diesel is predominantly made from rapeseed oil and most information and data available are dealing with the rapeseed methyl ester (RME). Most of the experience in Austria, Italy, is also on RME. Germany has developed a standard for fatty acid methyl ester. Most of the Irish experience is on use of tallow fat for manufacture of bio-diesel. Very little experience is available on ethyl or propyl esters. No matter what the process or feedstock used, the bio-diesel produced must meet rigorous specifications to be used as a fuel in a compression ignition engine. It is not possible to recognize any blanket superiority of one feedstock over other since feedstock does not reliably predict a fuel's final properties.

Knowing that fuel adulteration is very rampant in India it is important that we ensure that chemical-grade fatty acid methyl esters used for purposes such as detergent manufacture must not be allowed to use as engine fuel. A Worldwide survey of bio-diesel specification was done and an attempt was made to understand the rationale behind them before proposing a norm for India.

Table 3.16 gives the current worldwide specifications of bio-diesel and also includes the tentative proposed specifications recommended for India.

ASTM has issued bio-diesel standard D 6751 in December 2001, which covers the use of pure bio-diesel (B100) into conventional diesel fuel up to 20 % by volume (B20). This replaces the provisional specification PS 121 issued in1999. Austria (ON C 1191), France (JO), Italy (UNI 10635) and Germany (DIN E 51606) had issued bio-diesel standards in 1997, Sweden in 1996 and a common draft standard EN 14214 for the European Union has also been announced. The new Italian bio-diesel standard, which will replace UNI 10 635, has been finalized and will be released this year for public.

In India , we have lots of European Engine technologies, specially that for older engines. We have also adopted the European Emission Regulations. Moreover, compared to USA diesel engines are more popular in Europe. Europe has also done expensive work on bio-diesel. Production of bio-diesel in Europe is much ahead of that in USA. The result is the EN14214 standard is more comprehensive than the ASTM standard. It is recommended that we adopt the EN1421112 standard for India

3.13.1 Test Methods for Biodiesel:

Table 3.17 gives the corresponding test methods used worldwide. Lot of work need to be done to clearly understand the requirements, accuracy and precision, and applicability of these test methods for India. For India, as far as possible, use the current BIS specifications or modify them to suit the requirements.

It is important to note that, as seen by the term " prEN" in Table 17 several methods are under development or in proposal stage.

Table 3.16: Summary of various National Standards on Biodiesel

		Austria	Czech Republic	France	Germany	Italy	Sweden	USA	USA	India Proposal	Draft EU
Standard/ Specification		ON C 1191	CSN 65 6507	Journal Official	DIN E 51606	UNI 10635 ***	SS 15543 6	ASTM P121-99	ASTM D675 1	BIS	EN 14214
Date		July 1, 1997	Spt. 1998	Spt.14 1997	Spt. 1997	April21, 1997	Nov., 27 1996	July, 1999	Feb. 2002	TBD	2001
Application		FAME	RME	VOME	FAME	VOME	VOME	FAME	FAME		
Density @15°C	g/cm3	0.85-0.89	0.87-0.89	0.87-0.89	0.875-0.90	0.86-0.90	0.87-0.90	--	--	0.87-0.90	0.86-0.90
Viscosity @40 °C	mm2/s	3.5-5.0	3.5-5.0	3.5-5.0	3.5-5.0	3.5-5.0	3.5-5.0	--	1.9-6.0	3.5-5.0	3.5-5.0
Flashpoint	°C	≥100	≥110	≥100	≥110	≥100	≥100	≥100	≥130	≥100	>100
CFPP	°C	0/-15	-5	--	0-10/ -20	--	-5	--		?	0/-15
Pour point,	°C	--	--	-10	--	0/-15	--	--		?	
Sulfur, max% mass.		0.02	0.02	0.02	0.01	0.01	0.01	0.05	0.05	0.05	0.01
CCR		0.05	0.05	--	0.05	--	--	0.05	0.05		

100 ,%,max .											
10%disti.resid, max. % mass		--	--	0.3	--	0.5	--	--		0.3	0.3
Sulfated Ash, max, % mass		0.02	0.02	--	0.03	--	--	0.02	0.02	0.02	0.01
(Oxid). Ash. Max, % mass		--	--	--	--	0.01	0.01	--			
Water .max, mg/Kg		--	500	200	300	700	300	≤0.05%	≤0.05	500	500
Total Comtami., max.	mg/Kg	--	24	--	20	--	20	--		20	
Cu Corrosion 3h/50C, max		--	1	--	1	--	--	No.3	No.3	1	1
Cetane No. .		≥49	≥48	≥49	≥49	--	≥48	≥40	≥47	≥51	≥49
Neutral No mg KOH/g.		≤0.8	≤0.5	≤0.5	≤0.5	≤0.5	≤0.6	≤0.8	≤0.8	≤0.8	
Methanol/ ethanol % mass		≤0.20	--	≤0.1	≤0.3	≤0.02	≤0.02	--	≤	≤0.02	≤0.02
Ester Content , % mass		--	--	≥ 96.5	--	≥98	≥98	--	--	≥96.5	≥96.5
Monoglyceride, % mass		--	--	≤0.8	≤0.8	≤0.8	≤0.8	--	≤	≤0.8	≤0.8
Diglyceride % mass		--	--	≤0.2	≤0.4	≤0.2	≤0.1	--	≤	≤	≤0.2
Triglyceride,% mass		--	--	≤0.2	≤0.4	≤0.1	≤0.1	--	≤	≤	≤0.2
Free Glycerol ,%		≤0.02	≤0.02	≤0.02	≤0.02	≤0.05	≤0.02	≤0.02	≤0.020	≤0.02	≤0.03

mass											
Total Glycerol %mass, max.		0.24	0.24	0.25	0.25	--	--	0.24	0.24	0.25	0.25
Iodine No.		≤120	--	≤115	≤115	--	≤125	--	--	≤115	≤115
C18: 3and higher unsat. Acids		≤15	--	--	--	--	--	--		?**	
Phosphorus ,ppm		≤20	≤20	≤10	≤10	≤10	≤10	--	≤10	≤10	10
Alkaline Matter (Na, K)		--	≤10	≤5	≤5	--	≤10	--	≤	≤	10
Distillation 95%	^{o}C	--	--	≤360	--	≤360	--	--	≤360	≤360	≤360
IBP Min.	^{0}C										*
5%											*
Bound glycerin											Max0.8
Oxid. stability	hrs										6 min.
Sediment											≤0.05
Cloud point									Report		

*report
** in the table means still to decide on this property
*** A new Italian Standard is already finalized and is under mandatory circulation before release to public.

Table 3.17:Test Methods for determination of biodiesel properties

Property	Others	ASTM	ISO/EN	DIN
Density			ISO 3675, ISO 12185	DIN 51 757
Flash point	ON ORM ,C1122, CD3679	D93	ISO 2719* EN 227 19,	
CFPP	ON ORM,		EN116	
Cetane number		D613	ISO 5156	
Kin. Viscosity		D445	ISO 3104	
CCR		D4530	EN ISO 10370 PrEN14104	DIN 51 551,
Neutral. No/ Acid no.	ON RM, C1146,	D664	prEN14104 EN 12634	
Methanol content	GLC, ,NF T 60 701		prEN14110	DIN 1608
Free glycerin	GLC/Enzymatic NF T 60 704, UNI 22054	D6548	prEN14105 prEN14106	
Total Glycerin	GLC/Enzymatic NF T 60 704	D6548	prEN14105	
Sulfur content	ON ORM C 1134	D5453	EN ISO 14596	
Iodine number		D 1510	ISO 3961 prEN14111	
Oxidation stability	IP 306 modified,	D2274	ISO 6886-1996 prEN14112	
Total contamination	EN 12662		EN12662	
FAME in mineral oil	NF M07 084 infrared			
Ester content	NF T60-703		ISO 5508 prEN14103	
Di-, triglycerides			PrEN14105	
Sulfated ash		D874	ISO 3987	
Water content	EN	D2709	ISO 12937	
Copper corrosion	EN	D130	ISO 2160	
Thermal stability	?			
Polysatu methyl ester C18:3+	NF T60 703			
Alkaline matter (K, Na)	NF T 60 706-1,-2		prEN 14108 prEN14109	
Phosphorous	NF T 60 705	D 4951	prEN1107	
Cloud point		D2500		
Thermal stability	?*	**?**	**?**	**?**

? means that an appropriate test method is yet to be identified

3.13.2 Proposed Bio-diesel Specifications for India

Table 3.18 below gives a comprehensive list of important fuel properties that have been considered for inclusion in the bio-diesel fuel specification. All these properties were considered, sometime or another, by different countries but not necessarily included in the final draft.

Table 3.18: Fuel Properties considered:

1	Density/specific gravity	17	Water content
2	Kinematic Viscosity	18	Cloud point
3	Flashpoint	19	(Oxi,) ash
4	CFPP	20	Net calorific value
5	Pour point	21	Acid Number/Neutral No.
6	Cetane number	22	Ester content
7	Distillation characteristics	23	Methanol content
8	Conardson carbon Residue	24	Mono - glycerides
9	Sulfur content	25	Di-glycerides
10	Copper corrosion	26	Triglycerides
11	Total contamination	27	Iodine number
12	Phosphorous content	28	Poly-Saturated ester(C 18:3 +)
13	Sulfated Ash	29	Free glycerol
14	Thermal stability	30	Total glycerol
15	Oxidation stability	31	Alkaline material(K, Na)
16	Storage Stability	32	Lubricity

Some of important properties specified are described below and reasons for the need to incorporate it in the fuel specification are mentioned in short. Since our feedstocks are going to be different from those used in developed countries, it was felt necessary to include all the relevant properties in the initial list for evaluation. An attempt should be made to reduce the final number of properties specified to the minimum possible. Of course, before the proposed specification for India are frozen, more deliberations would be necessary keeping in mind the local feedstocks, manufacturing and quality control techniques used

In India, we have lots of European Engine technologies, specially that for older engines. We have also adopted the European Emission Regulations. Moreover, compared to USA diesel engines are more popular in Europe. Europe has also done expensive work on biodiesel. Production of biodiesel in Europe is much ahead of that in USA. The result is the EN14214 standard is more comprehensive than the ASTM standard. It is recommended that we adopt the EN1421112 standard for India

Table 3.19 gives the proposed specifications for India. The column for test method is intentionally kept blank more work need to be done by the committee to understand the applicability of BIS test standards.

Table 3.19: Summary of Proposed BIS Standard for Biodiesel

Standard/Specification		prBIS	Test Method
Date		TBD* **	
Density @15°C	g/cm3	0.87-0.90	
Viscosity@40 °C	mm2/s	3.5-5.0	
Flashpoint	° C	≥100	
CFPP	° C		
Sulfur, max.,	% mass	0.035	
CCR,100%disti.resid.max.. ,	% mass	0..05	
Sulfated Ash, max,	% mass	0.02	
(Oxid). Ash. Max,	% mass	?	
Water .max	mg/Kg	500	
Total Comtami., max.	mg/Kg	20	
Cu Corrosion(3h/50C), max		1	
Cetane No..		≥51	
Acid No,	mg koh/g	≤0.8	
Methanol,	% mass	≤0.02	
Ester Content,	% mass	≥96.5	
Monoglyceride, ?**	% mass	≤0.8	
Diglyceride, ?	% mass	≤0.2	
Triglyceride,?	% mass	≤0.2	
Free Glycerol,	% mass	≤0.02	
Total Glycerol,	% mass	≤0.25	
Iodine No.		≤115	
Phosphorus	ppm	≤10	
Alkaline Matter(Na, K)		≤10	
Distillation, T 95%	°C	≤360	
Cloud point		*	

* measure and report

** in the table means that this property needs further discussion.
***TBD means to be decided

Though the test methods used for petroleum products are available there is very little experience in the use of materials like karanja, jatrophaa, rice brawn oil etc. These test methods must be reviewed to ensure their applicability for biodiesel, the precision and the accuracy achievable.

3.13.3 Engine Warranties and biodiesel approval endorsements from engine manufacturers:

Engines are designed, manufactured and warranted for a fuel that has certain specified properties. The engine manufacturers give warranty for material and workmanship of the products they make and typically recommend/ define use of a fuel in their manuals. They do not warrant fuel of any kind. If there is a problem due to fuel, the fuel supplier must stand behind the customer. Therefore it is important to take endorsements from engine manufacturers for use of bio-diesel and their blends.

Caterpillar and several other engine manufacturers recognize biodiesel meeting ASTM PS121, DIN 51606 Specifications. However, the stance taken by some manufactures is rather vague, such as caterpillar says it " neither approves nor prohibits use of biodiesel in their engines". For some of their engines, a blend of 5% biodiesel with diesel fuel (B5) is approved More than 5% biodiesel in diesel fuel is not covered under engine warranty. John Deere takes similar stance.

Several Marine engine manufacturers of Japan, USA and Europe (like Mercuiser, Yanmar etc) endorse use of B100 as fuel. Some engine manufactures warranties the newer engines and insists on change of hoses, seals and rubber parts in their older engines. While other engine manufactures give warranties on case-by-case basis. Most of the tractor companies in Europe and U.S.A. permit use of biodiesel in their engines.

3.13.4 Fuel Quality Test Procedures:

It is important to maintain the fuel quality within the fuel specification otherwise severe engine problems can occur. Two types of test procedures are necessary for ensuring good quality fuel to the customers:

1) Test procedures for production and supply quality of the biodiesel
2) Quick test procedures to check the quality of the fuel in field.

Table 3.17 gives the various test methods required to check the production and supply quality of biodiesel. Biodiesel manufacturing is essentially a batch production process. Therefore, better production and quality control methods are must for a consistent fuel quality. There is an acute need to develop tests for procedures for field testing of bio-fuels. This is very important in view of the large problems of fuel adulteration in India.

In BIS meeting it was agreed to do field trials on biodiesel. It is recommended that these trials must investigate at least the effect of cetane number, distillation, specific gravity, aromatics, oxygen and cloud point of biodiesel and its blends

3.14 Marketing & Trade

3.14.1 Barriers for Bio-diesel introduction

3.14.1.1 Economics

In order to promote biodiesel and to help it compete with petroleum diesel, several countries have drawn up tax support packages, for example, Germany and Italy levies no tax on biodiesel, UK has 20% lower tax, several US States imposed lower tax on fuels containing biodiesel.

Soybean is the most investigated and used for energy-crop for production of biodiesel. All most all the biodiesel in US and Brazil is of soybean origin. It is estimated that about 7.3 Pounds of soybean oil, which cost about 20 cents/ pounds, produce about one gallon of biodiesel. Therefore, the feedstock cost currently is 1.5 USD / Gallon of biodiesel and after processing the biodiesel costs about 2 USD / Gallon. However, US is currently working on mustard seed program, which cost about 10 cents / Pound and cost of producing mustard biodiesel shall be around 1.0 USD / Gallon. This compares well with current cost of petrodiesel which is approximately 1.30 USD / Gallon. The US program on biodiesel is driven and supported by soybean lobby as US has excess production for soybean. It is estimated that cultivation of soybean on set aside farmland in the US can fulfill 5% biodiesel introduction targets in the US.

Though biodiesel has proven its credentials as a clean alternate fuel to the petroleum diesel, some barriers do remain for its large-scale commercial introduction. The biggest barrier presently is its high cost, which is approximately 1.5 times to that of petroleum diesel. The cost estimate of biodiesel is only available from the studies in US and Europe, where biodiesel has been produced on the commercial scale. However, these estimates are based upon Soybean, Rapeseed and Sunflower oil as the primary feedstock. It has been estimated that the biodiesel from these feed stocks competes with petroleum diesel at a crude price of 35 USD/barrel and above. No economic data is available on non-edible bio crops.

Studies have been made to evaluate direct and indirect impact of biodiesel program. The National Biodiesel Board, US conducted a macro-economic study in 2001 to quantify direct and secondary economic benefits i.e. employment generation, balance of trade, positive effect on green house gas reduction and increased level of downstream processing activity. It has been concluded that taken these secondary effects into consideration the biodiesel competes with the petroleum diesel presentably and will have economic benefits in longer run.

3.14.1.2 Present Availability of Non-edible oils

The second barrier for introduction of biodiesel on large scale is its present availability. The biodiesel program in any country has a time lag between policy planning and actual implementation and hence the introduction could be gradual, gaining the maturity only after 4-5 years. This is especially applicable to India where Biodiesel is proposed to be made from non-edible oils. Presently, the availability of these oils is very limited and the price of such oils is quoted very high (Rs. 25-40 per kg). For successful launch of Biodiesel availability of oil on large scale has to be ensured at reasonable prices.

3.14.2 Marketing Frame Work for Biodiesel

Though in few isolated instances neat biodiesel (B100) has been used primarily in diesel engines on-board marine equipment, generally a blend 5-30% biodiesel in diesel has been used. France, Italy and Spain for example have been using 5% biodiesel in all conventional diesels. Biodiesel at 1-2% level has also been used as a lubricity additive for low sulphur diesel.

World experience has also indicated that biodiesel blends were first introduced either in heavily polluted cities or in remote areas producing biodiesel. The big fleets like bus companies and taxies were first to introduce biodiesel. Biodiesel mixes easily in any proportions to the conventional diesel and by virtue of its high density it can be easily mixed in a tank containing petroleum diesel. Its handling and storage is just like the petroleum diesel and no separate infrastructure is required. Therefore, the blending of biodiesel, which transported by tankers, is carried out at marketing depots. The biodiesel blends do not need separate dispensing and existing diesel dispensing station can also dispense biodiesel blends.

3.14.2.1 Amount of biodiesel to be blended in diesel

Use of biodiesel has been due to following factors: -

- Support to agriculture sector
- Part replacement of imported crude
- Emission benefit
- Rural development programme
- Lubricity improver

If the main purpose of the use of biodiesel is emission benefits, then higher %age of biodiesel is generally used. World over about 20 – 40% biodiesel blends (B20, B40) have been used for getting appreciable emission benefits. However, this approach needs OEM's approvals as some rubber seals etc. need changing for use of higher %age of biodiesel.

The lubricity benefits of using biodiesel, specially in ultra low Sulphur Diesel, can be obtained even at a very percent addition e.g. 0.5 – 1.0%

For support to agriculture sector and for part replacement of imported crude the amount of biodiesel to be blended in diesel will depend upon:

a) Availability of biodiesel
b) Cost of biodiesel and
c) Technical acceptability

In Indian context, presently the availability of feed stock (non-edible vegetable oils) is limited. However, with the massive plantation plans, it is envisaged that feed stock shall be available in large amount. This full scale availability of feed stock can be possible after a time lag of 4 – 5 years. It is also understood that a large emulsified potential of various oil bearing seeds is available in the country and there are plans to collect these materials.

In view of above, it is recommended that biodiesel should be introduced generally in our country starting from a low percent addition. The initial %age could be as low as 2% to 5% of biodiesel and this can be gradually increased when feed stock is available. France is using 5% biodiesel which is blended in all the diesel sold in that country.

3.14.2.2 Marketing framework -

The blending of biodiesel can be taken up at the depot level of the diesel distribution and marketing company. However, it should be emphasised that marketing of biodiesel blended diesel should be done as an organised trade and this activity should be handed by the diesel distributing companies. The biodiesel to be blended has to mandatorily tested for its quality. This will also keep in check any adulteration activity. The storage of biodiesel does not need any specialised tanking and the storage tanks used for biodiesel can also be used for biodiesel. The blending of biodiesel is also a simple affair and the circulatory pumps generally available in any diesel storage depot are sufficient to make a homogenous blend.

Another option for marketing of biodiesel blended diesel is for specialised fleet operations e.g. bus fleets etc. For this blending may be taken up at these locations

3.14.3 Trade of Biodiesel

For making available fuel grade biodiesel the following sequence of events need to be firmed up.

a) Availability of raw material of desired quality
b) Chemical treatment to produce biodiesel
c) Testing of biodiesel
d) Transportation of biodiesel to selected locations for blending
e) Blending of Biodiesel into diesel
f) Financial support

3.14.3.1 Availability of raw material of desired quality

For a National level Biodiesel programme availability of raw vegetable oil for conversion to Biodiesel needs to be ensured. Presently, the oil is available in limited quantity and that to on seasonal basis. There is need to identify the oil seeds extractors and the parties working in the area of extraction of oils may be contacted.

3.14.3.2 Chemical treatment to produce Biodiesel

Vegetable oil once extracted from the seed need a chemical treatment called Transesterification with lower alcohol (Methanol or Ethanol) in order to make fuel grade Biodiesel. Presently this technology is available only at laboratory scale or at best on the bench scale. Though this chemical process is simple and well understood whoever there is a need to develop commercial scale plants. These plants could be integrated with oil extractions plants so as to reduce cost by sharing of utilities. Though both batch scale and continuous type plants are used world over, it may be better to start with batch type plants in order to reduce initial cost. An estimate of 1 ton per day batch plant by IISC (Bangalore) is Rs. 6.5 lacs.

3.14.3.3 Testing of Biodiesel

Biodiesel produce must meet the specifications (ASTM D – 6751) in order to use it as a fuel component for transportation fuel. This specification requires elaborate testing and these tests can be done with the association of diesel marketing companies. It is recommended that some critical tests for example water content and acidity may be done at the plant level while the other test could be done at the centralised location.

3.14.3.4 Transportation of biodiesel to selected locations for blending

Transportation of Biodiesel does not require any special precautions and can be transported by tankers just as the diesel. In order to reduce the cost the initial introduction of Biodiesel should be done at locations near to the production site.

3.14.3.5 Blending of Biodiesel into diesel

Blending at depot level may be a good solution for initial selective introduction of Biodiesel at some locations. Biodiesel does not require any special storage or handling precautions whoever storage tanks and circulatory pumps for mixing need to be stationed at the blending site.

3.14.3.6 Financial support

Taxation and cross-country movement of materials would need attention. The price of biodiesel would have to be worked out. Though it is expected to be with in a narrow range of HSD, the duty structure will have to be so designed that the price of Biodiesel is slightly lower than that of the HSD. Every country which has promoted the use of biodiesel has followed this route in order to make biodiesel compete with diesel. However, macro-economics studies have proved that direct and indirect impact of biodiesel e.g. employment generation, balance of trade, emission benefits etc are substantial and need to be accounted for while considering the duty structure on Biodiesel and HSD.

3.15 Conclusion

It is clear by now that for us blending of Bio-diesel produced from non-edible vegetable oil with conventional diesel i.e. H.S.D. is unavoidable to achieve the objectives of emission standards, regeneration of degraded lands, poverty alleviation, employment generation, better use of natural resources etc. A National Mission is, therefore, proposed to be launched. The potential, viability and details of the National Mission are discussed hereafter.

CHAPTER 4

Environmental & Legal Issues

4.1. Effects on environment and human health - Biodiesel:

Biodiesel (mono alkyl esters) is a cleaner-burning diesel fuel made from renewable sources such as vegetable oils. Just like petroleum diesel, biodiesel operates in combustion-ignition engines. The use of biodiesel in a conventional diesel engine results in substantial reduction of unburned hydrocarbons, carbon monoxide and particulate matter. However, Emissions of nitrogen dioxides are either slightly reduced or slightly increased depending on the duty cycle and testing methods. The use of biodiesel decreases the solid carbon fraction of particulate matter (since the oxygen in biodiesel enables more complete combustion to CO2), eliminates the sulphur fraction (as there is no sulphur in the fuel), while the soluble or hydrogen fraction stays the same or is increased. Therefore, biodiesel works well with new technologies such as oxidation catalysts.

As per U.S.EPA biodiesel has been comprehensively evaluated in terms of emissions and potential health effects under the Clean Air Act Section 211(b). These programmes include stringent emissions testing protocols required by EPA for certification of fuels in the U.S. The data gathered through these tests include thorough inventory of the environmental and human health effects attributes that current technology will allow. The results of the emissions tests for pure biodiesel (B100) and mixed biodiesel (B20-20% biodiesel and 80% petrodiesel) compared to conventional diesel are given in Tables -4.1 & 4.2.

Table-4.1: Biodiesel Emissions Compared to Conventional Diesel

Emissions	B100	B20
Regulated Emissions		
Total Unburned Hydrocarbons	-93%	-30%
Carbon Monoxide	-50%	-20%
Particulate Matter	-30%	-22%
Nox	+13%	+2%
Non-Regulated Emissions		
Sulphates	-100%	-20%*
Polyciclic Aromatic Hydrocarbons (PAH)**	-80%	-13%
NPAH (Nitrated PAHs)**	-90%	-50%***
Ozone Potential of Speciated HC	-50%	-10%
Life-Cycle Emissions		
Carbon Dioxide (LCA)	-80%	
Sulphur Dioxide (LCA)	-100%	

***Estimated from B100 results. **Average reduction across all compounds measured. ***2-nitroflourine results were within test method variability.**

Table - 4.2:Emission results of Biodiesel and blends tests on IDI diesel engine

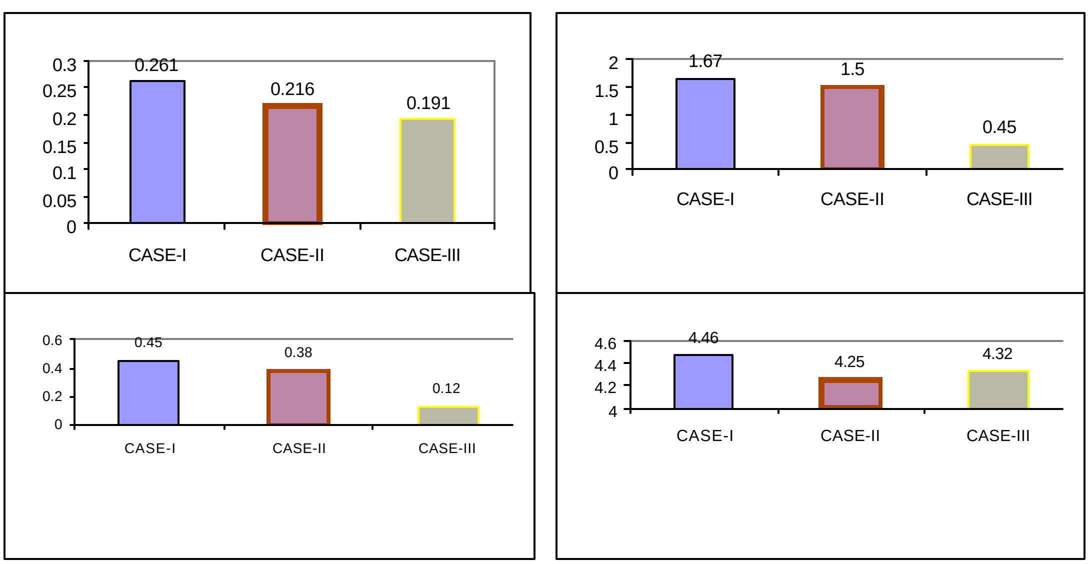
Test Cycle : EEC+EUDC 90 kmph Cold Start.

	All in g/km				
	CO	HC	NOX	HC+NOX	PM
BS-II Limit	**1.5**			**1.2**	**0.17**
Base Line	0.77	0.37	0.79	1.16	0.129
With 10 % Blend	0.65	0.22	0.83	1.04	0.093
With 15 % Blend	0.62	0.16	0.89	1.05	0.080
% Improvement with respect to the base line					
10 % Blend	15%	41 %	-4 %	10%	28%
15 % Blend	20%	50%	-12%	10%	38 %

(Source: Mahindra & Mahindra)

The life-cycle production and use of biodiesel produces approximately 80% less carbon dioxide and almost 100% less sulphur dioxide compared to conventional diesel. Comparative emissions of petrodiesel, biodiesel and biodiesel blends are shown in Figure-1.

Fig 4.1Comparative Emissions from petrodiesel & biodiesel



CASE-I: Petrodiesel with o.o5% sulphur. CASE-II: 20% biodiesel with 3-degree injection timing adjustment. CASE-III: CASE-II + Catalytic Converter

Biodiesel emissions are nontoxic. From Table-1 it is clear that biodiesel gives a distinct emission benefit almost for all regulated and non-regulated pollutants when compared to conventional diesel fuel but emissions of NOx appear to increase from biodiesel. NOx increases with the increase in concentration of biodiesel in the mixture of biodiesel and petrodiesel. This increase in NOx emissions may be neutralized by the efficient use of Nox control technologies, which fits better with almost nil sulphur biodiesel then conventional diesel containing sulphur. It may also be noted that emission of NOx also varies with the different family of feedstocks for biodiesel. Moreover, the problem of increased NOx emission can be effectively tackled by retarding the fuel injection timing.

4.1.1. Comparison of particulate composition-Diesel Vs. Biodiesel (Rapeseed Methyl Easters, RSME):

When the engine is operated on RSME, soot emissions (insolubles) are dramatically reduced, but the proportion of emissions composed of fuel derived hydrocarbons (fuel solubles), condensed on the soot, is much higher. This implies that the RSME may not burn to completion as readily as diesel fuel. It should, however, be noted that gaseous HC emissions were reduced with RSME in the above tests. Since concern over particulates arises partly from the potential harmful effects of the soluble fraction, it might be suspected that emissions from RSME would be more harmful however data shows no tendency for the mutagenicity of exhaust gas to increase for a vehicle running on 20% RSME and 80% diesel blends.

Test	Fuel	Total PM (g/mile)	Insolubles (g/mile)	Fuel Solubles (g/mile)	Lube Solubles (g/mile)	Soluble Inorganic Fraction %
Cold FTP Difference %	Diesel RSME	0.311 0.258 -17%	0.259 0.118 -54%	0.021 0.104 +491%	0.031 0.036 +16%	17 54 +318%
Hot FTP Difference %	Diesel RSME	0.239 0.190 -21%	0.206 0.101 -51%	0.012 0.068 +567	0.021 0.021 0%	14 47 +335

4.1.2. Toxicity issues:

Biodiesel does not present any problems of toxicity as discussed below:

- Biodiesel is non-toxic. The acute oral LD50 (lethal dose) is greater than 17.4-g/Kg-body weight.

- Very mild human skin irritation. It is less than the irritation produced by 4% soap and water solution.
- It is bio-degradable.
- There is no tendency for the mutagenicity of exhaust gas to increase for a vehicle running on biodiesel (20%RSME80% diesel).

4.1.3. Indian Initiative on Biodiesel:

During 1995, CPCB had interactions with one of the biodiesel expert company of USA called Twin Rivers Technologies for examining the efficacy of biodiesel blends in reducing emissions from diesel vehicles. The task of conducting the tests was lined up with IOC (R&D) and sample of biodiesel was imported from USA for the tests. However, this initiative did not materialize at the end.

In recent years trials on automobiles using biodiesel have been conducted by institutes like IOC (R&D), SIAM, IIT, Delhi, ICAR etc. IOC (R&D) has already set up a biodiesel production facility of 60 kg/day at Faridabad. Mahindra & Mahindra Ltd. has a pilot plant utilizing Karanj for biodiesel in Mumbai. This plant has carried out successful trails on tractors using this fuel. Parameters such as power, torque, fuel consumption, emissions, etc. have been found quite satisfactory on tractors operating on this biodiesel. Field trials for about 30000 kms have also been carried out on the tractors. Production of biodiesel unlike petrodiesel, is relatively a less cumbersome process and therefore large scale production can be undertaken with a short lead time. In India most of the trials were done using biodiesel from feedstock like Karanj and Jatropha. Biodiesel from different feedstocks, even though meeting ASTM standards, may vary in composition, lubricity, oxidation stability, etc. It is desirable to carry out tests on biodiesel from all possible feedstocks available in India and generate comparative data on fuel composition.

4.1.4. Safety & Environmental Regulations of other countries:

Biodiesel is considered a safer fuel. Biodiesel has a flash point of about 300 F well above conventional diesel fuel. The National Institute for Occupational Safety and Health (NIOSH), USA lists its aquatic toxicity as “insignificant” in its Registry of the Toxic Effects of Chemical Substances. EPA rates biodiesel to have the same safety concerns to that associated with conventional fuels. This product (biodiesel) is not “hazardous” under the criteria of the Federal OSHA Hazard Communication Standard 29 CFR 1910.1200. As per the California Proposition 65- this product contains no chemicals known to the state of California to cause cancer. This fuel is registered under Fuel and Fuel additives at 40 CFR79 of US-EPA.

4.2. Effects on environment and human health - Ethanol:

Ethanol (ethyl alcohol, grain alcohol, EtOH) is a clear, colourless liquid with a characteristic, agreeable odor. In dilute aqueous solution, it has a somewhat sweet flavour, but in more concentrated solutions it has a burning taste. Ethanol (CH_3CH_2OH) is a group of chemical compounds whose molecule contains a hydroxyl group, -OH, bonded to a carbon atom. Ethanol made from cellulosic biomass materials instead of traditional feedstocks (starch crops) is called **bio-ethanol**.

Government of India has taken a decision to introduce petrol blended with ethanol for 5% use in motor vehicles all over the country in a phased manner. In the first phase, the 5% ethanol blended petrol will be introduced in the States of Andhra Pradesh, Gujarat, Haryana, Karnataka, Maharastra, Punjab, Tamil Nadu and Uttar Pradesh. Rest of the States/Union Territories will be taken up in the second phase.

4.2.1. Studies in India:

In the year 1980, IIP and IOC, R&D conducted a study with ethanol as the fuel in some 13-passenger cars including army vehicles. The test included city driving, highway driving and hill driving conditions. Some of the findings of this study are:

- Loss in volumetric fuel economy of 1% and 3.9% with E10 and E20 fuels respectively under city driving conditions and 3.5% and 4.3% under highway driving conditions.
- Improvement in fuel economy in Ambassador and standard cars under hill driving conditions ranged from 4% to 13%.
- Cold starting at ambient temperatures from 0 deg C to 30 deg C remained unaffected.
- Hot startability and driveability demerits found higher with ethanol blends.
- No compatibility problems observed with metallic and non-metallic components.

Oil companies have also taken up 3 pilot projects (2 in Maharastra at Miraj and Manmad and 1 in UP at Bareilly) for blending and trial marketing of 5% ethanol in petrol which have been completed successfully except few minor problems reported in some 2-wheelers. The pilot project will now be conducted with 10% ethanol in petrol. The current BIS standard allow only 5% ethanol in petrol which requires change in specification for allowing use of 10% ethanol in petrol.

Most of the field trials in India with fuel ethanol were conducted with old vehicles. Studies on new vehicles are required to be done to see the material compatibility, range, drivability and emission benefits in Indian conditions.

4.2.2. Emission Results:

A recent Australian study with E10 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

Recent Australian life-cycle analysis work has revealed that E10 blends are considered greenhouse neutral. The same study revealed that E10 decreased tail pipe emissions of hydrocarbons and NOx (25% and 15% respectively), but particulates (PM10) remained unchanged.

4.2.3. Emissions outcomes for higher ethanol/petrol blends:

In 1995, the US EPA assessed various ethanol/petrol blends and their effects on exhaust emissions. The tests, performed at US EPA's national vehicles and fuel laboratories, looked at emissions resulting from nine ethanol blends from 10% to 40% ethanol. Six 1990 or later model, in-use vehicles were tested on a baseline petrol. No modifications were made to the vehicles.

The study indicates that, for the majority of the vehicles, total hydrocarbons and carbon monoxide emissions, as well as fuel economy decreased, while NOx and acetaldehyde emissions increased as the ethanol content in the test fuel increased. Formaldehyde and vehicle exhaust CO2 were largely unaffected. Most of the emission responses to increasing ethanol concentrations were approximately linear- as the ethanol content increased; the emission reduction or increase became larger.

Hydrocarbon emissions decreased with higher blends:

- at 10% ethanol, HC emissions decreased by about 18%.
- at 20%, HC emissions decreased by about 22%.
- at 40%, HC emissions decreased by 45%.
-

CO emissions were lowered by higher blends:

- at 10%, CO reduced by about 18%.
- at 25%, CO reduced by over 30%.
- at 40%, CO reduced by over 40%.
-

NOx emissions increased with higher ethanol volume:

- at 10%, NOx emission increase was about 10%.
- at 20%, NOx emission increase was about 14%.
- at 40%, NOx emission increase was about 20%.
-

CO2 emissions initially increased at ethanol volumes from 10% to 20%. At about 25% blends, CO2 emissions decreased by about 2%.
Formaldehyde emissions increased slightly with ethanol content, especially at volumes of greater than 30%. Acetaldehyde emissions increased significantly with the addition of ethanol At 35% the increase was about 400%.

4.2.4. Toxicity issues:

Spills of ethanol blends may result in more persistent BTEX (benzene, toluene, ethylebenzene and xylene) plumes in groundwater. There are three properties of ethanol blends of potential concern: co-solvency effect that makes other petroleum constituents more soluble in groundwater, depletion of oxygen and other nutrients in groundwater due to rapid biodegradation of ethanol that inhibits the degradation of other more toxic components in petrol, and a surface tension effect that takes place when ethanol, in contact with a layer of gasoline on top of the water table, causes greater lateral spreading of the petrol. Studies suggested that ethanol blends can cause the toxic BTEX compounds of petrol to travel up to 2.5 times farther than in absence of ethanol.

4.3. Greenhouse gas emissions from Biodiesel & Ethanol (Well-to-Wheels):

Life-cycle analysis for various fuels as shown in Figure-2 shows that biodiesel (RSME) has the lowest Greenhouse emissions followed by ethanol from wood. Gasoline gives the highest greenhouse gas emissions. Emissions from CNG, diesel, water-diesel emulsified fuel and ethanol from corn are comparable.

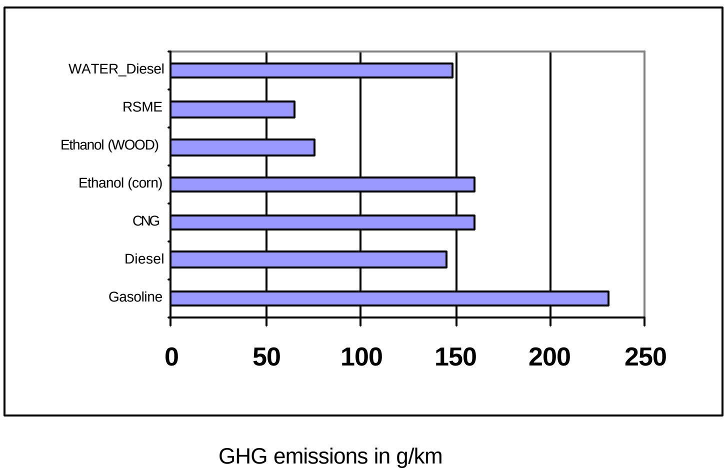


Figure 2 Green House Gas Emissions From Various Sources

4.4. Alcohol Diesel Blends (Ethanol-Diesel):

Apart from ethanol-gasoline blends, ethanol-diesel blend is also another alternative option. Ethanol-diesel blend projects are under trial in Brazil and Sweden. Unlike ethanol-gasoline blend, ethanol-diesel blend has some concerns regarding lubricity, reduced flash point and startability problems.

4.4.1. International Experience:

Several technologies are currently under trials in different parts of the world. An Australian non-profit organization APACE has developed a ethanol-diesel emulsion agent which is under trial in Australia. Thailand, Chile, Malawi, Germany and Sweden. This diesohol technology claims successful blends up to 15% of ethanol in diesel.

APACE claims that this emulsion, which allows use of hydrated ethanol with diesel, gives improvements in NOx, PM including PM2.5, hydrocarbons and also increases the thermal efficiency of the engine. Vehicles can use diesohol and diesel fuels interchangeably. The fire point of diesohol is higher than flash point and the magnitude of the difference depends upon the composition of the diesel fuel. Australian Government is currently in the process of developing fuel quality and operability standards for dieshol. There are several issues that need to be resolved before diesohol can be introduced commercially, some of the important issues are:

- Vapour lock-use of ethanol changes the vapour lock characteristics of the fuel.
- Material compatibility of pump seals, timing belts and some nitirle rubber seals used in the fuel injection systems of a vehicle is still a concern.
- Toxicity of the emulsifier.
- Dosage quantities of the emulsifier which may vary from base fuel to base fuel.
- Blend stability, especially at low temperature.
- Establishment of diesohol test standards.
- Stability under water addition.

As on date BIS specification does not permit blending of ethanol and diesel. Sufficient field trials in Indian conditions need to be carried out and its benefits on emissions, material compatibility and drivability, etc. may be assessed before trying this fuel in India.

4.5. **Recommendations:**

1. Ethanol/Bio-ethanol may be used as blends in gasoline. Recently, 5% blend of ethanol-gasoline has been introduced in some states of India. As more indigenous ethanol is available, blends of 10% and more, may be considered. In the mean time, evaluation may be carried out by field trials.
2. Due to lack of data and field trials, blending of ethanol in diesel may be taken up only after the problems encountered are solved.
3. Biodiesel from different feedstocks may vary in composition, lubricity, oxidation stability, etc. It is desirable to carry out tests on biodiesel from all possible feedstocks available in India and generate comparative data on fuel composition emissions and materials compatibility, etc.
4. Fuel Standards and test methods for biodiesel should be developed for India. Specifications of the fuel should be the same for both blends and pure form and should necessarily be neutral to various feedstocks.
5. Oxidation stability of biodiesel from different feedstocks in India should be assessed through scientific studies.
6. Toxicological study is a pre-requisite for introduction of any fuel. It is recommended that such studies in India should be initiated through concerned R&D centers.
7. Procedure for detecting percentage of biodiesel in the blended fuel and to check adulteration of the fuel should be developed.

8. Emission norms for biodiesel vehicles may be similar to that of the conventional diesel vehicles.

4.6. **Legal Issues**

Legal provisions are required to give effect to the government's policy. A sound legal frame work presumes the existence of necessary infrastructure in respect of biofuels and their uses. Biofuels is a generic term and includes a large number of fuels. We are, however, concerned, at the present moment, with biofuels that will be used in the transport sector being substitutes of motor spirit or gasoline and diesel. Since a beginning is being made, it is only natural that as more experience of mroducing and using the biofuels is gained, these provisions will have to be refined from time to time.

The subject matter can be approached from two possible approaches, viz. one, the minimalist approach and the comprehensive approach. A comprehensive legislation will deal with too many issues which are in the process of evolution and may prove counterproductive through imposing too many restrictions impeding the development and use of biofuels. Legal regulations employing the minimalist approach use broad and enabling language, providing for necessary accommodation for future developments facilitating use of biofuels through recognition and removal of legal barriers. Hence the attempt will be to lay down a basic framework for development and use by amending the present laws without enacting a separate law on the subject. However, reference in this regard may be made to Canadian Alternative Fuels Act, 1995 a copy of which is at Annexure III.

The subjects needing to be brought with in the ambit of law are discussed below

4.7. **Definition of Bio-fuels.**

The term 'Bio-fuels' needs to be suitably defined under section 19 of the Standards of Weights and Measures Act, 1976 so as to avoid any ambiguity in this regard. Further, the term should be so defined so as to provide for necessary adjustments in its contents in respect of technological developments. Bio-fuels are alternative to conventional fuels and as such may be viewed as alternative fuels which term has been defined in Canadian Alternative Fuels Act, 1995 as follow:

"alternative fuel" means any fuel that is

(a) for use in motor vehicles to deliver direct propulsion.
(b) Less damaging to the environment than conventional fuels, and
(c) Prescribed by regulation, including, without limiting the generality of the foregoing, ethanol, methanol, propane gas, natural gas, hydrogen or electricity when used as a sole source of direct propulsion energy and
(d) Satisfies the specifications that may be prescribed in this behalf.

Alternative fuel shall also mean. “such other fuel as the Central Government may specify, by notification in the Official Gazette.

An alternative formulation to this can be based on the Paper “Perspective of Bio-fuel Development in India by Dr. D. N. Tiwari, Member, Planning Commission & Dr. A. P. Dikshit”. Accordingly, “Bio-fuels” means plant bio mass based fuels that can substitute petroleum based oils as motor / engine fuels and include bio-gas, producer gas, vegetable oils, alcohols, ethers, esters and other chemicals derived from cellulosic bio-mass, such as, herbaceous and woody plants, agricultural and forestry residues and such other fuels as the Central Government may specify by notification in the Official Gazette.

4.8. Amendments in Motor Vehicles Act, 1988 and Rules framed thereunder

Section 110 of the Motor Vehicle Act, 1988 deals with power of Central Government to make rules under the said Act. Accordingly, the Central government may make rules regulating the construction, equipment and maintenance of motor vehicles and trailors with respect to all or any of the matters specified in clauses (a) to (p) of sub-section (1) of section 110. Clause (g) thereof relates to “the emission of smoke, visible vapour, sparks, ashes grift or oil. Clause (m) thereof relates to standards for emission of air pollutants. Clause (n) thereof relates to installation of catalytic converters in the class of vehicles to be prescribed. The Central Government have made necessary rules under the aforesaid provisions in respect of use of Compressed Natural Gas (in short CNG) and Liquefied Petroleum Gas (in short LPG) in automobiles. Similar rules have to be enacted in respect of bio-fuels. The rules made in respect of CNG and LPG are enclosed for reference and are collectively marked as Annexure-I.

Section 52 of the Motor Vehicle Act, 1988 deals with alteration in motor vehicles. The said section, inter alia, provides that modification of the engine or any part thereof, of a vehicle for facilitating its operation by a different type of fuel or source of energy including battery, compressed natural gas, solars power or any other fuel or source of energy other than liquid petroleum gas, will be treated as alteration and will be subject to such conditions as may be prescribed. The Central Government have made rules for safety in respect of CNG and LPG by substituting the section with a new section, a copy of which is enclosed for ready reference and marked as Annexure-II.

4.9. Action under Environment (Protection) Act, 1986.

Section 3 of the Environment (Protection) Act, 1986 confers power on Central Government to take measures to protect environment with respect to all or any of the matters specified in sub-section (2) of the said section. Clauses (3) & (4) of Section 3(2) respectively relates to laying down standards for the quality of environment in its various aspects; and laying down standards for emission or discharge of environmental pollutants from various sources whatsoever:

Provided that different standards for emission or discharge may be laid down, under this clause from different sources having regard to the quality of composition of the emission or discharge of environmental pollutants from such sources.

In exercise of the powers conferred by sections 6 and 25 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government/ Ministry of Environment & Forests may notify the introduction of new fuels like biodiesel/ biodiesel blends/ethanol as automotive fuels.

4.9.1. Action under Air (Protection and Control of Pollution) Act, 1981.

Section 17(1)(G) of the Air (Prevention and Control of Pollution) Act, 1981 empowers State Boards to lay down, in consultation with the Central Board and having regard to the standards for the quality of air laid down by the Central Board, standards for emission of air pollutants into the atmosphere from any other source whatsoever not being a ship or an aircraft.

Section 20 of the said Act provides for instructions to be issued by the State Government for ensuring standards for emission from automobiles. Accordingly, with a view to ensuring that the standards for emission of air pollutants from automobiles laid down buy the State Boards under clause (g) of sub-section (1) of section 17 are complied with, the State Government shall, in consultation with the State Board, give, under section 20 of the Act, such instructions as may be deemed necessary to the concerned authority incharge of registration of motor vehicle under the Motor Vehicle Act and such authority shall notwithstanding anything contained in that Act or the Rules made thereunder be bound to comply with such instructions. It may be mentioned in this regard that in pursuance of clause (1) of section 239 of the constitution, the President has directed that the Lt. Governor of the National Capital Territory of Delhi shall, subject to the control of the President and until further orders also exercise the powers and discharge the functions of the State Government under section 20 of the Act within the said territory. (See S.O.150(E), dated 25th February, 1977 published in the Gazette of India Extraordinary, Part II, Section 3(ii), dated 26th February, 1997).

Care should be taken in this regard to ensure that both the Central and State Governments act in unison, and in consultation with each other. The provisions of section 3 of Environment (Protection) Act, 1986 on the one hand and the provisions of sections 17 & 20 of the Air (Prevention and Control of Pollution) Act, 1986 on the other should be kept in view. Furthermore, necessary rules under the Motor Vehicles Act may have to be made on the lines on which corresponding rules in respect of CNG and LPG have been made earlier.

4.9.2. Provisions for Manufacture, storage and Import:

In exercise of the powers conferred by Section 6, 8 and 25 of the Environment (Protection) Act, 1986 (29 of 1986), the Central Government/Ministry of Environment & Forests may notify and list this fuel under the provisions of the "Manufacture, Storage & Import of Hazardous Chemical Rules, 1989.

4.9.3. Motor Spirit & High Speed Diesel (Regulation of supply & distribution and prevention of malpractices) Order, 1998:

In exercise to the powers conferred by Section-3 of the Essential Commodities Act, 1955 (Central Act 10 of 1955), the Central Government/MoP&NG may notify this fuel under the provisions of the "Motor Spirit & High Speed Diesel (Regulation of supply & distribution and prevention of malpractices) Order, 1998.

4.9.4. Motor vehicles rules, 1989:

In exercise of powers conferred by clause (P) of section 64 read with sub-section (1) od section 52 and section 110 of the Motor Vehicles Act, 1988 (59 of 1988), the central government may amend rule 115 of the central motor vehicle rules 1989 to notify the emission norms for vehicles to run on other fuels like ethanol and biodiesel.

4.9.5. Subsidies, incentives, etc.

Although the European Parliament in February 1994 adopted 90% exemption for Bio-diesel and the combination of legislation supporting the use of alternative fuels, differential tax incentives and oilseed production subsidies, resulted in Bio-diesel being priced competitively with diesel fuel in a number of European countries. Tax incentives take the form of significantly reduced assessments or exemption from taxes normally assessed on diesel fuel. Even recently Parliament in Denmark expressed its support for a lower tax level on Bio-fuels and on certain mineral oils containing Bio-fuels. There is a proposal by European commission according to which Bio-fuel should account for 2% of fuel sold in the Member States by 31st December, 20005 and 5.75% by 2010. However, no minimum percentage of compulsory blended fuel has been insisted upon. There is a strong backing for green fuel source to enable the European Union to fulfill its Kyoto commitments as Member States are bound to put the legislation into force by 31st December, 2004.

However, in India the cost of Bio-fuel is likely to be approximately the same as the cost of conventional petroleum fuel/ diesel and so there may be only marginal need for measures to equalize the cost. But adequate incentive may have to be provided to people to invest in producing Bio fuels and higher returns may have to be ensured. The tax regime in respect of Bio-fuels may, therefore, have to be suitably designed. This may be taken care of through differential Excise-duty and other taxes-Any ubsidies need to be excluded as they would be unsustainable in the present economic policy.

It would be relevant to mention in this regard that any concession which may be provided in this regard must be in conformity with the TRIPS and WTO regimes.

4.9.6. Action under Standards of Weights and Measures Act, 1976

Section 19 of the Standards of Weights and Measures Act, 1976 empowers the Central Government, in relation to any weight or measure, to prescribe physical characteristic, configuration, constructional details, materials, equipment, performance, tolerance methods or procedure of test either in accordance with the recommendations made by the international organization of legal meterology, or as the case may be, on its own as it may think fit. Accordingly, IS 2796 : 2000 has been prescribed in respect of motor gasolines – specifications. As per Clause 4.2 of this IS, organic oxygenates have been permitted and the percentage of their blending has been shown in Table 2 of this IS. Copy of IS 2796: 2000 is at Annexure IV. However, clause 4.2 is reproduced in Annexure – for ready reference.

Similar specifications in respect of Bio fuels may have to be prescribed. Precise contents of these specifications may be worked out by the appropriate authority in consultation with other concerned authorities and technology experts.

Chapter 5

'National Mission On Biodiesel

Introduction

According to the American Heritage Dictionary of the English Language, oil is defined as any of the numerous mineral, vegetable and synthetic substances and animal and vegetable fats that are generally slippery, combustible, viscous, liquid or liquefiable at room temperatures, soluble in various organic solvents such as ether but not in water, and used in a great variety of products, especially lubricants and fuels. Sources of vegetable oil mainly include agriculture and forestry. Among the non-edible crops, Jatropha is pioneer to green wastelands and marginal areas.

As one of the most important oilseed grower, producer, importer and exporter, India is one of the four major players in the vegetable oil scenario of the world. Vegetable oil scenario is complex and is highly influenced by market sources, conflicting interests, policies of the government, income of the consumers, demands of industry, economies of production, correction and processing vagaries of weather, technology and various biotic and abiotic problems.

For mitigating climate change by reducing emission of green house gases, meeting rural energy needs, protecting the environment and generating gainful employment, *Jatropha curcas* has multiple role to play. All attempts to increase its production and productivity, oil extraction by application of appropriate technology, product development and diversification and policies that will protect and promote national interest would be welcome.

The technology mission on oilseeds initiated in 1986 showed the way to meet different challenges and complexities in the oilseed sector. For development of non-edible oil sector the situation demands both short and long range well coordinated planning, vision and execution at all levels. It is proposed to start a "National Mission on Biodiesel" with the needed zeal, vision, direction, appropriate technology, policy support and financial inputs.

Undertaking plantation of *Jatropha curcas* and collection of seed, processing of seeds for producing oil, processing it in to biodiesel will achieve the objectives mentioned above. In addition, the oil cake is rich in nutrients and will give us bio-gas and very good compost for our soils which are getting increasingly deficient in carbon and nutrients. Every component of the programme will generate massive employment for the poor belonging to the Scheduled Tribes, Scheduled castes and other under privileged categories living mostly in backward areas which have experienced the adverse impact of forest degradation, and loss of natural resources.

5.1 Issues Involved in the Mission:

5.1.1 Oil Bearing Trees – Selection of *Jatropha curcas*

There are many tree species which bear seeds rich in oil having properties of an excellent fuel and which can be processed into a diesel-substitute. Of these some promising tree species have been evaluated and it has been found that there are a number of them such as *Pongamia pinnata* ('Honge' or 'Karanja') and *Jatropha curcas* (Ratanjyot) which would be very suitable in our conditions: However, to start the programme, the advantage is clearly in favour of Jatropha due to the following reasons:-

- Oil yield per hectare is among the highest of tree borne oil seeds **(Refer Annexure IV)**
- It can be grown in areas of low rainfall (200 mm per year) and in problematical soils. In high rainfall and irrigated areas too it can be grown with much higher yields. Therefore, it can be grown in most parts of the country.
- Jatropha is easy to establish, grows relatively quickly and is hardy.
- Jatropha lends itself to plantation with advantage on lands developed on watershed basis and on low fertility marginal, degraded, fallow, waste and other lands such as along the canals, roads railway tracks, on borders of farmers' fields as a boundary fence or live hedge in the arid/semi-arid areas and even on alkaline soils. As such it can be used to reclaim waste lands in the forests and outside.
- Jatropha seeds are easy to collect as they are ready to be plucked before the rainy season and as the plants are not very tall.
- Jatropha is not browsed by animals.
- Being rich in nitrogen, the seed cake is an excellent source of plant nutrients.
- Seed production ranges from about 0.4 tons per hectare per year to over 12 t /ha.

The experience in India and elsewhere, a plant density of 2500 per hectare (spacing of 2X2 meters) has been found to be optimal - although in one trial in rainfed areas on poor soils a lower plant density of 1666 has been felt to be more desirable. In suitable plantation Jatropha gives about 2 kgs of seed per tree. In relatively poor soils such as in Kutch (Gujrat) the yields have been reported to be 1 kg per plant while in lateritic soils of Nashik (Maharashtra), the seed yields have been reported between 0.75 kg to 1.00 kg per tree. If planted in hedges, the reported productivity of Jatropha is from 0.8 kg. – 1.0 kg. of seed per meter of live fence This is equivalent to seed production of between 2.25 t/ha and 5 t / ha, depending upon whether the soils are poor or average for plantations and between 2.5 t. /ha. /annum. and 3.5 t. /ha. /annum for hedges. Assuming a square plot, a fence around it will have a length of 400 sq.meters and a production of 0.4 MT of seed. A hedge along one hectare will be equal to 0.1 hectare of block plantation. Assuming oil content of 35% and 94% extraction, one hectare of plantation will give 1.6 MT of oil if the soil is average, 0.75 MT if the soil is lateritic, and 1.0 MT if the soil is of the type found in Kutch (Gujarat). One hectare of plantation on average soil will on an average give 1.6 Metric Tons of oil. Plantation per hectare on poorer soils will give 0.9 MT of oil.

- The plant starts giving seed in a maximum period of two years after planting.

- Raising plants in nurseries, planting and maintaining them and collection of seed are labour intensive activities. Except for the cost of fertiliser and transportation of the plants from the nursery, all the activities in the nurseries and in planting consist of labour. The cost of seed is entirely in the form of wage for labour.
- Various parts of the plant are of medicinal value, its bark contains tannin, the flowers attract bees and thus the plant has honey production potential.
- Like all trees, Jatropha removes carbon from the atmosphere, stores it in the woody tissues and assists in the build up of soil carbon. It is thus environment friendly.
- Jatropha can be established from seed, seedlings and vegetatively from cuttings. Use of branch cutting for propagation is easy and results in rapid growth;
- The plant can be expected to start bearing fruit within two years.
- The plant is undemanding in soil type and does not require tillage.
- It can meet a number of objectives such as meeting domestic needs of energy services including cooking and lighting; as an additional source of household income and employment through markets for fuel, fertilizer, animal feed medicine, and industrial raw material for soap, cosmetics, etc. in creating environmental benefits – protection of crops or pasture lands, or as a hedge for erosion control, or as a windbreak and a source of organic manure.

5.1.2 Types of Lands where It can Grow With advantage and Potential of Plantation

The list of advantages mentioned above make Jatropha plantation very attractive on the kinds of lands mentioned below. The potential for coverage of each kind of land is also discussed.

- Forests cover 69 Million hectares of which38 million hectare is dense forest and 31 million hectare is understocked. Of this 14 million hectares of forests are under the Joint Forestry Management. About 3.0 million hectare (notional) of land in forests should easily come under *Jatropha curcas* plantation.
- 142 million hectare of land is under agriculture. It will be reasonable to assume that farmers will like to put a hedge around 30 million hectare of their fields for protection of their crops. It will amount to 3.0 million hectare (notional) of *Jatropha curcas* plantation.
- The cultivators are expected to adopt it by way of agro-forestry. Considerable land is held by absentee land lords who will be attracted to *Jatropha curcas* as it does not require looking after and gives a net income of Rs 15000 per hectare. Two Million Hectare of notional plantation is expected.
- Culturable fallow lands are reported to be 24 million hectare of which current fallow lands are 10 million ha and other fallows are 14 million hectares. Ten

percent of such land (2.4 million hectare) is expected to come under *Jatropha curcas* plantation

- On wastelands under Integrated Watershed Development and other poverty alleviation programmes of Ministry of Rural Development a potential of 2 million hectare of plantation is assessed..
- On vast stretches of public lands along railway tracks, roads and canals. One million hectare of notional coverage with *Jatropha curcas* is a reasonable assessment.

On the basis of above analysis it should be reasonable to assume that with proper extension, research, availability of planting material and funds plantation of *Jatropha curcas* on 13.4 million hectares of land is feasible in the immediate future. Institutional finance for private plantation and governmental allocation for public lands will have to be provided.

Once success is achieved on the lands described above it should be possible to include very low fertility soils which are classified unculturable in this programme. A significant proportion of such lands can also be brought under *Jatropha curcas* plantation in an economically feasible manner. It will result in their (degraded flands) rehabilitation also. Table 5.1 gives the extent of these lands category wise.

Table 5.1

Estimation of Lands For Jatropha curcas plantation (National Mission On Biofuels)

Area in Million Hectare

Land Type	Area	Potential for Jatropha plantation
Under stocked forests	31.0	3.0
Protective hedge around agricultural fields	142.0	3.0
Agro-forestry		2.0
Fallow Lands	24.0	2.4
Land related programmes of Ministry of Rural Development		2.0
Public lands -railway tracks, roads, canals etc.		1.0
TOTAL	197.0	13.4

5.1.3 Promotional Programme in Forest & Non Forest Areas

The programme of promotion of Jatropha planation needs to be taken up in two distinct modes as below:

- Understocked forest lands including areas adjoining them through the JFM Committees and under Social Forestry Programme by Government agencies, and

- Lands outside forest areas - public, community and private - through voluntary organisations and government agencies making use of the programmes of NOVOD, CAPART and programmes of the Ministry of Rural Development such as Integrated Wasteland Development Programme (IWDP), Drought Prone Area Programme (DPAP) etc.

5.1.3.1 Plantation Through JFM Committees & Social Forestry Programme

As on 1.12.2001, out of about 31 million ha of understocked forest, 14.25 million ha of forest are being managed and protected by 63,000 JFM Committees. In the areas, both in the Forest and outside, which are covered or are proposed to be brought under the JFM scheme, the activities of plantation, maintenance and seed collection will be taken up by the JFM Committees with the active help of the Forest Department. In the areas where the Department of Social Forestry of the State Government is active, the programme will be taken up on public lands including wastelands and along railway track, roads and canals by them. They may also promote the programme on private lands including the field boundaries where the plant provides excellent fence. Consultations with the State Governments revealed that against an estimated potential of 3.0 million hectare, immediately it is feasible to bring 2 million hectares of land under *Jatropha curcas* through JFM mode details as given in the **Annexure V**.

5.1.3.2 Through Voluntary Organisations:

Potential to promote this programme in 200 districts in 19 states has already been identified on the basis of rural poverty, availability of waste lands and agro-climatic conditions suited for Jatropha cultivation. A list of such districts is at **Annexure VI**. Voluntary Organisations, Cooperatives, Corporate bodies in the private and public sectors, autonomous bodies such as ICAR and ICFRE institutions, State Agriculture Universities and others could be involved in promoting this programme on private land holdings and on non-forest public lands.

5.1.4 Nursery Raising and Plantation

It is proposed to establish nurseries which will supply plants to the beneficiary to ensure success of plantations and quick return. It will also result in seed production at the end of the first year itself. Nurseries will supply seedlings to the farmers in their village. A seedling will start yielding seed after a year of its plantation. It is proposed to plant it at a spacing of 2m X 2m and 2500 plants will be deemed to constitute 1 hectare of Jatropha plantation. Although using a seedling of 4 to 6 months grown in a nursery should not result in the usual rates of mortality of plantations, it will be reasonable to assume that 20% of the plants will need replaced.

A nursery will produce 20 lakh plants a year. Hence over a period of 3 years it will produce 60 lakh plants and will be sufficient to cover 2000 Hectares of plantation. For the non-forest area 1500 nurseries will be required. For the plantation in forest and adjoining areas one thousand nurseries will be established These nurseries will be developed by the Forest Department involving the JFM Committees in an appropriate manner.

5.1.5 Capacity Building:

Training of trainers and of farmers and others who will participate in the programme will be organised using appropriate techniques. Information, education and communication (IEC) will also be undertaken.

5.1.6 Employment Generation & Cost of Plantation:

Sixty two percent of the expenditure on plantation is estimated to be in the form of direct wages for unskilled labour. Of the remaining 38%, considerable proportion will be in the form of wages, but it is difficult to estimate at this stage its magnitude and how much of it will go to the poor. Employment generated will be 311 mandays per hectare of plantation by the time seed production starts. Seed collection is again labour intensive and after the plantation has been established it will need 40 person days of labour per hectare. As such when one hectare of plantation will create employment during the implementation of the project (first three years) of 311 person days and of 40 man days per year on a long term basis. Details of employment generation on various components of plantation activities and expenditure on them are given in **Annexure VII**.

Apart from generation of employment in plantation and seed collection there would be employment generation in storage of seed and oil extraction.

5.1.7 Cost of Plantation:

The cost of plantation has been estimated to be Rs. 30,000 per hectare. inclusive of plantation and maintenance for one year, training, IEC, extension, overheads etc as in **Annexure VII**. It includes elements such as site preparation, digging of pits, fertilizer & manure, cost of plants and planting, irrigation, de-weeding, plant protection, maintenance for one year i.e., the stage up to which it will start seed production etc. The cost of training, awareness generation, monitoring & evaluation is also included..

5.1.8 Food & Non-food components of wages for plantation:

The implementing agencies would be free to pay the wages cash or in combination of cash and food grains. In view of the fact that the programme would be taken up mainly in degraded areas which are short of food it is assumed that 50 % of the wages will be in cash and 50 % in food grains.

5.1.9 Establishment of Seed Procurement cum Oil Extraction Centres:

For the plantation within the jurisdiction of a nursery a seed procurement centre with facility to store the procured seed and an oil extraction plant will be necessary. Assuming 2000 Ha of land to be covered by a nursery, 7500 MT of seed will arrive at the procurement centre and suitable facilities to store the seed and extract oil will need to be created. The cost of setting up a Centre is given in **Annexure VIII**.

Modern oil expellers with a capacity to express about 94 % of oil contained in the seed are available. The traditional oil expellers have very low expression capacity. Hence modern oil expellers are proposed. Looking to the conditions prevalent in areas where Jatropha will be grown, the size of expeller unit should be 1 MT/day (Capital Cost Rs 70,000), 1 MT / hour (Capital Cost Rs. 300,000) and 2 MT /hour (Capital Cost Capital Cost Rs.. 500,000). Depending on the capacity of the plant the cost of expelling oil will be between Re. 0.19 per litre to Re 0.90 per litre of oil. **Annexure IX** gives the details of these estimates.

The agency which will be assigned the responsibility to implement the programme i.e., the JFM Committee assisted by the State Forest Department in the case of degraded forest lands and NGO or other organisation managing the non-forest wasteland are expected to establish seed procurement centres and oil extraction centres themselves or get some other organisation/entrepreneur to set them up so that the seed grown is collected easily. An integrated procurement cum oil extraction centre will employ about 8 persons through out the year, i.e., generate an employment of 8 person years per centre.

The Seed Procurement cum Oil Expelling Centres will be engaged in commercial activity and, therefore, should be able to mobilise the funds required from the financial insititutions. Some share capital subsidy could also be considered. Keeping the cost factor in view, it seems economical to set up an oil expelling unit for all the seed produced in the area served by one nursery, which is estimated to be about 7,500 MT. However, if a JFM Committee or NGO wants to set up smaller capacity oil extraction plants, they are free to do so.

The raw oil extracted from seed can be used for a number of applications such as lighting and heating & softening of hide and even for operating irrigation motors and pumps. The production of cook stoves, lamps and motors to run on this oil will need to be developed. With encouragement from the government it is expected that the private sector will produce such things for sale in the rural market. This oil, therefore, will be offered first to the local community.

The surplus oil passed on by the oil Expelling Centres will need to be processed if it is to be blended with the diesel. But this activity will be a commercial activity which will be supported and encouraged by the Petroleum Companies under the area of responsibility of the Ministry of petroleum. As such, the oil remaining after the requirement of the community has been met will be sold to the agency which sets up the transesterification plant (for making raw oil suitable for blending with diesel).

As discussed above, the oil extraction can be done at the JFM Committee level also but the cost is high. If the seed from 2000 to 3000 Has of plantation can be procured and brought to one place the cost of extraction would be reduced to 25 %. Depending upon the circumstances in a particular area the level at which the Oil Expellers will be installed and their capacities would need to be determined. It is expected that compact area of at-least 2000 hectares of plantation should be available producing 7,500 MT of seed. Hence in most locations oil expeller plant with 1 Ton/hour capacity should meet the purpose. On an average there may be one expeller for the area covered by one nursery. The requirement of Expeller Plants each year are given in the Table giving production of seed and oil year-wise.

The seed collection centre and oil expelling facility is treated as one unit. Its cost is estimated as Rs. 80 lakh per unit. For all the 2500 units, the total cost is estimated as 2000 Crore.

5.1.10 Oil processing (Transesterification):

The viscosity of raw Jatropha oil is very high as compared to that of petroleum diesel and the fatty acids need to be converted to esters through a process known as transesterification.. In a paper presented by J. Connemann and J Fischer at the International Liquid Bio-fuel Congress held in July 1998 at Curitiba, Parana, Brazil, Proctor & Gamble, the largest producers of methyl esters, estimate the conversion cost as US $ 0.60 per US Gallon of oil. European bio-diesel producers have enjoyed much lower conversion cost of US $ 0.30 per US gallon i.e., Rs. 4.00 per litre. the operating cost for a plant with a capacity of 8000 MT per year is reported to be 142 DM / MT(about Rs 3.25 / litre), that of a plant with a capacity of 80000 MT per year as 33 DM/ MT (about Rs 0.75 / litre) and that of a plant with a capacity of 1,25,000 MT per year as 137 DM / MT (Rs. 3.15 / litre). Taking in to consideration the factor of economy, a processing plant with a capacity of 80,000 MT of Jatropha oil should be set up. As the blending of bio-diesel with diesel has to be made by the Petroleum Companies this facility needs to be set up by the oil companies themselves or parties sponsored by them. This will be an additional investment not included in the estimates below. It will be the responsibility of oil companies to either themselves establish the facility or encourage the private entrepreneurs to do so.

Looking to the fact that such a plant will be set up for the first time in the country, the investment required for a 80, 000 MT processing capacity plant may be of the order of Rs. 70-75 Crore and the cost of processing will be Rs.3359 per MT of oil as given in **Annexure X**. However, there will be recovery of glycerol whose value as per the paper referred to above will be about Rs. 2500 per MT of oil processed. In view of the fact that the figures quoted in the research paper are with reference to Rapeseed oil, there may be some uncertainty about the recovery of Glycerol. Even if very conservative view is taken of glycerol recovery (only half of the figure given in the research paper, the cost of transesterification should not exceed Rs. 2.25 per litre of bio-diesel; it is likely to be near Re. 1.00 per litre.

The abstract of cost is given in the table 5.2

Table 5.2

Cost of Bio-Diesel Production

	Rate (Rs. / Kg)	**Quantity (Kg)**	**Cost (Rs.)**
Seed	5.00	3.28	Rs. 16.40
Cost of Collection & Oil Extraction	2.36	1.05	Rs. 2.48
Less Cake Produced	1.00	2.23	-Rs. 2.23
Trans-esterification Cost	6.67	1.00	Rs. 6.67
*Less Cost of Glycerol produced	*40 to 60.0	0.095	- *Rs. 3.8 to - 5.70
Cost of Bio-Diesel per Kg			Rs. 19.52 – 17.62
Cost of Bio Diesel per litre (Sp. Gravity 0.85)			Rs. 16.59 –14.98

* The price of Glycerol is likely to be depressed with processing of such large quantities of oil and consequent production of Glycerol. However, new applications are likely to be found creating additional demand and stabilizing its price.

5.1.11 Requirement of Biodiesel:

Before a programme of Biodiesel production is drawn it is necessary to keep in mind the requirement over time. This has been discussed elsewhere but for ease of reference, the table showing the demand of Biodiesel and the area required to be covered under plantation to meet the demand is given in Table 5.3

Table 5.3

Area Coverage Vs. Blending Requirements

Year	Diesel Demand MMT	Bio-Diesel @ 5% MMT	*Area for 5% Mha	Bio-Diesel @ 10% MMT	*Area for 10% Mha	Bio-Diesel @20% MMT	*Area for 20% Mha
2001-02	39.81	1.99	1.67	3.98	3.34	7.96	6.68
2002-03	42.15	2.11	1.76	4.22	3.52	8.43	7.04
2003-04	44.51	2.23	1.87	4.45	3.74	8.90	7.48
2004-05	46.97	2.35	1.96	4.70	3.92	9.39	7.84
2005-06	49.56	2.48	2.07	4.96	4.14	9.91	8.28
2006-07	52.33	2.62	2.19	5.23	4.38	10.47	8.76
2011-12	66.90	3.35	2.79	6.69	5.58	13.38	11.19

- Area calculated on the basis of plantation density of 2500 per hectare, seed production of 1.5 kg per tree or of 3.75 MT of seed per hectare corresponding to 1.2 MT of oil per hectare of plantation.

5.2 National Mission on Biodiesel

The reasons why a Biodiesel production programme must be taken up immediately in the country have been discussed in detail in Chapter 3 on 'Biodiesel' and have also been mentioned in Chapter 1 'Introduction'. In order to meet the enormous demand of the Biodiesel, it is necessary that the programme is based on the initiative and enterprise of the rural communities, entrepreneurs, oil companies with the State facilitating such involvement and providing key inputs as needed. However, before the mission becomes a mass movement it will be necessary for the Government to demonstrate the viability of the programme with all its linkages in different parts of the country and widely inform and educate the potential participants and stake holders.

It is, therefore, proposed that a 'National Mission on Biodiesel' be launched to produce enough seed for the production of bio-diesel in sufficient quantities to enable its blending with diesel (HSD) to the extent of 20%. While there are a number of non-edible oilseed producing species in India scattered all over the country, the seed collected is being used by the rural communities. It is not available for an organized programme of Biodiesel production. It is clear that any such programme will have to be based on fresh and additional plantation. Jatrophas curcas, for reasons mentioned in paragraph 5.2.1 of this chapter is proposed to be the species based on which we should have the National Mission.As a part of this National Mission it is proposed to take up a Demonstration Projet which will lay the foundation of a self sustaining programme of plantation and non-edible oil transesterification to produce enough Biodiesel so as to meet the blending requirements of 20 % within the stipulated period.The Mission is therefore proposed in two phases.

5.2.1 Phasing

The National Mission is proposed to be implemented in two phases.

5.2.1.1 Phase I Demonstration Project

Phase I will be a Demonstration Project which would seek to demonstrate the viability of all activities including plantation, seed collection, oil extraction, transesterification, blending and marketing, its acceptance as automotive fuel and the institutional arrangements put in place for effective implementation of the various components of the Mission. This will be launched in 2003 and its results should be available by 2007. The Government will play the role of the prime mover and ensure that the necessary resources are arranged for each of the components, the stake holders are fully involved in the project and that all components and activities of the national Mission are properly planned and implemented.

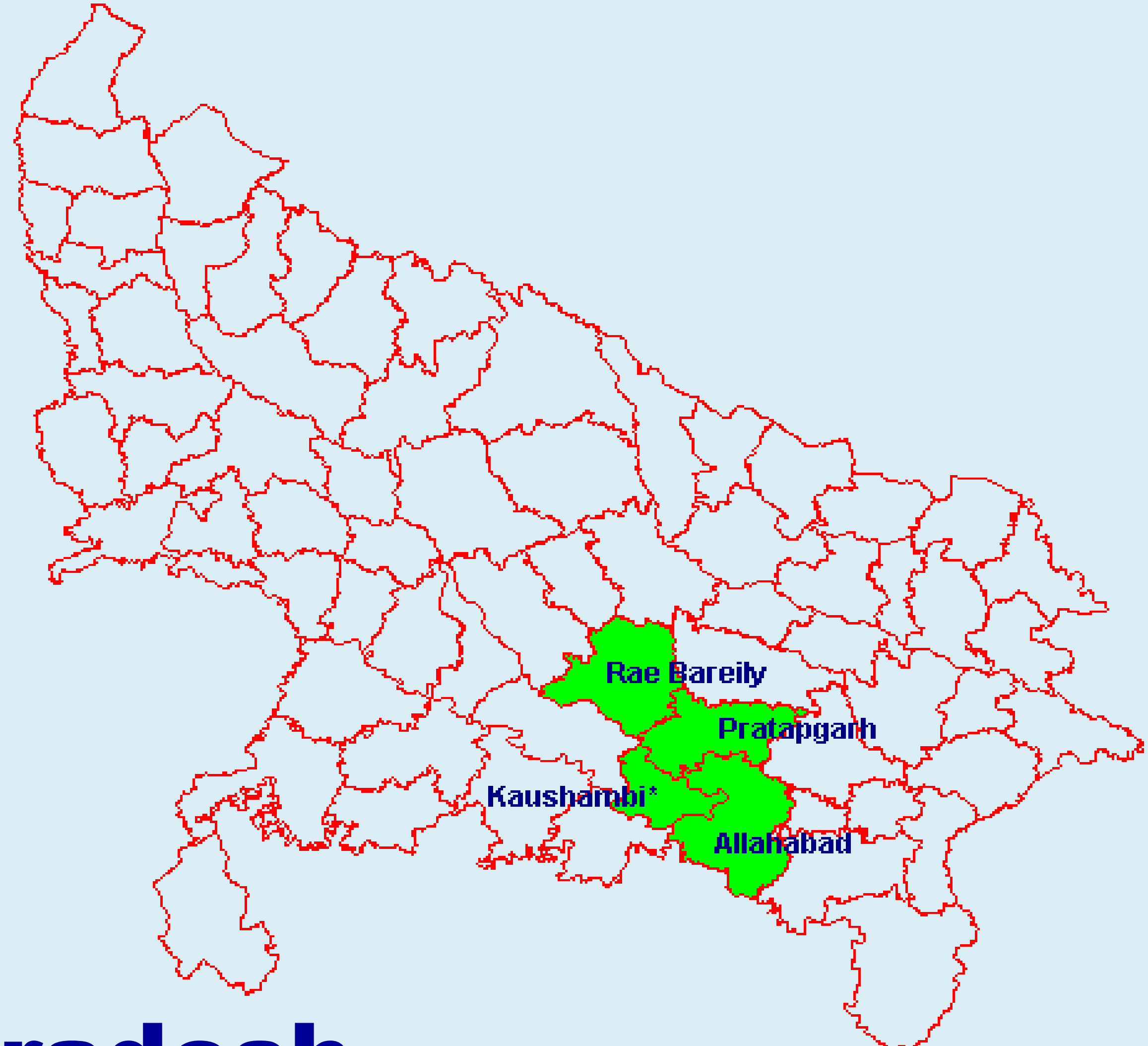
5.2.1.2 Phase II-Self sustaining Expansion of Biodiesel Programme

Phase II of the National Mission will have the objective of producing sufficient vegetable oil based Biodiesel to achieve 20% blending of HSD through accelerating the momentum achieved in the Demonstration Project, converting plantation in to a mass movement and consequent geometrical expansion of plantation and other connected activities all over the country. It will begin in 2007 and will be completed during the XI Plan. The success of the Demonstration Project is expected to galvanise all the stake holders and participants to mobilise resources with the Government playing the role of a facilitator.

5.2.2 Duration of National Mission

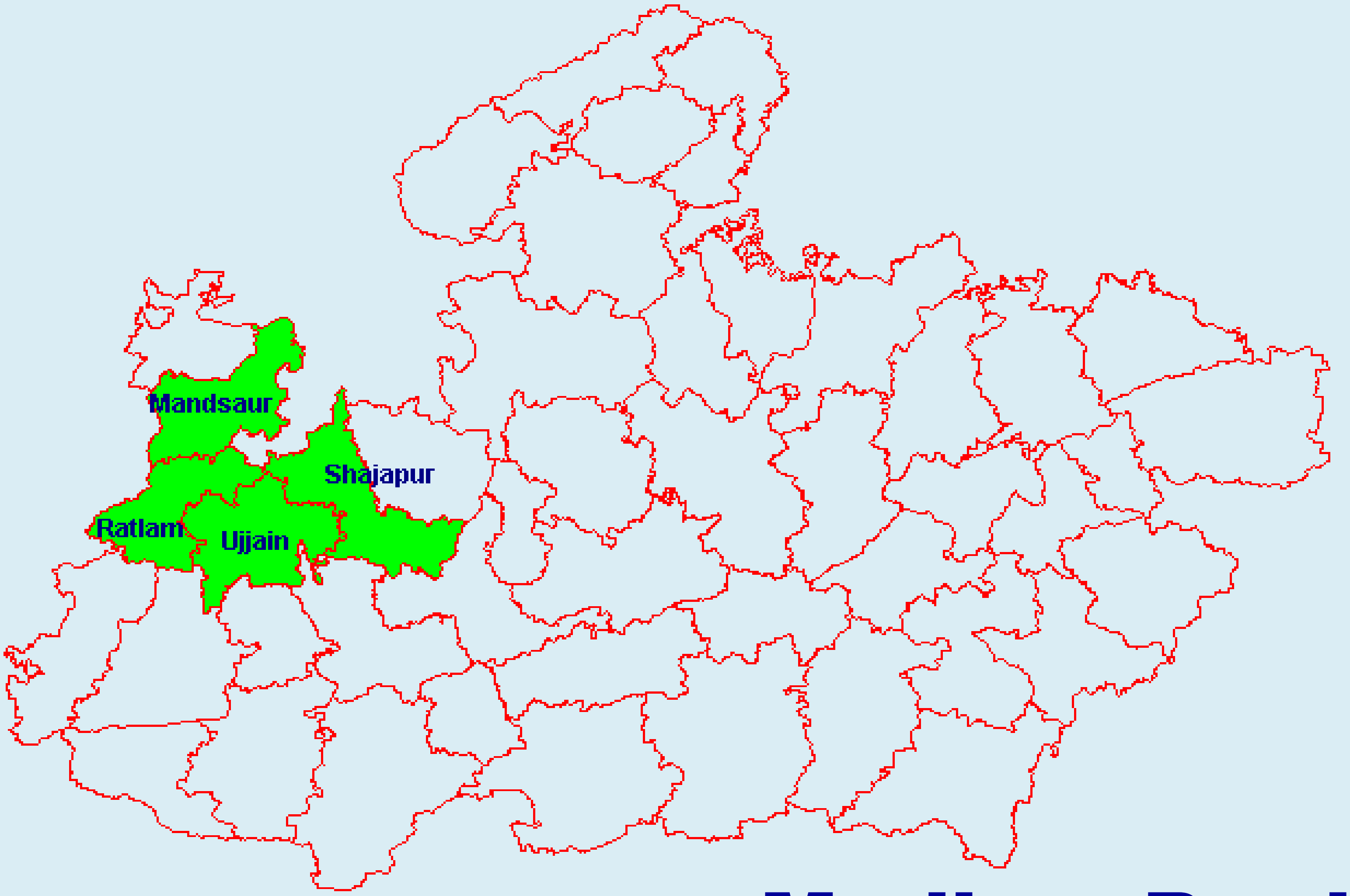
The demonstration project will be initiated in 2003 and completed by 2007 while Phase II will be started in 2007 and completed by 2012.

Plantation of Jatropha



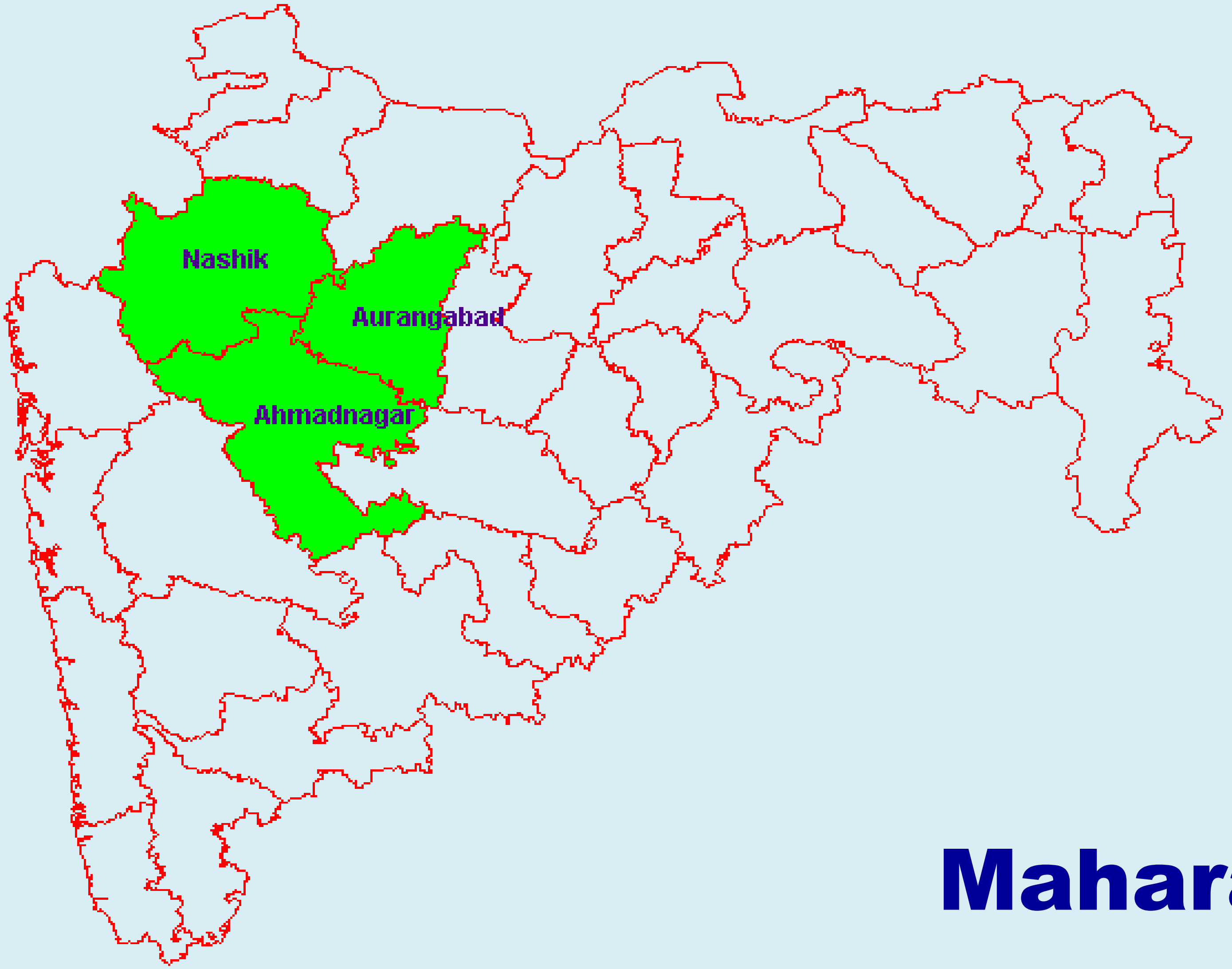
Uttar Pradesh

Plantation of Jatropha



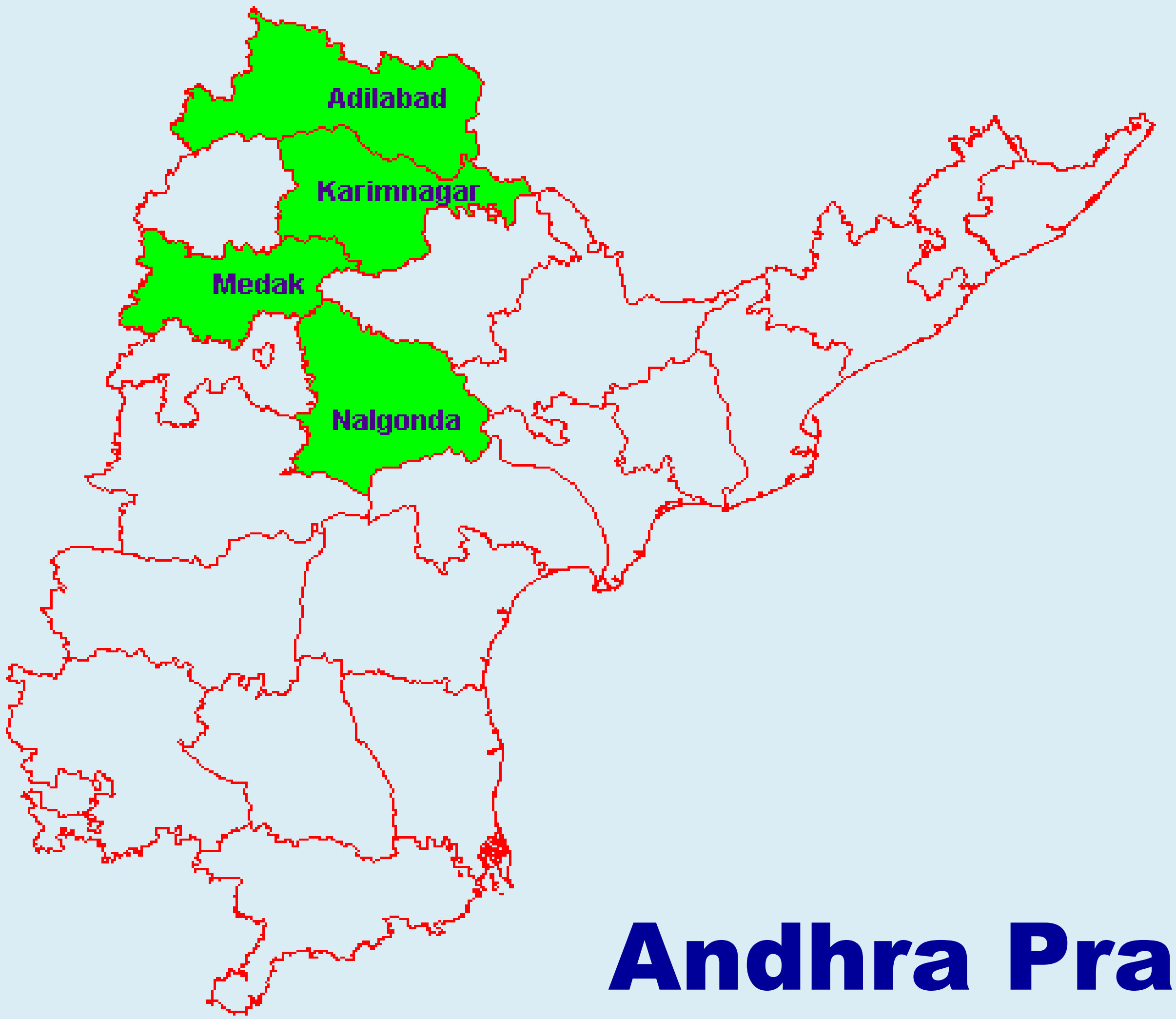
Madhya Pradesh

Plantation of Jatropha



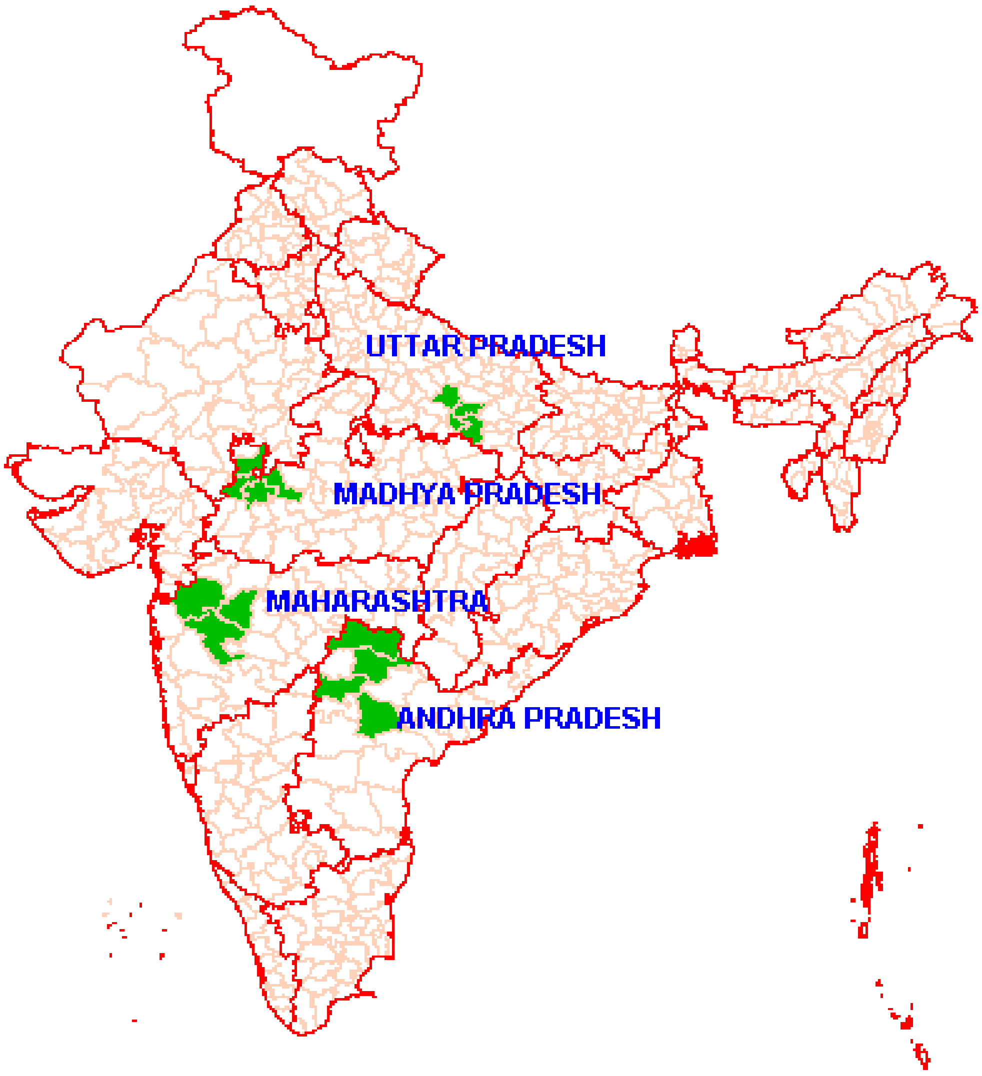
Maharashtra

Plantation of Jatropha



Andhra Pradesh

Plantation of Jatropha



Uttar Pradesh

Allahabad, Kaushambhi, Pratapgarh, Raebareily

Madhya Pradesh

Ujjain, Shajapur, Ratlam and Mandsaur

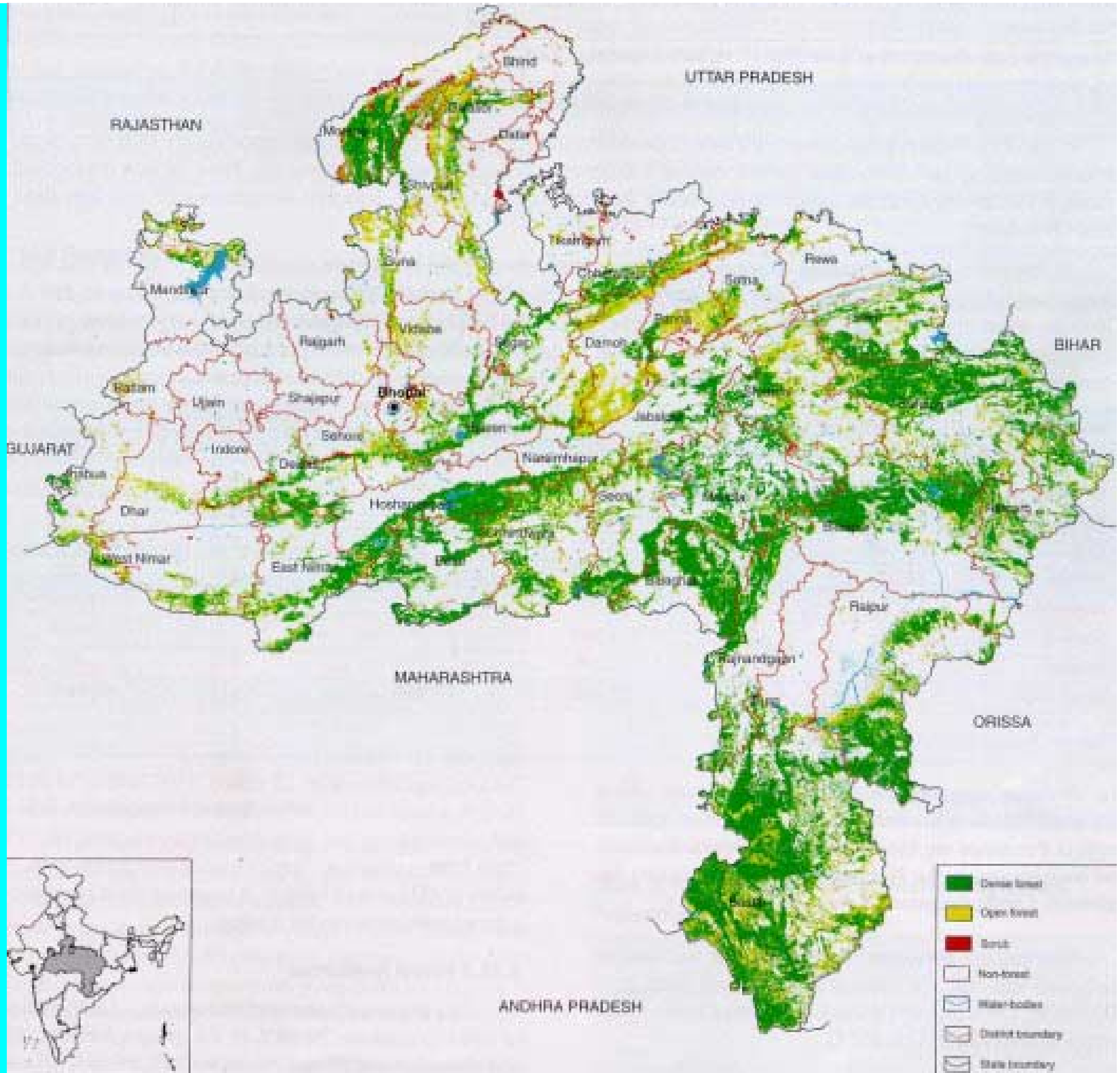
Maharashtra

Nasik, Ahmadnagar, Aaurangabad

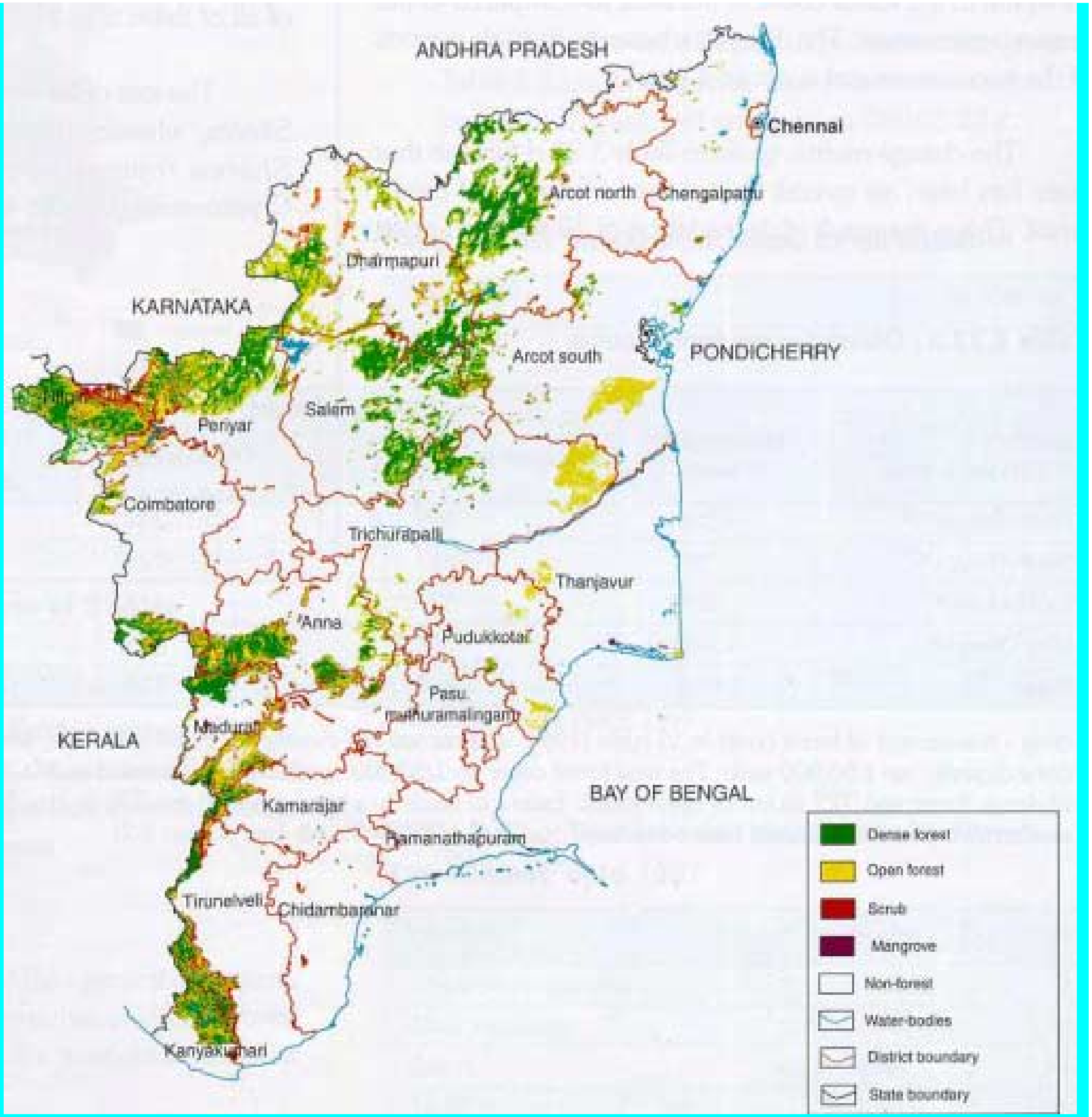
Andhra Pradesh

Adilabad, Karimnagar, Nalgunda, Medak

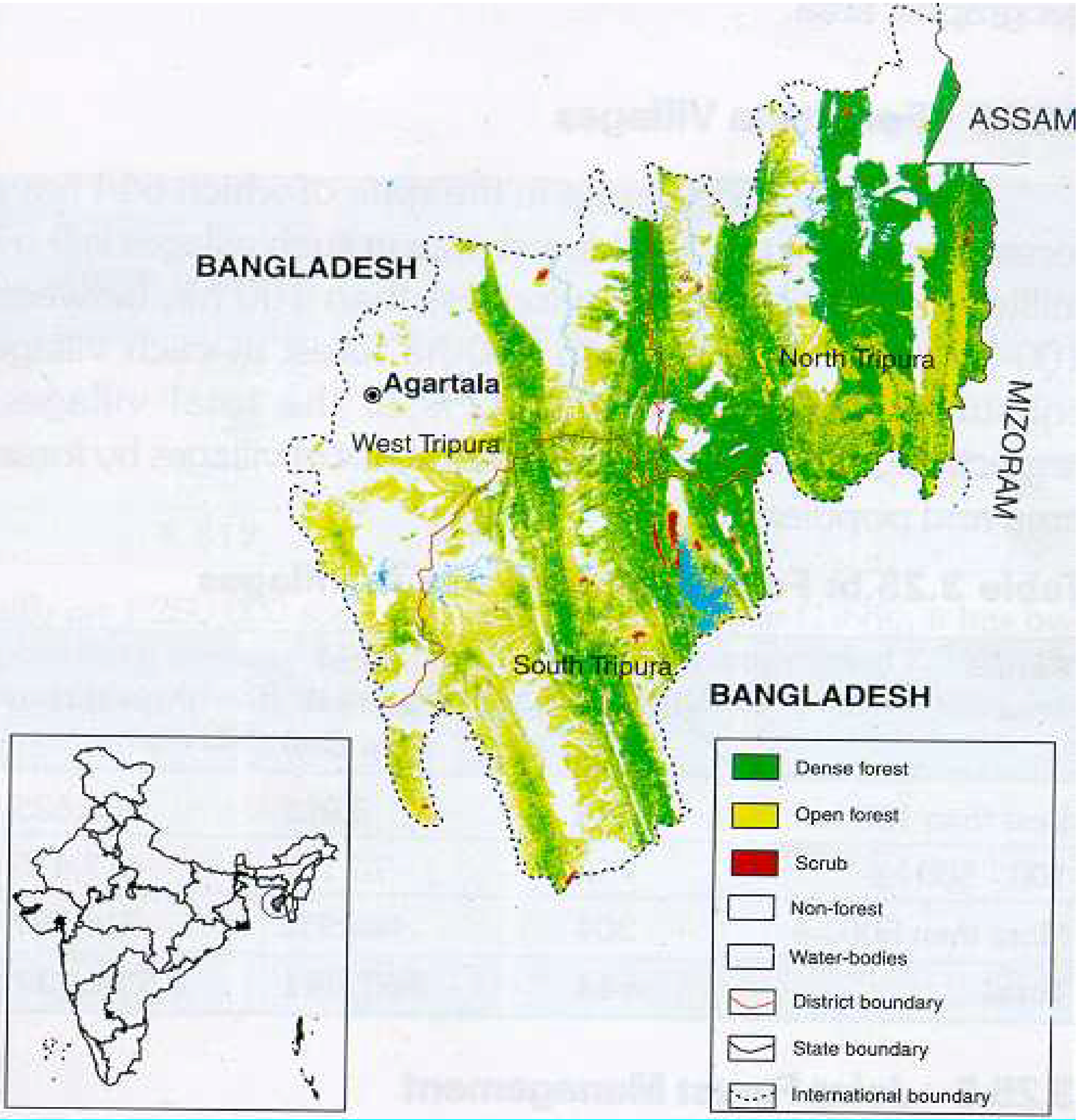
Forest Cover of Chattisgarh State



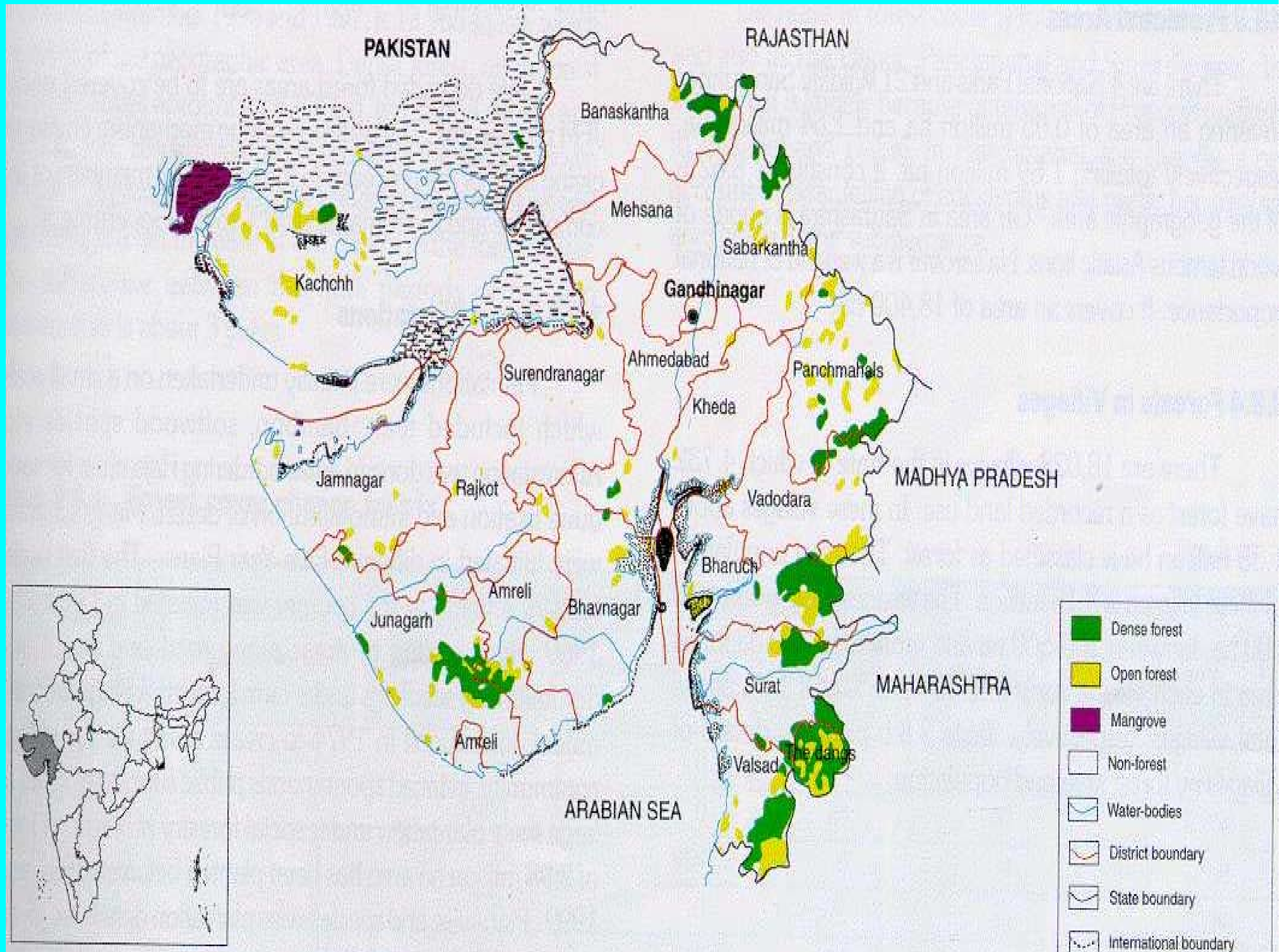
Forest Cover of Tamilnadu State



Forest Cover of Tripura State



Forest Cover of Gujarat State



5.2.3 Components of National Mission

The major activities required to be undertaken have been discussed earlier in this chapter. They are plantation- including raising of nurseries, seed collection and oil expelling centres, transesterification, blending and marketing, Research and Development. Each Component will be planned and implemented through a Micro-mission as explained in paragraph 5.3.5.

5.2.4 Coverage of Area under Demonstration Project of the National Mission:

It will involve plantations on 4 lakh hectares of land in compact groups of districts each having an area of 50000 to 60000 Ha and ensuring setting up of facilities for all the activities involved in forward and backward linkages. A total of eight compact areas are proposed – four for implementation by the JFM Committees and the Forest Department and four by other agencies on non-forest lands. The areas chosen are such as have good potential and would lead to massive dissemination of information, awareness generation and education through visits to actual Jatropha plantations to the maximum number of persons. The size of the compact area selected is such that all the activities can be carried out in a cost effective manner. Experience in Europe has demonstrated that a transesterification plant of an annual capacity of 80,000 to 100,000 tons is economical. This much of oil is expected to be produced from a plantation over an area of 50 to 60 thousand hectares. This area under plantation will cover four districts and will support one unit of transesterification. Similarly four compact areas in forest are proposed to be selected. The Ministry of Environment & Forest will be the nodal ministry for this component and take the work as a Micro-Mission of the National Mission.

These areas are shown in the maps – and are described below:

5.2.5 Micromissions:

The national Mission and its Phase I i.e., the Demonstration Project will consist of a number of micro-missions as below:

5.2.5.1 Micromission on Plantation on Forest Lands

The States proposed for plantation on forest lands are different from the States covered for plantation on non forest land. For this purpose the States selected are Gujarat, Chhattisgarh, Tamilnadu and Tripura. Each State has agreed to take up 50,000 hectares of plantation through the JFM and the Forest Department.

The Ministry of Environment & Forests through the State Forest Departments will implement this plantation through the JFM Committees. The funds would be made available to them under Plan Allocations.

5.2.5.2 Micromission on Plantation on Non-forest Lands

Plantation over non-forest land including marginal lands of farmers, fencing of farmers fields, public lands along roads & highways, canals and railway tracks to be implemented by NGOs, Self-help and User groups, cooperatives, public and private sector corporate and other bodies. NOVOD Board will be the nodal agency providing the necessary help, support and financial and other assistance. The Ministry of Agriculture and Cooperation will have overall responsibility for this micro-mission and NOVOD will be the nodal agency.

- A compact area in four districts around Allahabad in U.P.where Crores of people come on the occasion of Kumbh and other auspicious festivals. There is enough land in these districts where Jatropha plantation would be preferred. These districts are:

Allahabad, Kaushambi, Pratapgarh and Raebareilly

- A compact of area of four districts around Ujjain where again Kumbh melaand other festivals attract crores of villagers. The land in these districts is suitable for Jatropha plantation.

Ujjain, Shajapur, Ratlam and Mandsaur

- Nasik attracts a very large number of persons regularly and in the area around it 50,000 to 60,000 Ha of land suitable for Jatropha can be found. Hence the following districts are proposed:

Nashik, Ahmadnagar, Aaurangabad.

- Some districts which are rainfed and have low rainfall are eminently suited for Jatropha Plantation. Hence a compact area of the following districts in Andhra Pradesh is proposed:

Adilabad, Karimnagar, Nalgunda, Medak.

National Oilseeds & Vegetable Oil Development Board will be the nodal agency and get the programme implemented through the Voluntary Organisations, State Agricultural Universities, KVKs, public undertakings and government departments and ICAR institutions.

5.2.5.3 Micromission on Plantation on Other Lands

The Department of Rural Development, the Department of land Resources and CAPART will be responsible for plantation in degraded and wastelands all over the country in districts outside the districts included in Micromission through the Panchayats and NGOs by using the funds available under IWDP, SGRY and SGSY etc This plantation will be in addition to the 0.4 million hectare of plantation in the first two micromissions.

- The programme elements and objectives of the National Mission are in consonance with the ongoing schemes of the Ministry of Rural Development such as the SGSY, SGRY, IWDP. As such it is proposed that plantation of Jatropha curcas be dovetailed with these programmes and implemented out of the funds available for them. This plantation will not be restricted to the areas mentioned above, will be in addition to the 4 lakh hectares to be covered under the national Mission and shall have coverage all over the country.

- The rural community will have the first right of access to the oil for its use. The surplus oil will be sold to the Units that would established for processing the raw oil in to bio-diesel and blending it with petroleum diesel. The responsibility for ensuring that such facilities are set up will be that of the Ministry of Petroleum.

5.2.5.4 Micromission on Procurement of Seed and Oil Extraction:

KVIC, Small Scale Industries and Rural Agro Industries will have overall responsibility and will be the nodal agency for encouraging and supporting this activity. The finances for this micro-mission will be provided by SIDBI and NABARD. The Seed Procurement cum Oil Expelling Centres will be engaged in commercial activity and, therefore, should be able to mobilise the funds required from the financial insititutions. Some share capital subsidy could also be considered. Keeping the cost factor in view, it seems economical to set up an oil expelling unit for all the seed produced in the area served by one nursery, which is estimated to be about 10,000 MT. However, if a JFM Committee or NGO wants to set up smaller capacity oil extraction plants, they could be free do so.

The raw oil extracted from seed can be used for a number of applications such as lighting and heating & softening of hide and even for operating irrigation motors and pumps. The production of cook stoves, lamps and motors to run on this oil will need to be developed. With encouragement from the government it is expected that the private sector will produce such things for sale in the rural market. This oil, therefore, will be offered first to the local community.

The surplus oil passed on by the oil Expelling Centres will need to be processed if it is to be blended with the diesel. But this activity will be a commercial activity which will be supported and encouraged by the Petroleum Companies under the area of responsibility of the Ministry of petroleum. As such, the oil remaining after the requirement of the community has been met will be sold to the agency which sets up the transesterification plant (for making raw oil suitable for blending with diesel).

5.2.5.5 Micromission on Transesterification, Blending and Trade

Arrangements to ensure creation of facilities for transesterification of oil in to bio-diesel and its blending with diesel will be the responsibility of the Ministry of Petroleum. As the blending of bio-diesel with diesel has to be made by the Petroleum Companies this facility needs to be set up by the oil companies themselves or parties sponsored by them. It will be the responsibility of oil companies to either themselves establish the facility or encourage the private entrepreneurs to do so.

Looking to the fact that such a plant will be set up for the first time in the country, the investment required for a 100, 000 MT processing capacity plant may be of the order of Rs. 70-75 Crore and the cost of processing will be Rs.3359 per MT of oil as given in **Annexure X**. However, there will be recovery of glycerol whose value as per the paper referred to above will be about Rs. 2500 per MT of oil processed. In view of the fact that the figures quoted in the research paper are with reference to Rapeseed oil, there may be some uncertainty about the recovery of Glycerol. Even if very conservative view is taken of glycerol recovery (only half of the figure given in the research paper, the cost of transesterification should not exceed Rs. 2.25 per litre of bio-diesel; it is likely to be nearer Re. 1.00 per litre.

The blending of biodiesel can be taken up at the depot level of the oil companies. However, it should be emphasised that marketing of biodiesel blended diesel should be done as an organised trade and this activity should be handed by the oil companies. The biodiesel to be blended has to mandatorily tested for its quality. This will also keep in check any adulteration activity. The storage of biodiesel does not need any specialised tanking and the storage tanks used for biodiesel can also be used for biodiesel. The blending of biodiesel is also a simple affair and the circulatory pumps generally available in any diesel storage depot are sufficient to make a homogenous blend. Another option for marketing of biodiesel blended diesel is for specialised fleet operations e.g. bus fleets etc. For this blending may be taken up at these locations

5.2.5.6 Micromission on Research and Development:

Considerable work on bio-fuels has been done in Europe and USA. However, it is based on oils derived from edible vegetable oils such as rapeseed and soyaben. In view of the feed stock being different in our case, minor differences are anticipated in properties, processing – oil extraction from seed and transesterification- and the behaviour of bio-diesel which have implications for every stake holder, studies need to be done on a number of subjects many of which have been identified in the chapters on Ethanol and Biodiesel. In view of the fact that CSIR has in-house facilities to carry out studies and is equipped to coordinate with other R&D institutions both in the industry and academic institutions, it may be the nodal agency for this Micromission. The role of other organizations is given under the portion of this chapter dealing with institutional Arrangements. The R&D issues which need attention are

a Raw Material :

Production of improved feedstock / raw material for quality and quantity of oil ; Selection of the bio-crop for production of Bio-diesel i.e Jatropha & others ; Developing agro-technologies for different agro-climatic regions ; Total chemical analysis of all potential non-edible oils with special reference to Jatropha Curcas Oil.

b Production Technology :

Research efforts for perfecting an efficient chemical/ catalyst conversion process ; Development of Bio-catalyst i.e. Lipase catalyzed esterification ; Development of Heterogeneous Catalyst i.e. use of smart polymers ; Alternate uses of by-products i.e. glycerol and meal cake.

c Utilization as Fuel :

Data generation & Production of bio-diesel from all possible feed stocks ; Response of different available additives and their dosages on the bio-diesel ; Effect of bio-diesel on elastomers, corrosion etc ; Stability of Bio diesel - Oxidation stability, Thermal Stability and Storage Stability; Engine Performance and emissions based on different feedstock based Bio-diesels ; Toxicological Studies ; Tests to check Adulteration, Development of Alternate Devices to work on non-transesterified i.e. raw oil for rural areas.

5.2.6 Financial requirement :

The plantation of trees bearing non edible oil seeds has not been undertaken on a large scale in this country. The other activities such as setting up a network of nurseries, mobilizing the JFMs, Voluntary organizations and farmers to undertake plantation on a commercial scale, setting up seed collection centres and state-of-art oil extraction units, establishing transesterification plants, blending and marketing are activities which will be done for the first time. The viability and profitability of such activities have to be demonstrated and widely disseminated. There are many gaps in the knowledge relating to the field of plantation of Jatropha curcas and other oilseed bearing tree species, processes, technologies, economic and management issues which need to be filled up through studies. It will be necessary for the Government to plan and implement the Demonstration Project at its own cost specially the component dealing with plantation. The activities relating to seed collection and oil extraction may be feasible with partial support. The transesterification units should be expected to be set up by entrepreneurs. Most of the expenditure on studies and development will have to be borne by the Government.

It will be reasonable to expect that after the Demonstration Project has been successfully implemented, its expansion will be possible through the financial resources of the individuals, entrepreneurs and companies and those of the financial institutions with the government being required to give some incentives and having supportive policies.

The plantation undertaken under the programmes of the Ministry of RD will be met out of its own funds. The financial requirement of the Demonstration Project dealing with plantation on 4 lakh hectares of land and all forward and backward linkages is given in the table 5.4.

Table5.4

Financial Requirement of Demonstration Project

(Rs. Crore)

Component	Year 2003	Year 2004	Year 2005	Year 2006	Year 2007	Total
Nursery	96	192	192	0	0	480
Plantation	104	208	208	0	0	520
Protection	0	40	80	80	0	200
Seed & Expeller Centres @ Rs. 0.8 Cr/ Centre	0	4.8	17.6	32	105.6	160
Sub-total	200	444.8	497.6	112	105.6	1360
Administrative Expenditure @ 5%	10	22.4	24.8	5.6	5.28	68.08
R & D @ 5%	10	22.4	24.8	5.6	5.28	68.08
Grand Total	220	489.6	547.2	123.2	116.16	1496.16

5.2.7 Financing Arrangement:

5.2.7.1 Demonstration Project:

For the plantation component of the Demonstration Project, the funds need to come from the Government. As yet, the people are not aware of the potential of Jatropha curcas to give economic return and that too in a short time from degraded - unproductive lands, fallow lands and field boundaries. Hence to begin with the funds cannot be expected to come from the people. The government will have to make this investment.

For the Plantation on degraded forest lands through JFM Committees, the funds made available for forest development may be used.

For the component of setting up Seed Collection Centre and Oil extraction unit, the funds could be a mix of entrepreneurs' own contribution (margin money), subsidy and loan from NABARD and SIDBI in the ratio of 10:30:60. The amount of subsidy will again have to be provided by the Government. The Administrative Expenses should come from the Government. Since Jatropha has never been used as a source of automotive fuel, some studies will have to be conducted relating to planting material, agro technologies, detailed studies of properties of oil and biodiesel produced from it, its behaviour in various kinds of vehicles and problems which have been listed in the relevant place.

For the Transesterification Unit, it is a commercial venture involving relatively large sum of money (Rs. 75 Crore). It is expected that the oil companies guided by the Ministry of Petroleum will induce private sector to set up such plants with financing from Financial Institutions. Hence the funds for R&D should be contributed by the Government, oil companies, Associations of automobile manufacturers (SIAM) and other companies and associations connected with petroleum and automobiles.

5.2.7.2 Phase II-Self sustaining Expansion of Biodiesel:

On the basis of experience of the Demonstration Project, the villagers are expected to be attracted to Jatropha plantation on their field boundaries and relatively unremunerative holdings, on community lands and government lands. A scheme of margin money, subsidy and loan may need to be instituted. Companies having lands should be encouraged to undertake jatropha plantation. They may be given technical advice and elite planting material.

Funds for plantation in degraded forests through JFM could come from the JFM members provided tree pattas can be given to each member who may be then induced to spend his own money as margin money and the remainder may come from the banks. The Government could provide subsidy, say of 30 %.

The funds for the Seed Collection Centres and oil extraction units, transesterification units and R&D will be mobilized in the same manner as during the Demonstration Project (Phase I).

Plantation undertaken by the Ministry of RD will be financed by that ministry.

5.2.7.3 External Funding:

In view of the facts that the Biodiesel Programme addresses global environmental concerns and deals with poverty alleviation, bilateral and multilateral funding agencies could find the project worthy of support. In the run up to Phase II, projects should be prepared and posed to these agencies.

5.2.8 Expected Achievements of Demonstration Project

5.2.8.1 Assumptions:

- The propagation of Jatropha curcas will be done through nursery to ensure high rate of survival, planting of a healthy and vigorously growing plant and achieve start of production of seed within one year of planting.
- The plant density will be 2500 per hectare.
- For mixed plantation or agro forestry 2500 plants will be deemed to cover one hectare of land even though the total coverage is much more. Hence whereever 'hectare' is used in the context of jatropha plantation it is notional hectare.
- While under very good conditions the seed production is reported to be as high as 5 kg/tree or 12.5 MT per hectare and in rainfed and poor soils as low as 1.5 MT/hectare, we have assumed average conditions and soils and the production of seed as 1500 gms per tree corresponding to 3.75 MT per hectare.
- The oil content will be 35% by weight of seed and extraction efficiency will be 94%.
- One hectare of Jatropha Plantation on an average will produce 3.75 MT of seed yielding 1.2 MT of oil.
- At the end of two years Jatropha plant will give seed to its full potential. Hence four lakh hectares will produce 4.8 lakh MT of oil and 10.2 lakh MT of compost.
- If the programme is approved nurseries will be set up and the seedlings will be available next year for plantation. The availability of biodiesel will start in the year 2005-6.

5.2.8.2 Achievements

The expected achievements of the Demonstration Project under the National Mission on Biodiesel are given below:

- Demonstrate the viability of the programme to produce Biodiesel from non-edible vegetable oil – to begin with jatropha curcas seed oil and proved that the objectives set out for the programme are in fact achievable.
- Create awareness among potential participants and stakeholders and laid the foundation of a rapid expansion of plantation and linked facilities to produce enough Biodiesel for blending with HSD.so that the programme takes off rapidly after the completion of the Demonstration Project.

- Make available sufficient planting material of quality for the expansion of the programme in Phase II.
- The Demonstration Project itself would create a capacity to produce 4.8 lakh MT per year of Biodiesel which will replace HSD valued at Rs. 830 Crore @ Rs. 17.28/Kg (Rs 14.00/Litre) and 10.2 lakh MT of oil cake valued at Rs 102 Crore. @ Re 1/Kg.
- Generated by 2007 employment of 127.6 million Man days in plantation and 36.8 million Man days per annum on a sustained basis in seed collection and 3680 person years for running the Seed collection and oil-extraction Centres.

Table 5.5

Yearly & Cumulative Achievements of Demonstration Project

Year	Cumul. Area (Th. Ha)	Availab of seed (Th MT)	Expeller (Nos)	Plantation Employm. (MPD)	Seed Collection Employm. (MPD)	Seed Centre Employm. (PY)	Availab of oil (Th MT)	Value of diesel substituted (Rs. Cr)
2003	80	0	0	21	0	0	0	0
2004	240	200	20	45.9	1.6	160	48	82.9
2005	400	800	80	53	6.4	640	192	331.8
2006	400	1600	160	7.68	12.8	1280	384	663.7
2007	400	2000	200	0	16	1600	480	829.6
Cumulative total				127.6	36.8	3680	1104	1908

* Assumptions: Density of HSD 0.81, Price of l HSD Rs. 14 / litre or Rs. 17.28/ Kg

5.2.9 Institutional Arrangements :

The National Mission can succeed only if there is a dedicated and co-ordinated effort by various participants and stake-holders in its planning and implementation.

A Coordination Committee at the political level and a Steering Committee at the official level with a cell in the Planning Commission to serve the two committees are envisaged. Four principal sectors are envisaged viz. Plantation, Production, Marketing & Trade and Research & Development. The national Mission will consist of micro-missions at least one for each sector- there can be more than one for a sector as in plantation.

A table showing the roles of the **various agencies** involved in the programme is at **Annexure XI**. The Diagram showing the institutional / organizational arrangement is given in the chapter.

5.2.10 Coordination Committee for National Mission on Bio-Diesel

Under the chairmanship of Deputy Chairman, Planning Commission a Coordination Committee is proposed to oversee the programme, formulate policy, give guidance for raising resources and effective implementation, dealing with issues of coordination and monitoring of the programme..

The composition of Coordination Committee may be as under:

Composition of Coordination Committee:

Deputy Chairman, Planning Commission – Chairman

Members:

Member (Environment & Forest), Planning Commission

Minister of Petroleum & Natural Gas

Minister of Environment & Forests

Minister of Road Transport & Highways

Minister of Rural Development

Minister of Agriculture

Minister of Science & Technology

Minister of Law & Justice

Minister of Water Resources

Minister of Finance

Minister of Railways

Minister of Non-Conventional Energy Sources

Minister (In-charge) of Department of Consumer Affairs

Minister of Information & Broadcasting

Secretary, Planning Commission

Principal Adviser (E&F), Planning Commission - Member Secretary

The Coordination Committee may meet at least once a year.

5.2.11 Steering Committee:

A Steering Committee comprising of officials may perform the following functions :

- Be responsible for implementation of the programme.
- Oversee the programme, monitor the progress , identify difficulties in implementation and find solutions.

- Advise participating Ministeries and organizations so as to make their participation more effective and efficient.
- Keep the Coordination Committee informed of the progress and seek guidance as necessary.
- Implement the decisions of Coordination Committee..

The composition of Steering Committee may be as under :

Member (S&T), Planning Commission - Chairman

Secretary , Planning Commission

Principal Adviser (E&F), Planning Commission

Secretary , Ministry of Petroleum & Natural Gas

Secretary, Ministry of Environment & Forests

Secretary, Ministry of Road Transport & Highways

Secretary, Ministry of Rural Development

Secretary, Ministry of Agriculture

Secretary, Department of Bio-Technology

Secretary, Department of Legal Affairs

Secretary, Ministry of Water Resources

Secretary, Ministry of Finance & Company Affairs

Secretary, Ministry of Railways

Secretary, Ministry of Non-Conventional Energy Sources

Secretary, DSIR

Secretary Information and Broadcasting

Director General, Bureau of Indian Standards

Adviser (E&F), Planning Commission – Member Secretary

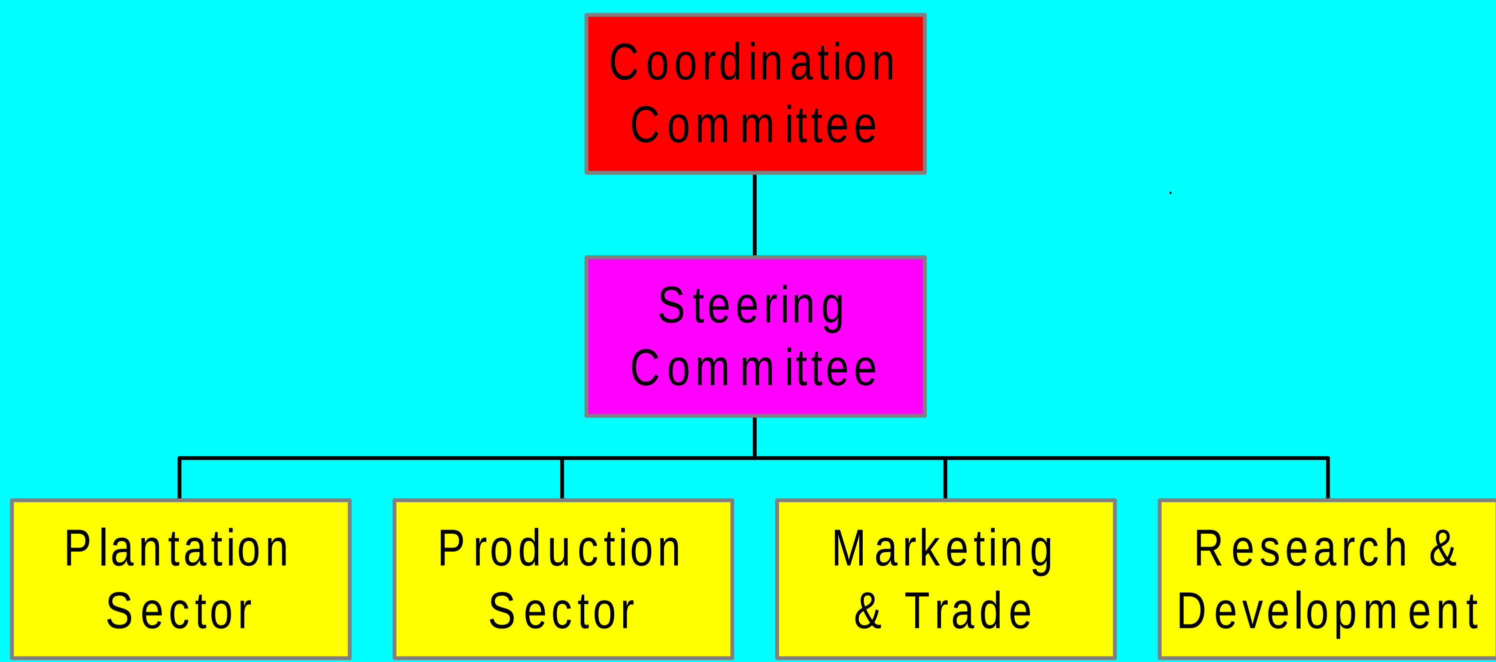
The Steering Committee may meet once a quarter and may have 4 sub-committees one each for Plantation , Production , Research & Development and Marketing & Trade as shown in the diagram.

The Coordination and Steering Committees may co-opt any individual and organization as a member if his presence is considered useful to consider any matter.

5.2.12 Cell to Service Steering and Coordination Committees

A compact cell may be created in the Planning Commission to serve the Steering Committee and the Coordination Committee.

Institutional Networking



Institutional Networking

Plantation Sector

Wasteland Development	Nursery Raising & Plantation	Seed Collection & Extraction of Oil
DAC, NOVOD	NOVOD	Min. of SS &VI
DARE	ICAR	KVIC
MOEF	SAUs	TRIFED
MRD,DOLR	CAPART	PVT. ENTERPS.
DRD,CAPART	NGOs	NGOs
MORT(NHAI)		
RAILWAYS		

Institutional Networking

- Production sector
  - Trans-esterification of oil
  - Blending with Petro-diesel

MOP&NG
PVT. ENTERPRISES
OIL COMPANIES

OIL COMPANIES

Institutional Networking

Marketing & Trade

Supply & Distribution	Legal Issues & Legislations	Finance & Pricing	Quality Standards / Specifications	Vehicle Manufacturers Approvals/Guarantee	Education & Awareness
OIL COS.	Dept. of Legal Affairs	MOP&NG	BIS	SIAM	MOEF
	MOP&NG	Min. of Fin.	SIAM	OIL COS.	PCRA
	MOEF	Min. of Agr.	OIL COS.		IREDA
	CPCB		Min.of Road Trpt. & High.		KVIC
			IIP		Dept. Of Field Pub.
					Min. of I&B and its agencies

Institutional Networking

- Research & Development
  - Raw Material (DBT, ICAR, NOVOD)
  - Production Technology (CSIR, IIP, Pvt. Sec. Inst.)
  - Utilization as blended & straight Oil
    - Engine / Emissions Testing
    - Stability / Toxicology Studies
    - Alternate Devices
    - Life Cycle Analysis
    - Adulteration Check Tests

Engine / Emissions Testing	Stability / Toxicology Studies	Alternate Devices	Life Cycle Analysis	Adulteration Check Tests
IIP	Institute of Toxicology	IIP	IIP	IIP
IOC(R&D)	IIP	CSIR	CPCB	IOC(R&D)
ARAI, Pune	IOC(R&D)	MNES	IOC(R&D)	
CPCB	IICT, Hyd.			

Chapter 6

Conclusions and Recommendations

6.1. Background:

The envisaged bio fuels programme is based on several compulsions and imperatives each strengthening the case for bio fuels. Some of these are:

- the impending international oil crisis;
- the growth momentum generated since the 1990s causing a steady spurt in oil demand for transport;
- domestic crude oil output reaching a plateau and hence the need to reduce dependence on imported crude oil;
- the national commitment to provide clean air to the citizens as a part of their fundamental rights by enforcement of stricter emission norms;
- technical and economic feasibility of producing bio fuels for blending with Motor Spirit and Diesel on a large scale due to availability of land, technology, capacity for supply of quality planting materials, positive response of the farming community, market, enterprise and financial institutions
- the implications of integrated bio-fuel development for upliftment of the poor, through reclamation of degraded land, drought proofing provision of income and employment opportunities in plantation, primary processing and procurement and transport; and
- as a means to "green & rehabilitate" degraded lands on a sustainable basis.

India faces the difficult task of fine balancing the growing energy needs, the environmental damage from fossil energy sources and the energy security of the country. Worldwide concerns regarding the threat of climate change have sharpened focus on green energy as it will not only meeet the goal of sustainable development but also contribute to a reduction of Carbon Dioxide emissions.

These imperatives and the estimates of incremental demand of diesel and motor spirit in 2006-7 and 2011 suggest that a programme to produce biofuels which are transport fuel substitutes and blend them - ethanol with motor spirit and Biodiesel with HSD - must be started right now to create necessary plantation base and infrastructure which takes time.

6.2. Ethanol – its Prospects:

The advantages of using ethanol and methanol as blends in motor spirit are that they are oxygenates containing 35% oxygen and renewable. They reduce vehicular emission of Hydrocarbons and Carbon Monoxide and eliminate emission of lead, benzene, butadiene etc. It is technically feasible to design and run automobiles on 100% ethanol; but for the reason of availability and compatibility with vehicles presently in use, blending of ethanol with motor spirit needs to make a very modest beginning.

Motor Spirit forms only 7 - 8% of oil consumption. Feasibility of blending it with ethanol, a sugarcane industry based bio fuel, has been established with the current availability of molasses being far in excess of quantity needed for producing and meeting domestic demand of industrial and potable Alcohol. The sugar industry is presently faced with excess capacity, uneconomic use of sugarcane, over production, and fall in prices and with little export prospects. Maintenance of the existing sugarcane plantation area is vital for protecting the livelihood of the sugarcane growers and the agricultural labourers who depend on work associated with sugarcane plantation. As such the production of ethanol directly from sugarcane juice - without going through the sugar and molasses route - needs to be encouraged at the sugar factories, especially where sugar cane production is in excess of the requirement for making sugar. However, a sugarcane based ethanol plant requires the facility to dehydrate alcohol which most sugar factories do not possess. If this constraint is removed, the existing sugar factories could increase their output of ethanol by setting up a combined plant to produce sugar and ethanol, the viable size of such a plant being 250 MT/day. This is logical as under the existing price structure sugar production provides higher value addition than sugar cane to ethanol.

Under the present demand and supply of ethanol, 7% blend of ethanol is a feasible objective if the facility to dehydrate ethanol at our distelliries is created and restriction on movement of molasses and putting up ethanol manufacturing plants removed. Measures, as mentioned below, may also need to be considered:

- Provision of incentives for new economic sized distilleries incorporating state of art technology such as, molecular sieve technology for making anhydrous alcohol.
- Integration of distillery with sugar plant to have multiple choice of making sugar, or direct sugarcane to ethanol.

Presently the economics of production of ethanol from other crops such as sugar beet, corn, sweet sorghum though technically possible have not been commercially established which should be examined as rising oil price may in the near future make conversion viable. This is an area which calls for coordination between the technology developers and the financial institutions as optimization of production of ethanol from different feed stock has to be an economic objective. As demand for ethanol increases other bio mass resources such as agricultural and forestry wastes, municipal solid wastes, and crops grown solely for energy purposes could be used to make ethanol. It is also assessed that the present area of 4.36 million ha. Under sugar cane may expand to 4.96 million ha. in 2006-7 yielding additional cane production of 50 Million MT. This will provide an adequate base for ethanol for 10% blending even in the Tenth Plan and result in oil substitution of 1.01 Million MT/per annum and substantial reduction in crude oil import bill. However, this will require imposition of some duty on imported ethanol to protect domestic ethanol production.

6.3. Bio diesel:

Since diesel constitutes 50% of oil consumption chiefly for transportation and other purposes, its demand is integrally related to economic growth and is seen as a growth inducing factor. The estimated increase of demand for diesel from the 2001-02 level of 38.815 Million MT to 52.324 Million MT in 2006-7 and 66.095 Million MT shows a massive hike of 34% to 70% respectively over 2001-02 level in physical terms which will lead to increase of crude oil import from the present level of 85 Million MT to 147 Million MT per annum raising the oil import bill from US $ 13.3 Billion to over US $ 20 Billion. As emissions from automotive engines using diesel is a major source of air pollution in urban areas, enforcement of stricter emission norms has become a national priority.

Bio-diesel has been accepted as clean alternative fuel all over the world. Though bio-diesel could be produced from soyabean, rapeseed, sunflower, the source of edible oil, existing shortage of edible oil in the country and its price, would not make these crops viable for use as feed stock for production of bio-diesel. Similarly the existing output of 5.253 Million MT of Tree borne oil seeds have been put to different uses and cannot contribute to organized production of bio diesel on account of a number of factors including scattered location, low yield and consequently low level of seed collection of 15-20% of total exploitable seeds.

The rationale of taking up a major programme for the production of bio-diesel in India for blending with diesel lies in the context of:

- Bio-diesel being superior fuel from the environmental point of view;
- use of bio-diesel becomes compelling in view of the tightening of automotive vehicle emission standards and court interventions;
- addressing global concern relating to containing Carbon emissions for mitigation of climate change;
- providing nutrients to soil, by using oil cake as manure;
- reducing import of oil and consequentially reducing import and improving energy security;
- greening the country through *Jatropha curcas* plantation; and
- generation of gainful employment to the people.

Similar to the ethanol for blending with petrol, bio diesel is a substitute for petro-diesel, the main liquid fuel for our heavy vehicles, railways, trucks, tractors, marine engines etc.

6.4. *Jatropha Curcas* – Source of Biodiesel:

There are many tree species which bear seeds rich in oil. Of these some promising tree species have been evaluated and it has been found that there are a number of them such as *Jatropha curcas* and *Pongamia Pinnata* ('Honge' or 'Karanja') which would be very suitable in our conditions. However, ***Jatropha curcas*** has been found the most suitable tree specie for the reasons summarized below:

- It can be grown as a quick yielding plant even in adverse land situations viz. degraded and barren lands under forest and non-forest use, dry and drought prone areas, marginal lands and as agroforestry crop. It can be planted on fallow lands and along farmers field boundaries as hedge because it does not grow too tall as well as on vacant lands alongside railways, highways, irrigation canals and unused lands in townships etc. under Public/Private Sector Undertakings.
- The seeds of Jatropha are available during the non-rainy season, which facilitates better collection and processing. The cost of plantation is largely incurred in the first year and improved planting material can make a huge difference in yield.
- Raising Jatropha plant and its maintenance creates jobs for the rural poor, particularly the landless, in plantation and primary processing through expellers.

- It has multiple uses and after the extraction of oil from the seeds, the oil cake left behind is an excellent organic manure, the bio mass of *Jatropha curcas* enriches the soil and it can also be put to other uses.
- Retains soil moisture and improve land capability and environment.
- Jatropha adds to the capital stock of the farmers and the community, for sustainable generation of income and employment.

6.5. Economics of Jatropha Bio-diesel:

In India, it is estimated that cost of Bio-Diesel produced by trans-esterification of oil obtained from *Jatropha Curcas* oil-seeds shall be approximately same as that of petro-diesel. On The cost of Bio-diesel varies between Rs. 16.59 –14.98 per litre. Assumptions are that the seed contains 35% oil, oil extraction will be 91-92%, 1.05 Kg of oil will be required to produce 1 Kg of Biodiesel, recovery from sale of glycerol will be at the rate of Rs. 40-60 per Kg. The price of Glycerol is likely to be depressed with processing of such large quantities of oil and consequent production of Glycerol raising the cost of Bio-diesel. However, new applications are likely to be found creating additional demand and stabilizing its price. With volatility in the price of crude, the use of Bio-diesel is economically feasible and a strategic option.

6.6. Target of bio-diesel production:

It is estimated that Petro-Diesel Demand by the end of 10th Plan (in 2006-07) shall be 52.33 million MT. In order to achieve 5% replacement of petro-diesel by bio-diesel by the year 2006-07, there is need to bring minimum 2.29 million ha area under *Jatropha curcas* plantation.

6.7. Quality Standards & Specifications:

The formulation of standards and specifications for bio-diesel in its pure form and as blends, neutral to feed stock used to produce bio-diesel, is under the consideration of the Bureau of Indian Standards (BIS). They are proposed to be based on standards adopted by European Union. It is necessary that the consent of the vehicle, engine and Fuel Injection manufactures is taken before finalizing the standards and introducing change of fuel. Test methods also need to be prescribed.

6.8. Research and Development Issues:

A number of institutions have been engaged in India in looking in to the various aspects of bio-fuels. For example, IOC R&D has already set up a pilot biodiesel production facility and Mahindra & Mahindra Ltd have a pilot plant utilizing Karanj for biodiesel production. Some areas where R&D efforts are needed in the fields of Ethanol and Biodiesel are mentioned below

In so far as **Ethanol** is concerned, processing technologies to convert other biomass resources, such as grains sugar, beet, potato, straw, agricultural and forestry wastes, municipal solid wastes, industrial wastes, and crops grown solely for energy purposes, need to be improved to reduce costs and optimize production processes. Soon, new technologies will be economically viable for converting plant fiber to ethanol. Connecting the established ethanol industry with the emerging technologies that produce ethanol from the sources mentioned above is important. Use of higher blends of ethanol and the related changes that need to be made in the specifications of engine currently in use will also be an area of study.

In the field of Biodiesel, presence of moisture or high FFA content has posed problems. Other subjects needing attention are briefly mentioned below:

- **Raw Material (*Jatropha curcas* seed and oil):**

Selection of improved germplasm material for quality and quantity of oil; developing agro-technologies for different agro-climatic regions; total chemical analysis of all potential non-edible oils with special reference to *Jatropha curcas* Oil. Testing of Biodiesel from various feed stocks and generation of comparative data on fuel composition, emissions, material compatibility etc.

- **Production Technology :**

Research efforts for perfecting an efficient chemical/ catalyst conversion process ; Alternate uses of by-products i.e. glycerol and meal cake.

- **Utilization as Fuel :**

Data generation & production of bio-diesel from all possible feed stocks ; response of different available additives and their dosages on the bio-diesel ; effect of bio-diesel on elastomers, corrosion etc ; stability of Bio diesel - oxidation stability, thermal stability and storage stability; engine performance and emissions based on different feedstock based Bio-diesels ; toxicological studies and tests to check adulteration. Toxicological study is a pre-requisite for introduction of any fuel and should be carried out. Procedure for detecting percentage of Bio-diesel in the blended fuel and to check adulteration of the fuel should also be developed.

- **Plants in operation/ under construction**

Plants with different capacities and technologies are currently available and used in the industrial production of bio-diesel. A number of units are manufacturing bio-diesel worldwide using various feed stock including Jatropha oil.

- **Blending of Esters & Diesel**

The most common blending ratio is 80% conventional diesel fuel and 20% vegetable oil ester (biodiesel), also termed "B20," as significant emission reductions are achieved with these blends are stable, simple to prepare and no engine problems are encountered. One limitation to the use of bio-diesel is its tendency to crystallize at low temperatures below 0°C. causing problems in fuel pumping and engine operation. One solution to this problem may be the use of branched-chain esters, such as isopropyl esters. Another method to improve the cold flow properties of vegetable oil esters is to remove high-melting saturated esters by inducing crystallization with cooling, a process known as winterization. These aspects need to be studied..

- **Storage & handling of Bio-Diesel**

As a general rule blends of bio-diesel and petroleum diesel should be treated like petroleum diesel and pose no problems There is no aromatic hydrocarbon (benzene, toluene, zylene) or chlorinated hydrocarbons. There is no lead or sulphur to react and release any harmful or corrosive gases. However, in case of bio-diesel blends significant fumes released by benzene and other aromatics present in the base diesel fuel can continue.

- **Engine Development & Modifications**

Engine oil dilution is a potential problem with biodiesel since it is more prone to oxidation and polymerization than diesel fuel. The presence of biodiesel in engine could cause thick sludge to occur with the consequence that the oil becomes too thick to pump. Engine oil formulations need to be studied to minimize the effect of dilution with biodiesel keeping in mind that the light duty diesel engines are sufficiently different from heavy duty diesel engines in many aspects including emission behaviour.

- **Marketing & Trade:**

The role of marketing companies in distribution, pricing, taxation,, interstate movement and the direct and indirect impact of biodiesel e.g. employment generation, balance of trade, emission benefits etc need to be studied.

6.9. Recommendations:

It is clear that the country must move towards the use of biofuels - ethanol as substitute for motor spirit and biodiesel for diesel. It implies the production of biodiesel in 2011-12 and coverage of land with *Jatropha curcas* as below:

- 3.25MMT for blending @ 5% and coverage of area of 2.9 M.Ha
- 6.5 MMT for blending @ 10% and coverage of area of 5.8 M.Ha
- 13 MMT for blending @ 20 %, and coverage of area of 11.2 Mha

Blending of motor spirit with ethanol @10% can be achieved if only additional facility to dehydrate ethanol could be added.

To achieve the above blending levels the following recommendations are made:

6.9.1. For Ethanol

a Though it is technically feasible to design and run automobiles on 100% ethanol, for the reason of availability and compatibility with vehicles presently in use blending of ethanol with motor spirit needs to make a very modest beginning.

b Five percent blending has already been introduced in some states. According to the information availability about production and demand of ethanol for all applications, production of molasses and distillery capacity, 7% blend of ethanol in gasoline is feasible provided facilities to dehydrate alcohol are added to the required extent. The target should be to raise the blending in stages to 10% by the end of the X Plan.

c Ethanol may be manufactured using molasses as the raw material. If the industry finds it economically feasible, it should be encouraged to produce alcohol also from sugarcane juice directly in areas where sugarcane is in surplus.

d Restrictions on movement of molasses and putting up ethanol manufacturing plants may be removed.

e Imported ethanol should be subject to suitable duties so that domestically produced ethanol is not costlier than the imported one.

f Ethanol diesel blending requires emulsifier and also poses certain storage and technical problems. Indian Institute of Petroleum is working on the subject. Ethanol diesel blending should await the solution of the problems.

g Buyback arrangement with oil companies for the uptake of anhydrous alcohol should be made.

h To reduce cost of production of ethanol, the following measures may be considered:

- Provision of incentives for new economic sized distilleries incorporating state of art technology such as, molecular sieve technology for making anhydrous alcohol.
- Integration of distillery with sugar plant to have multiple choice of making sugar, or direct sugarcane to ethanol.

i The cost of ethanol produced using other raw materials such as grains, potato, sugar beet and straw is estimated to be more than the price of motor spirit and may need subsidy. Economics of ethanol production from other feedstocks as sugar beet, corn, potatoes, etc should be studied. It may be left to the industry to use these raw materials for producing ethanol as and when if it finds them economical.

j The subjects needing study or R&D have been identified in paragraph 6.8 above. The micromission on R&D proposed to be set up under the National Mission on Biodiesel will look after the areas of relevance to Ethanol sector also.

6.9.2. Recommendations For Biodiesel

a A National Mission on Biodiesel should be launched immediately with the objective of producing biodiesel required for blending to the extent of 20% with HSD in 2011-12.

b As its Phase I, a demonstration project may be taken up on 4 lakh hectares in eight States. Of this area two lakh hectare of plantation may be taken up on understocked forest lands placed under the management of Joint Forest Management Committees in four States (Tamilnadu, Chattisgarh, Jharkhand and Tripura) and two lakh hectare of plantation on non forest lands spread over four states (U.P., Madhya Pradesh, Maharashtra and Andhra Pradesh). In addition, the Ministry of Rural Development may take up plantation under the IWDP and other poverty alleviation programmes as the programme elements of the two programmes are similar.

c The bio-diesel demonstration project is expected to produce 1.5 million MT of seed and 0.48 million MT of oil from the year 3 and will generate by 2007 employment of 127.6 million mandays in plantation and 36.8 million mandays per annum on sustained basis in seed collection and 3680 Person Years of employment for running seed collection and oil extraction centers. On an overall basis, the employment under the Project will directly enable 5.50 lakh rural poor families to escape poverty. The entire project will be community and farmer driven from plantation up to primary processing stage involving seed collection, procurement and oil extraction at the village level. The esterification factory will be set up by a private entrepreneur availing financing facilities under the existing policies.

d The national Mission on Biodiesel may be based on Jatropha as it has many advantages over other species including Karanja (*Pongamia Pinnatta*). To mention a few, it has very high oil content, has very small gestation period, is hardy, grows on good and degraded lands and in low and high rainfall areas, the seed comes in non rainy season and the tree is not very high making collection of seed convenient.

e The Demonstration Project may be completed by 2007. The next phase of the National Mission should be people driven and should involve a self sustaining expansion of plantation and setting up of corresponding facilities for seed collection, oil extraction, esterification etc. The Government should act mainly as a facilitator providing incentives as may be necessary.

f Efforts should be made to get external funding for Phase II of the national Mission..

g The Demonstration Project under the National Mission may be funded by the Government.

h As the implementation of the Demonstration Project makes progress and Biodiesel starts becoming available, a beginning should be made with 5% blending in areas where the production of Biodiesel is taken up by the year 2005.

6.9.3. Micromissions Under National Mission:

The National Mission may be implemented in a mission mode. The Demonstration Project may consist of a number of micro-missions as below:

- **Micromission on Plantation on Forest And Adjoing Lands.**

This plantation may be undertaken by the Forest Departments in the four states included in the Demonstration Project through the JFM Committees. The Ministry of Environment & Forests will be the nodal Agency for this micromission.

- **Micromission on Plantation on Non-forest Lands – Implementation by NOVOD;**

The plantation on non-forest lands in four States identified under 6.9.2 (b), the Demonstration Project may be undertaken with NOVOD under the Ministry of Agriculture playing the nodal role.

- **Micromission on Plantation Not Covered By The Above Two Micromissions – Implementation by Ministry of Rural Development**

Since *Jatropha curcas* plantation has all round implications for poverty alleviation and upgradation of land resources, various programmes; such as IWDP, SGSY, SGRY, PMGY etc. could include Jatropha planatation as a part of their programme to help the farmers to escape poverty for which necessary funds are already provided under the Plans of the respective Ministries. Similarly, KVIC, SIDBI, NABARD can step in to support procurement of seeds, oil extraction activity at the village level. The Ministry of Rural Development and its two departments namely the Department of Rural Development and the Department of Land Resources and CAPART may be made responsible for plantation in degraded and wastelands through out the country but not included in the Micromission to be implemented by NOVOD. districts outside the districts included in Micromission to be implemented by NOVOD through the Panchayats and NGOs by using the funds available under IWDP, SGRY and SGSY etc

- **Micromission on Procurement of Seed and Oil Extraction:**

KVIC under the Department of Agro and Rural Industries should be the nodal agency for encouraging and supporting this activity. It will do the extension work, provide all help in the setting up of the Seed procurement and oil Expelling Centres, identify suitable technology of oil expelling units and assist in obtaining finance from the financial institutions.

- **Micromission on Transesterification, Blending and Trade**

Arrangements to ensure creation of facilities for transesterification of oil in to bio-diesel and its blending with diesel may be the responsibility of the Ministry of Petroleum.

- **Micromission on Research and Development:**

The problems needing solution as identified above will need R&D. The institutions under ICAR, ICFRE, CSIR, Research and Training Institutions supported by the GoI, State Agriculture Universities and interested institutions in the industry – both public sector and private sector- other organizations will be invited to make their contribution.

6.9.4. Financing for Demonstration Project:

- The total cost has been estimated to be Rs. 1496 Crore.
- For the plantation component of the Demonstration Project (Rs 1200 Crore), the funds need to come from the Government. As yet, the people are not aware of the potential of Jatropha curcas to give economic return and that too in a short time from degraded - unproductive lands, fallow lands and field boundaries. Hence to begin with, the funds should be provided by the government. There will be a number of options for raising the required funds. The manner in which the required funds would be mobilized will be decided by the Coordination Committee
- For the component of setting up Seed Collection Centre and Oil extraction unit, the funds could be a mix of entrepreneurs' own contribution (margin money), subsidy

and loan from NABARD and SIDBI in the ratio of 10:30:60. The amount of subsidy will again have to be provided by the Government.

- For the Transesterification Unit, it is a commercial venture involving relatively large sum of money (Rs. 75 Crore). It is expected that the oil companies guided by the Ministry of Petroleum will induce private sector to set up such plants with their own funds being supplemented by funds from Financial Institutions.
- The Administrative Expenses of the mission should be borne by the Government.
- Funds for R&D will need to be provided under the Mission. Funds available for R&D with the various Ministries, Industry and their Associations, R&D institutions should be used. However, dedicated funds to be provided by the Government for R&D have been proposed.

6.9.5. Assumptions:

- The propagation of *Jatropha curcas* will be done through nursery to ensure superior germplasm, high rate of survival, planting of a healthy and vigorously growing plant and achieve start of production of seed in the second year of planting.
- The plant density will be 2500 per hectare.
- For mixed plantation or agro forestry 2500 plants will be deemed to cover one hectare of land even though the total coverage is much more. Hence whereever 'hectare' is used in the context of jatropha plantation it is notional hectare.
- While under very good conditions the seed production is reported to be as high as 5 kg/tree or 12.5 MT per hectare and in rainfed and poor soils as low as 1.5 MT/hectare, we have assumed average conditions and soils and the production of seed as 1500 gms per tree corresponding to 3.75 MT per hectare.
- The oil content will be 35% by weight of seed and extraction efficiency will be 91%. This works out to oil recovery of 32% implying that one kg of oil will be produced by 3.125 kg of seed. The price of seed has been assumed to be Rs. 5 per Kg.
- One hectare of Jatropha Plantation on an average will produce 3.75 MT of seed yielding 1.2 MT of oil.
- At the end of two years Jatropha plant will give seed to its full potential. Hence four lakh hectares will produce 4.8 lakh MT of oil and 10.2 lakh MT of compost.
- After the programme has been approved nurseries will be set up and the seedlings will be available next year for plantation. The availability of biodiesel will start in the year 2005-6.

6.9.6. Financing for Phase II-Self sustaining Expansion of Biodiesel- Preparation of Project:

In the last year of the Demonstration Project i.e., in 2006-07, on the basis of experience gained, a project will be formulated for Phase II of the National Mission. The villagers are expected to grow *Jatropha curcas* plantation on their fields as agro-forestry crop. A scheme of margin money, subsidy and loan may need to be instituted. Companies having lands could be encouraged to undertake *Jatropha curcas* plantation. They may be given technical advice and elite planting material.

Funds for plantation in degraded forests through JFM could come from the JFM members provided seed pattas can be given to each member who may be then induced to spend his own money as margin money and the remainder could be a combination of subsidy from the government and loan from financial institutions.

The funds for the Seed Collection Centres and oil extraction units, transesterification units and R&D will be mobilized in the same manner as during the Demonstration Project (Phase I).

6.9.7. External Funding:

It is also noted that since bio-diesel programme will address global environmental concerns and will make a definite impact on poverty alleviation within a short period it is likely to attract the support of bilateral and multilateral funding agencies. While there is no need for external funding at the stage of the Demonstration Project, for Phse II, efforts should be made to obtain external funding on the basis of the project that will be formulated as mentioned in 6.9.5.

6.9.8. Institutional; Arrangement For the National Mission & Demonstration Project

A Coordination Committee under the Chairmanship of the Deputy Chairman of the Planning Commission and a Steering Committee of officials to be served by a compact cell in the Planning Commission may be set up. Their functions, composition and the roles of ministries departments and agencies participating in the Mission are given in Chapter 5.

6.9.9. Legislative Aspects

In the beginning there is need for flexibility as a very rigid legal regime may hamper the development of biofuels in India. Hence it is proposed that a separate legislation on biofuels need not be considered at this stage and the needed legal requirements may be met by using the already available statutes.

Annexure I

No. H-11018/3A/2002-E&F
Planning Commission
(E&F Division)

Yojana Bhawan
Sansad Marg, New Delhi
Dated 18th July 2002

OFFICE MEMORANDUM

Subject: Constitution of Committee on Development of Bio-fuels.

Environmental factors are becoming the main driving force for cleaner fuels and the quest for the alternative fuels. Bio-fuel is a new motor fuel that has emerged on the international scene in the wake of Clean Air Act Amendment of 1990 and the Energy Policy Act of 1992. Two or three percent oxygen present in diesel fuel has been found to reduce particulate emissions by 15% to 20%. Vegetable oil mono-esters (bio-diesel) contain about 11% oxygen and virtually no sulphur or aromatics. Bio-fuels include alcohols, ethers, esters and other chemicals derived from cellulosic bio-mass such as herbaceous and woody plants, agricultural and forestry residues.

Bio-diesel is extensively used in US, Brazil, Australia, Sweden and some other European countries, while many other countries including China, Thailand, etc. are also drawing up national plans for using the same. Naturally, US and Brazil, the two major agro-producers in the world had taken in a large way; US based its bio-ethanol programme on corn, while Brazil utilized sugarcane crop for this purpose. India, being in the same league of agro-based economies has a great potential to promote bio-fuels.

One of the most talked about bio-fuels options today is bio-diesel, oil derived from vegetable sources and use as a substitute for diesel. According to the US based World Energy Organization, overall potential of hydrocarbon emissions from bio-diesel was nearly 50% less than that of diesel. The US National Bio-diesel Board suggests that bio-diesel is non-toxic, bio degradable and fee of sulphur. Experiments done by the University of California, Davos, USA, showed that Cancer causing potential of bio-diesel particulate matter is 94% less than that of diesel emissions.

The popularity of biofuels in Europe has come from the urgency to reduce oil bills and allow the farming sector to reap benefits from them. Using biofuels is also helping. European nations meet their Kyoto Protocol Commitments. According to a proposal drafted by the Directorate General of the European Commission, the minimum share of biofuels by 2010 should be 5.75 per cent of the total transport fuel sold in each member state.

There is a worldwide trend towards the use of biodiesel as a substitute for diesel to reduce air pollution. USA Energy Policy Act provides for 30% motor fuel to be from non-petroleum sources (mainly biodiesel) by 2010. *Jatropha curcas* cultivation/ plantation can easily yield bio-diesel for substituting 20% import of crude oil and saving Rs.21,000 crores on yearly basis. The other species worth exploring are – *Pomgamia pinnata* (Karanj), Rubber tree (seeds) and *Calophyllum inophyllum*. The Petroleum Conservation Research Association (PCRA) also hold the view that there is a good potential of production of biodiesel in India and being a renewable source of energy it needs to be given encouragement.

Also, the road map for emission norms in India is under consideration wherein Euro-III & IV equivalent emission norms will be applicable in 7 mega cities with effect from April 2005 and April 2010, respectively. The Euro-III emission norms would be implemented in the entire country by year 2010. In order to meet these emission requirements, a drastic reduction in sulphur content (<350 ppm) and high cetane number (> 51) will be required. Use of bio-diesel will help in meeting these two important specifications related to emissions and would also help in improving the lubricity of low sulphur diesel. The present specification of flash point is 35^{o}C, which is lower than all the countries in the world (>55 ^{o} C). Blending of bio-diesel will help in raising the flash point from safety point of view. Apart from regulated emissions, the use of bio-diesel will reduce CO_2 emissions which is a green house gas resulting in climate change.

India being an agriculture oriented and net energy deficient country, there is a need to explore various alternative fuels options such as bio fuels. For a country like India, the bio fuels are attractive options for many reasons: low cost labour, high unemployment, high cost of delivered petroleum products, difficulties in obtaining hard currency, unfavourable balance of payments and the importance of agriculture. In view of the above factors in conjunction with environmental awareness, there is a need for a comprehensive national programme to utilize the available wastelands, forest and agro wastes to produce bio-fuels.

I Composition :

Dr.D.N.Tewari,Member, Planning Commission	Chairperson
Principal Adviser (E&F) , Planning Commission, New Delhi	Mem-Secretary
Secretary, Ministry of Finance,New Delhi	Member
Secretary, Ministry of Railways, New Delhi	Member
Secretary, Ministry of Surface Transport, New Delhi	Member
Secretary, Ministry of Petroleum & Natural Gas,N.Delhi.	Member
Secretary, Ministry of Rural Development, New Delhi	Member
Secretary, Min. of Env. & Forests, New Delhi	Member
Director General, CSIR,	Member
Director, Indian Institute of Petroleum,Dehradun	Member
DG, ICAR, New Delhi	Member
DG, ICFRE, Dehradun	Member
Director General, Bureau of Indian Standards, New Delhi	Member

Chairman, Central Pollution Control Board, New Delhi	Member
MD, IREDA Ltd, New Delhi	Member
Shri J. Shanmuganath, Bangalore	Member
Shri Pramod Sharma, All India Distiller Association	Member
Director, National Oilseeds & Vegetables Oils Dev.Board	Member
Prof. Rajender Prasad, Centre for Rural Dev.& Tech.,IIT,ND	Member
Dr. A.P. Dikshit, A.F.C.,Mumbai	Member
Dr. Kaushal Kumar, Secretary, Utthan, Allhabad	Member
President, All India Automobile Manufactures Association ,ND	Member

II Terms of reference :

The Committee will discuss the following issues and suggest recommendations.

The current level of use of bio-fuels and their prospects for commercial utilization.

The various aspects connected with blending of bio-fuels with mineral oil based fuels to improve environmental norms.

The storage, handling and distribution aspects concerned with bio-fuels.

The commercial scale development of bio-fuels (which includes bio-ethanol, bio-diesel, liquid fuels and hydrocarbons from bio-mass) based on relative costs and benefits.

Development of specifications and quality standards for bio-fuels.

Identification of prospective plant sources for bio-ethanol, bio-diesel and hydrocarbons and determine their R&D needs.

To frame a plan for development of plantations, development of demo scale and large-scale plantation, and strategies for collection of seeds and extraction of oil.

Suggest strategies for marketing.

Suggest measures for effective coordination between the concerned ministries in Govt. of India and institutions engaged in R&D of bio-fuels.

Suggest strategy and approach for mobilising requisite financial resources for promotion of bio-fuels on commercial scale.

Any other aspect that the Committee may consider important.

III The Committee may invite inputs/suggestions from other experts/agencies.

IV The Committee should submit the report to Planning Commission within six-month period.

-s/d-
T.R. Meena
Director (Admn)

Copy forwarded to:

Chairman and all members of the Committee.
PS to Dy.Chairman, Planning Commission.
PS to all Members, Planning Commission.
PS to Secretary, Planning Commission.
All Pr.Advisers/Advisers, Planning Commission.
Director (Admn.)

-s/d-
T.R. Meena
Director (Admn)

Annexure II

Extracts from the third assessment report of the IPCC to climate Change

According to IEA (International Energy Agency) assessment, the world energy use will increase steadily through 2030 though at a slower pace of 1.7% compared to 2.1% achieved over the past three decades. Fossil fuels will remain the primary source of energy meeting more than 90% of the increase in demand. Global oil demand will rise by about 1.6% from 75 Mb/d in 2000 to 120 Mb/d in 2030. Almost three quarters of the increase in demand will comer from the transport sector. Oil will remain the fuel of choice in road, sea and air transportation. Demand of natural gas will rise more strongly than for any other fossil fuel. Primary gas consumption will double between now and 2030 and the share of gas in world energy demand will increase from 23% to 28%. Transport demand almost entirely for oil will grow the most rapidly of all end use sectors at 2.1% per annum. It will overtake industry in the 2020s as the largest final use sector.

Between 1973 and 1996 world transportation energy use of which petroleum derived fuels comprise over 95%, increased by 66%. Alternative energy sources have not played a significant role in the world's transport systems. Despite two decades of price upheavals in world oil markets, considerable research and development of alternate fuel technologies, and notable attempts to promote alternate fuels through tax subsidies and other policies, petroleum's share of transport energy use has not decreased (94.7% in 1973 and 96.0% in 1996) according to EPA statistics. On a modal basis road transport accounts for almost 80% of transport use. Light duty vehicles alone comprise about 50%.

At the end of World war II, the world's motor vehicle fleet numbered 46 million vehicles and 75% of the world's cars and trucks were in USA. In 1996, there were 671 million highway vehicles world wide, and the US share stood at just over 30%. Since 1970 the US motor vehicle population has been growing at an average rate of 2.5% per year, but the population of vehicles in the rest of the world has been increasing almost twice at 4.8% per year. International Energy Outlook foresees transportation's share of world oil consumption climbing from 48% in 53% by 2010 and 56% by 2020. EIA expects a 77% increase in total world transport energy use by 2020, an average annual global growth rate of 2.4%. road dominance of energy use is maintained by the rapid increase in vehicle stocks outside of the OECD. The world motor vehicle population is projected to surpass 1.1 billion vehicles in 2020.

From 1980 to 1995 the average fuel consumption of passenger cars sold in Europe and Japan fell by 12%; from 8.3 litre/100 km to 7.3 litre/100 km. All of the decrease, however, occurred between 1980 and 1985. Since 1985 the fuel economics of light-duty vehicles sold in the USA and Europe have remained essentially constant. Energy efficiency improvements in other model have also slowed or stagnated over the past 10-15 years.

Direct injection lean burn gasoline engines costing $ 200 to $300 higher to conventional engines, have already been introduced in Japan and Europe. Preliminary evaluations suggest that benefits may in the 12 % to 15% range. Direct injection diesel engines have long been available for heavy trucks, but recently have become more competitive for automobiles and light trucks as noise and emission problems have been resolved. The new engines costing $500 to $1000 more, attain about 35% greater fuel economy than conventional gasoline engines and produce about 25% less carbon emissions over the fuel cycle. Current research programmes are aiming to achieve maximum thermal efficiency of 55% in heavy duty diesels compared to current peak efficiencies of about 40% -45%.

Fuel cells which have the potential to achieve twice the energy conversion efficiency of conventional internal combustion engines with essentially zero pollutant emissions, have received considerable attention recently, with most major manufacturers announcing their intention to introduce such vehicles by the 2005 model year. While fuel cell costs have been reduced by approximately an order of magnitude they are still nearly 10 times as expensive per kW as spark ignition engines. Hydrogen is clearly the cleanest and most efficient fuel choice for fuel cells, but there is no hydrogen infrastructure and on-board storage still presents technical and economic challenges. Gasoline, methanol or ethanol are possible alternatives, but require on-board reforming with consequent cost and efficiency penalties. Mid size fuel cell passenger cars using hydrogen could achieve fuel consumption rates of 2.5 gasoline equivalent litre/100 km in vehicles with lightweight, low drag body; comparable estimates for methanol or gasoline powered fuel cell vehicles would be 3.2 and 4.0 litre/100 km.

Annexure III

Emission Norms for Vehicles in Test Cycles

				Private cars: direct injection diesel
	EURO I 1992	EURO II 1996	EURO III 2000	EURO IV 2005
HC [g/km]	0.97	0.9	0.56	0.30
CO [g/km]	2.72	1.0	0.64	0.50
NOx [g/km]	-	-	0.50	0.25
PM [g/km]	0.14	0.10	0.05	0.025

				Private cars: gasoline
	EURO I 1992	EURO II 1996	EURO III 2000	EURO IV 2005
HC [g/km]	0.97[a]	0.5[a]	0.20	0.10
CO [g/km]	2.72	2.2	2.3	1.0
NOx [g/km]	-	-	0.15	0.08

(a) HC+NOx

					Trucks: diesel
	EURO I 1992	EURO II 1996	EURO III 2000	EURO IV 2005	EURO V 2008
HC [g/km]	1.1	1.1	0.66	0.46	0.46
CO [g/km]	4.5	4.0	2.1	1.5	1.5
NOx [g/km]	8.0	7.0	5.0	3.5	2.0
PM [g/km]	0.36	0.15	0.10	0.02	0.02

The European Emission Standards equivalent are followed in India as Bharat Standards.

Annexure IV

Oil Content in different crops

Crop	kg oil/ha	litres oil/ha	lbs oil/acre	US gal/acre
corn (maize)	145	172	129	18
cashew nut	148	176	132	19
oats	183	217	163	23
lupine	195	232	175	25
kenaf	230	273	205	29
calendula	256	305	229	33
cotton	273	325	244	35
hemp	305	363	272	39
soybean	375	446	335	48
coffee	386	459	345	49
linseed (flax)	402	478	359	51
hazelnuts	405	482	362	51
euphorbia	440	524	393	56
pumpkin seed	449	534	401	57
coriander	450	536	402	57
mustard seed	481	572	430	61
camelina	490	583	438	62
sesame	585	696	522	74
safflower	655	779	585	83
rice	696	828	622	88
tung oil tree	790	940	705	100
sunflowers	800	952	714	102
cocoa (cacao)	863	1026	771	110
peanuts	890	1059	795	113
opium poppy	978	1163	873	124
rapeseed	1000	1190	893	127
olives	1019	1212	910	129
castor beans	1188	1413	1061	151
pecan nuts	1505	1791	1344	191
jojoba	1528	1818	1365	194
jatropha	1590	1892	1420	202
macadamia nuts	1887	2246	1685	240
brazil nuts	2010	2392	1795	255
avocado	2217	2638	1980	282
coconut	2260	2689	2018	287
oil palm	5000	5950	4465	635

Annexure V

Areas identified for Jatropha Plantation through JFM & Forest Departments, Funds Required & Expected Employment Generation

State	Area under JFM & Social Forestry lakh ha	Funds required in Rs. Crores	Employment generation in plantation (Lakh man days)
Assam	0.5	150	150
Andhra Pradesh	1.0	300	300
Chhattisgarh	1.0	300	300
Karnataka	1.0	300	300
Jharkhand	2.0	600	600
Gujerat	1.0	300	300
Madhya Pradesh.	2.3	690	690
Maharashtra	2.0	600	600
Rajasthan	2.2	660	660
Tamilnadu	1.5	450	450
Tripura	0.5	150	150
Uttaranchal	0.5	150	150
Uttar Pradesh	1.50	450	450
West Bengal	0.5	150	150
Other states	2.5	750	750
Total	20	6000	6000

Annexure VI

Non-Forest Areas proposed for Jatropha Plantation

200 districts in 19 potential states have been identified on the basis of availability of wasteland, rural poverty ratio, below poverty line (BPL) census and agro-climatic conditions suitable for jatropha cultivation.Each district will be treated as a block and under each block 15000 ha jatropha plantation will be undertaken through farmers (BPL) .Proposed to provide green coverage to about 3 Million ha of wasteland through plantation of jatropha in 200 identified districts over a period of 3 years.

Andhra Pradesh
Adilabad, Anantapur, Chittoor, Cuddapah, Kurnool, Karim Nagar, Mehboob Nagar, Nellore, Nalgonda, Prakasam, Visakhapatnam, Warrangal.

Bihar
Araria, Aurangabad, Banka, Betiah (West Champaran), Bhagalpur, Gaya, Jahanabad, Jamui, Kaimur, Latehar, Muzzaffarpur, Munger, Nawada.

Chhattisgarh
Bastar, Bilaspur, Dantewada, Dhamtri, Durg, Jagdalpur, Janjgir-champa, Kanker, Kawardha, korba, Mahasaund, Rajnandgaon, Raipur, Raigarh, Surguja.

Jharkhand
Bokaro, Chatra, Daltenganj, Devgarh, Dhanbad, Dumka, Garhwa, Godda, Giridih, Gumla, Hazaribag, Jamshedpur, Koderma, Pakur, Palamu, Ranchi, Sahibganj, Singbhum(East), Singbhum(West).

Gujarat
Ahmedabad, Amerli, Banaskantha, Bhavnagar, Junagarh, Jamnagar, Kutch, Rajkot, Surendranagar, Surat.

Goa
Panaji, Padi, Ponda, Sanguelim

Himachal Pradesh
Bilaspur, Nahan, Parvanu, Solan, Unna

Haryana
Ambala, Bhiwani, Faridabad, Gurgaon, Hisar, Jind, Jhajjar, Mohindergarh, Punchkula, Rewari, Rohtak

Karnataka
Bijapur, Bellary, Bangalore, Belgaum, Chikmagalur, Chitradurga, Daksina Kannada, Dharwad, Gulbarga, Hassan, Kolar, Mysore, Raichur, Tumkur, Udupi

Kerala
Kottayam, Quilon, Trichur, Thiruvananthapuram

Madhya Pradesh
Betul, Chhindwara, Guna, Hoshingabad, Jabalpur, Khandwa , Mand Saur, Mandla, Nimar (Khargaon), Ratlam, Raisena, Rewa, Shahdol, Shajapur, Shivpuri, Sagar, Satna, Shahdol, Tikamgarh, Ujjain, Vidisha

Maharashtra
Ahmednagar, Aurangabad, Amrawati, Akola, Beed, Buldana, Dhule, Nasik, Osmanabad, Parbhani, Pune, Ratnagiri, Raigad, Thana, Yavatmal

Orissa
Bolangir, Cuttack, Dhenkanal, Ganiam, Gajapati, Jajapur, Koraput, Keonjhar, Kalahandi, Nowrangpur, Nawapra, Phulbani, Puri

Punjab
Ferozpur, Gurdaspur, Hoshiarpur, Patiala, Sangrur

Rajasthan
Ajmer, Alwar, Barmar, Bilwara, Bikaner, Churu, Chittorgarh, Jaisalmer, Jodhpur, Kota, Sikar, Sawai Madhopur, Udaipur

Tamil Nadu
Coimbatore, Chenai, Dharmapuri, Erode, Madurai, Perigar, Salem, Tirunelvelli, Vellore

U.P.
Allahabad, Agra, Balia, Bulandshare, Bhadohi, Baharaich, Chhitrakut, Deoria, Ferozabad, Faizabad, Ghazipur, Hardoi, Jaunpur, Jhansi, Kausambi, Lalitpur, Mainpuri, Partapgarh, Raibareli, Sultanpur, Shahjahanpur

Uttaranchal
Chamoli, Dehradun, Pithoragarh, Rishikesh, Udhamsingh Nagar, Uttrakashi

West Bengal
Balurghat, Barasat, Burdwan, Cochbehar, Darjeeling, Hoogly, Howrah, Jalpaigurri, Medinipur, Murshidabad, Malda, West Dinajpur, 24-Parganas South.

Annexure VII

Employment Generation and Costs in Jatropha Plantation

S.No	Item	COST (Rs.)		Employment in person days	
		Year		Year	
		1st	2nd	1st	2nd
1	Site preparation i.e. cleaning and levelling of field - 10 MD	600	-	10	-
2	Alignment and staking - 5 MD	300	-		
3	Digging of pits (2500 Nos) of 30 Cm3 size @ 50 pits per MD - 50 MD	3000	-	50	-
4	Cost of FYM (including carriage) 2 Kg. per pits during 1st year (2 MT) 1 Kg. per pit during second year onwards @ Rs. 400/MT	2000	-	20	-
5	Cost of fertilizer @ Rs. 6 per kg (50 gm. Per plant during 1st year and 25 gm from 2nd year onward and 2 MD for each application.	870	495	2	1
6	Mixing of FYM, insecticides fertilizers and refilling of pits @100 pits per MD 25 MD	1500	-	25	-
7	Cost of plants (including carriage) 2500 Nos. during first year and 500 Nos. of plants during second year for replanting @ Rs. 4.0 per plant.	10000	2000	100	20
8	Planting and replanting cost 100 plants per MD.- 25 MD and 5 MD, respectively	1500	300	25	5
9	Irrigation - 3 irrigation during 1st and one irrigation during 2nd year @ Rs. 500/- per irrigation.	1500	500	5	2
10	Weeding and soil working 10 MD. x 2 times for 2 years	1200	1200	20	20
11	Plant protection measure	300	-	1	-
	Sub total :	22770	4495	263	48
	Contingency (approx. 10% of the above)	2230	505	-	-
	Grand Total :	25000	5000	263	48

Annexure VIII

Unit cost of seed procurement and expelling centre

S.No	Item	Rs. in lakh
1	Seed godown	31.00
2	Weighing bridge	7.00
3	Oil extraction	5.00
4	Civil construction	5.00
5	Cost of land	2.00
6	Cleaner & grader	1.00
7	Drier	1.00
8	DG set	1.00
9	Storage tank	2.00
10	Cost of sub-centres (5 nos)	18.00
11	Miscelleneous expenditure 10 %	7.00
	Total =	80.00

Annexure - IX

Oil Expellers for Jatropha Seed Processing

Installed Cost	1 Ton/day Rs.70,000/-	1 Ton/Hr. Rs.3,00,000/-	2 Ton/hr. Rs.5,00,000/-
Processing Cost Power Consumption (Kwh/T)	45 Kwh - Rs.225/-	30 Kwh – Rs.150/-	24 Kwh – Rs.120/-
Stream	600 Kg/T – Rs.180/-	15 Kg/T – Rs.45/-	125 Kg/T – Rs.37.50
Manpower	3/day - Rs.450/T	3/day - Rs.20/T	6/day - Rs. 20/T
Cost of Processing/ Ton	Rs.855/-	Rs.215/-	Rs.177.50
Int. & Dep. / T	Rs. 45/-	Rs. 7.50	Rs. 6.50
Cost of Processing Inclusive of Dep + Maint. Per Ton	Rs.900/-	Rs.222.50	Rs.184/-

Annexure-X

Transesterification Plant to produce Bio diesel

Capacity : 100,000 Tons / Annum

Cost : 70-75 Crores

Utility Consumption per Ton

Steam -	660 Kg	Rs. 198/-
Power-	36 Kwh	Rs. 180/-
Methanol-	110 Kg	Rs.1130/-
Water (circulation)	55 M3	Rs. 11/-
Catalyst Solin	18 Kg	Rs. 180/-
Mineral Acid	6 Kg	Rs. 60/-
Total		Rs.1759/-
Interest & Depreciation		Rs.1600/-
		Rs.3359/-

Annexure XI

Ministeries / Departments / Organisations Involved and their roles

Name of Ministry / Organisation / Institute	Role / Responsibilities
Planning Commission	Coordination, Overseeing, Hosting cell to serve committees
Environment & Forest Division	Coordination, Overseeing, Hosting cell to serve committees
Petroleum Division	Coordinate with Ministry of Petroleum & Natural Gas
Ministry of Petroleum & Natural Gas	Ensure implementation of responsibility given to it, its institutions & monitor progress
Indian Oil Corporation (R&D)	Carry out studies, Collect data
Petroleum Conservation Research Association (PCRA)	Carry out studies, Collect data & Mass Awareness Programmes
Diesel Marketing Oil Companies	Ensure facilities for transesterification, blending & marketing, monitor performance of automobile engines
Ministry of Environment & Forests	Ensure implementation of plantations. Get CPCB to monitor env & health effects, carry out decisions of Coordination Committee.
Director General - Forests	Plantation, seed collection and oil expelling
Central Pollution Control Board (CPCB)	Monitor environment & health effects of emissions of ethanol and bio-diesel
Ministry of Non-Conventional Energy Sources	Support studies related to bio-diesel and ethanol, development of appliances to run on jatropha oil
Indian Renewable Energy Development Agency Ltd. (IREDA)	Support entrepreneurs wishing to establish seed centres, esterification units and plantatation
Ministry of Road Transport & Highways	Plantation along highways, use biodiesel blended fuels
National Highways Authority of India (NHAI)	Plantation along highways, use biodiesel blended fuels
Ministry of Rural Development	Fix targets for plantation under IWDP and other poverty alleviation programmes/ CAPART
Department of Land Resources (DLR)	Plantation, seed collection and oil expelling
Council for advancement of people's action & Rural Technology (CAPART)	Nurseries/Plantation, seed collection, oil extraction through Voluntary Organisations
Ministry of Agriculture	Ensure implementation of responsibility given to it, its institutions & monitor progress
Indian Council of Agriculture Research (ICAR)	Research in all aspects of Jatropha plantation
Indian Agricultural Research Institute (IARI)	Research in all aspects of Jatropha plantation
Department of Agriculture & Cooperation (DAC)	Ensure implementation of responsibility given to it, NOVOD & monitor progress
National Oilseeds & Vegetable Oils Development Board (NOVOD)	Plantation on non-forest lands and help seed collection
Ministry of Science & Technology	Ensure implementation of responsibility given to it, its institutions & monitor progress
Department of Bio-Technology (DBT)	Make available elite planting material at affordable prices
Council for Science & Industrial Research (CSIR)	Organise studies on aspects of biofuel
Indian Institute of Petroleum (IIP)	Carry out assigned studies
Indian Institute of Chemical Technology (IICT)	Carry out assigned studies
Indian Toxicology Research Centre (ITRC)	Carry out assigned studies

Annexure XI (contd.)

Ministeries / Departments / Organisations Involved and their roles

Name of Ministry / Organisation /	Role / Responsibilities
Ministry of Law & Justice	Advise on Legal aspects of bio-fuel programme
Ministry of Water Resources	To ensure availability of water for irrigation of plantations
Ministry of Finance & Company Affairs	Review taxation, make available resources, arrange external funding
National Bank for Agriculture & Rural Development (NABARD)	Support plantation, seed centres, oil expelling units
Small Industries Development Bank of India (SIDBI)	Support plantation, seed centres, oil expelling units
Ministry of Railways	Plantation along railway tracks, use biodiesel blended fuels
Ministry of Consumer Affairs, Food & Public Distribution	Ensure framing of standard specificatins as needed
Bureau of Indian Standards (BIS)	Formulate Standard Specifications for Bio-fuels
Ministry of Small Scale Industries & Agro & Rural Industries	Seed collection and oil expelling centres
Khadi & Village Industries Commission (KVIC)	Seed collection and oil expelling centres
Ministry of Industry	Ensure implementation of responsibility given to it, its institutions & monitor progress
Automotive Research Assn. of India (ARAI)	Carry out studies on use of bio-fuels in engines and emissions thereof.
Ministry of Tribal Affairs	Collection of seed from tribal areas
Tribal Cooperative Marketing Development Fed.of India (TRIFED)	Collection of seed from tribal areas
Ministry of Information & Broadcasting	Information, Education and Communication programme
Society of Indian Automobile Manufacturers	Carrying out of required tests for engine performance and vehicle manufacturers agreement and guarantees to use biofuels
NGOs	Setting up nurseries, contacting farmers for plantation, setting up seed collection and extraction centres
State Agriculture Universities	Helping set up nurseries, extension services, research
Indian Institute of Technology (IITs)	Solving process/engineering problems helping industry to supply indigenous plants

Annexure XII

Those who contributed in the Report

Planning Commission :

Shri K. C. Pant, Deputy Chairman, Planning Commission
Dr. D. N. Tewari, Member, Planning Commission
Shri N. K. Sinha, Secretary, Planning Commission
Shri Mantreshwar Jha, Principal Adviser, Planning Commission
Dr. R. Mandal, Adviser (E&F), Planning Commission
Shri Vinay Shankar, Sr. Consultant, Planning Commission
Shri Rangan Dutta, Sr. Consultant, Planning Commission
Shri B. K. Tiwary, Joint Adviser, Planning Commission
Shri Parveen Mithra, Consultant, Planning Commission

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DG, CSIR - Chairman
Shri Prakash Kumar, Executive Director, NOVOD Board, Gurgaon - Member
Director, Indian Institute of Petroleum, Dehradun - Member
Director, Indian Institute of Chemical Technology, Hyderabad - Member
Shri O. P. Rao, Scientist, CSIR - Convener

Sub-Committee on Engine Development & Modifications for using Bio-Fuels

Dr. Sudhir Singhal,Director,Indian Institute of Petroleum - Chairman

Sub-Committee on Standards and Quality aspects of Bio-Fuels

Shri R. P. Sharma, SIAM - Chairman
Dr. Sudhir Singhal, Director, Indian Institute of Petroleum - Member
Dr. Y. P. Rao, Chief Research Manager, Bharat Petroleum Corporation Limited - Member
Dr. D. K. Tuli, Chief Research Manager, Indian Oil Corporation Limited - Member
Representative from BIS - Member

Sub-Committee on Legal Regulations on Bio-Fuels

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Annexure XII (contd.)

Those who contributed in the Report

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Director (Technical & Field Services), ONGC - Member
Director (Refineries), Hindustan Petroleum Corporation Limited - Member
Director (Finance), Bharat Petroleum Corporation Limited - Member
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Shri L.N.Batra, Secretary General, All India Distillers Assn - Member
Managing Director, Praj Industries (Pune) - Member
Managing Director,Chemical Construction International (DELHI) - Member
Director, Indian Institute of Petroleum, Dehradun - Member
Executive Direcator, Petroleum Conservation Research Association, New Delhi - Member
Managing Director, IREDA, New Delhi - Member
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Shri Parveen Mithra, Consultant, Planning Commission - Co-opted Member

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Dr. S. K. Singhal , IIP, Dehradun

Road Map for Vehicular Emission Norms for New Vehicles

Road Map for Vehicular Emission Norms for New Vehicles
New Vehicles (except 2 & 3 Wheelers)

Entire Country

- **Bharat Stage II emission norms**
  From 1 April, 2005
- **Euro III equivalent emission norms**
  From 1 April, 2010

For Cities of Delhi/NCR, Mumbai, Kolkata, Chennai, Bangalore, Hyderabad, Ahmedabad, Pune, Surat, Kanpur and Agra

- **Bharat State II emission norms**
  - **Delhi, Mumbai, Kolkata & Chennai**
    Already introduced in the year 2000 and 2001
  - **Bangalore, Hyderabad, Ahmedabad, Pune, Surat, Kanpur and Agra**
    From 1 April, 2003
- **Euro III equivalent emission norms for all private vehicles, city public service vehicles and city commercial vehicles.**
  From 1 April, 2005
- **Euro IV equivalent emission norms for all private vehicles, city public service vehicles and city commercial vehicles**
  From 1 April, 2010

Road Map for Vehicular Emission Norms for New Vehicles
New 2 & 3 Wheelers

Emission Norms for 2 / 3 Wheelers to be the same in the Entire Country

- **Bharat Stage II norms**
  From 1 April, 2005
- **Bharat Stage III norms**
  Preferably from 1 April, 2008 but not later than 1 April, 2010 in any case.

Source : Auto Fuel Policy Report (August'2002) of Expert Committee constituted by Ministry of Petroleum & Natural Gas, Government of India.

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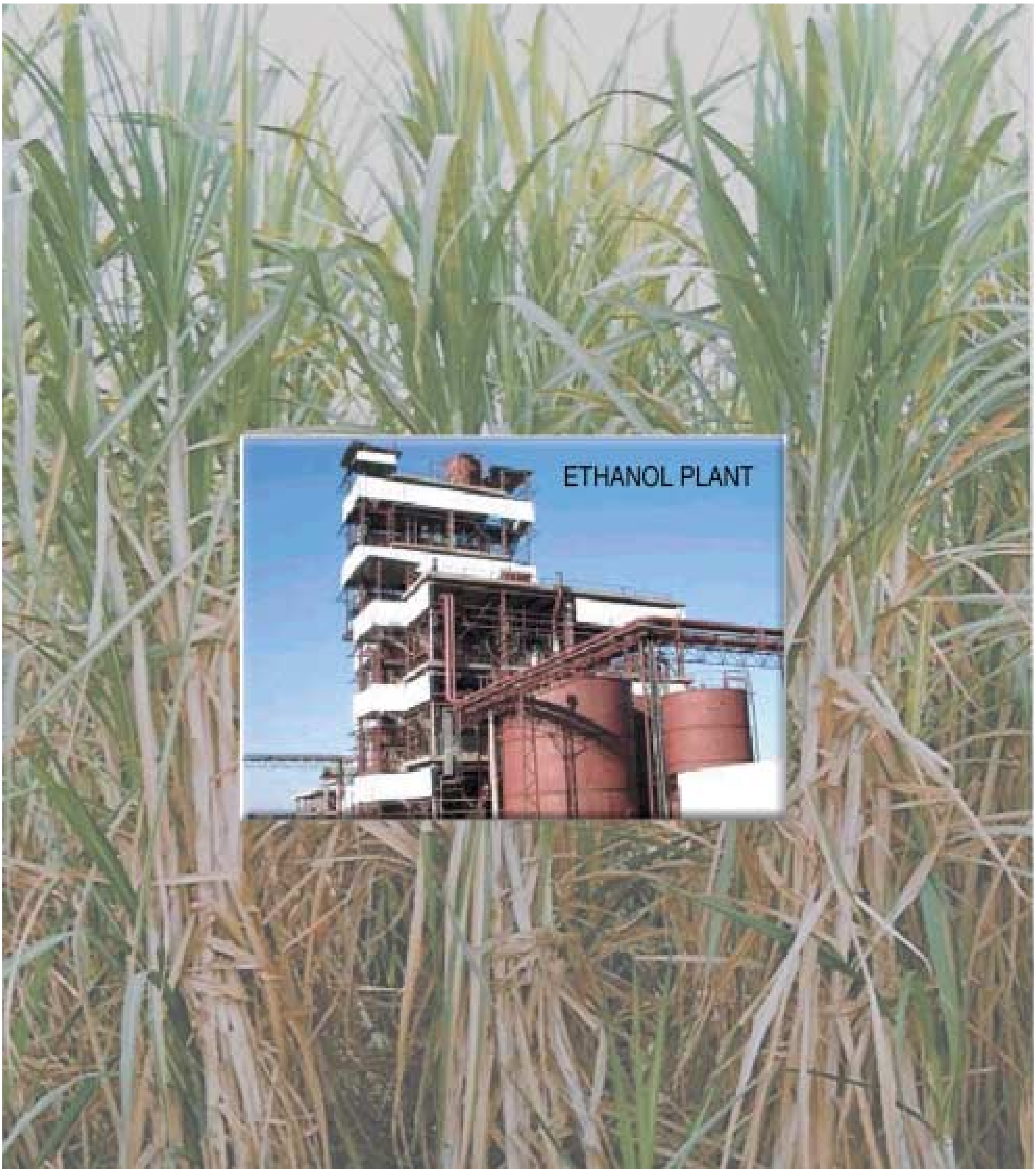
Praveen Kumar Saini, Artist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