Jatropha Cultivation for Biofuel Production in Mauritius

OCTOBER 2006

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EXECUTIVE SUMMARY

Scenario analyses have been performed to investigate the economic feasibility of production of biodiesel in Mauritius. Two scenarios have been considered, namely (1) the plantation of Jatropha Curcas in Mauritius as source of Jatropha oil feedstock for biodiesel production, and (2) the production of biodiesel in Mauritius from imported raw materials. In the first scenario, the plantation of Jatropha Curcas has been limited to the availability of marginal land, which is typically used for Jatropha plantation. The second alternative considers the importation of both Jatropha seeds (i.e. Jatropha oil extracted in Mauritius) and neat vegetable oil for biodiesel production. It investigates the feasibility of producing a fixed volume of biodiesel for various combinations of oil extracted from imported Jatropha seeds and neat vegetable oil. Several assumptions have been made.

Under scenario 1, biodiesel produced from Jatropha cultivated on marginal land is expected to displace between ~1.4% and ~3.0% of diesel consumption in the transport sector. Before deciding whether Jatropha can or should be cultivated in Mauritius, there are several alternatives that have to be considered including, among others, whether there are: (1) sustainable transport measures that can be implemented that would result in the reduction of energy consumption in the transport sector without adversely affecting mobility and accessibility (leaving marginal land for other uses); (2) more profitable alternative uses of marginal land.

The second scenario, which considers the production of biodiesel from import raw materials, appears to be more favourable. It shows that the production of biodiesel from imported vegetable oil is economically feasible level when the price of diesel is above ~Rs 25,500/tonne (current price is Rs 34,218/tonne).

Decision-makers should not substitute this study for a business plan to invest in biodiesel production. The objective of this desk study is to provide decision-makers with a clear indication of the pertinent parameters and factors to consider in making decision regarding specific energy policies.

INTRODUCTION

The transport sector occupied 49.5% of final energy consumption in 2005. Gasolene and diesel oil had 23.9% and 40.2% share, respectively, in transportation. On average, the energy consumption by the transport sector has been growing at about 3.4% per annum over the past 5 years. It is also important to note that the cost of Gasolene increased by 42.4% from Rs 11,751/tonne in 2004 to Rs 16,737/tonne in 2005, while the cost of diesel oil increased by 51.0% from Rs 9,701 to Rs 14,651 in the same time period. These dramatic increases in the cost of imported fossil fuels place significant strain on the economy, notwithstanding the negative social externalities (e.g. rising consumer price index).

It is in this context that alternative fuels have to be investigated in order to reduce the energy dependence of the nation. Indeed, biofuels that are carbon-neutral are promising candidates for substituting fossil fuels. The economic potential of the Jatropha plant was raised by the President of India during his recent visit to Mauritius. The immediate aim of this project was to investigate the economic feasibility of cultivating Jatropha in Mauritius for eventual production of biofuel, based only on desk research. The study was carried out upon request from the Ministry of Industry, Small and Medium Enterprises, Commerce and Cooperatives.[1]

Biofuels, like vegetable oil and biodiesel, are two types of renewable energies – i.e. they can be replenished after consumption by further growing the oil-bearing plants and conversion of oils into biodiesel. However, the demand of vegetable oils for energy production implies the uptake of land for agricultural use, which could be at the expense of alternative uses of land. It is in this light that the sustainability of biodiesel production through Jatropha cultivation in Mauritius has been investigated.

OBJECTIVES OF STUDY

The initial objective of the study was to:

1. **Investigate the economic feasibility of cultivating Jatropha Curcas in Mauritius for the production of biodiesel**

The scope of the study has been enlarged to also include a:

2. **Preliminary investigation of the economic feasibility of producing biodiesel in Mauritius from imported raw materials**

[1] Please refer to: Notes of Meeting of the Cultivation of Jatropha Plant held on Friday 7 April 2006 (Ministry of Industry, Small and Medium Entreprises, Commerce & Cooperatives, Port Louis), and formal request bearing reference IND/9/15/6, 22 June 2006, from the ministry to conduct study.

RESEARCH TEAM

This study was carried out by an interdisciplinary team. The Mauritius Research Council identified key organisations and requested them to nominate representatives to join the research team. The research team was made up of the following persons:

1. **Dr Chandradeo Bokhoree**, Lecturer, SOBISE, University of Technology, Mauritius

2. **Mr N Boodia**, Lecturer, Faculty of Agriculture, University of Mauritius

3. **Dr Sanju Deenapanray**, Research Coordinator, Mauritius Research Council

4. **Dr Noël Govinden**, Head, Food Crop Agronomy Department, Mauritius Sugar Industry Research Institute

5. **Mrs Mala Gungadurdoss**, Principal Research Scientist, Agronomy, Agricultural Research and Extension Unit

6. **Dr Romeela Mohee**, Associate Professor, Faculty of Engineering, University of Mauritius

7. **Mr Harris Neeliah**, Research Officer, Mauritius Research Council

The mandate of the team was to undertake desk research only. The report was drafted by the MRC on behalf of the research team.

SCENARIO ANALYSIS

The initial aim of investigating the viability of cultivating Jatropha in Mauritius for biodiesel production was enlarged to include a second scenario. Hence, this report has investigated the production of biodiesel in Mauritius either through local cultivation of Jatropha plants or by using imported raw materials. The two scenarios considered in this study are:

Scenario 1 Production of biodiesel in Mauritius through cultivation of Jatropha plants; and

Scenario 2 Production of biodiesel, through importation on raw materials

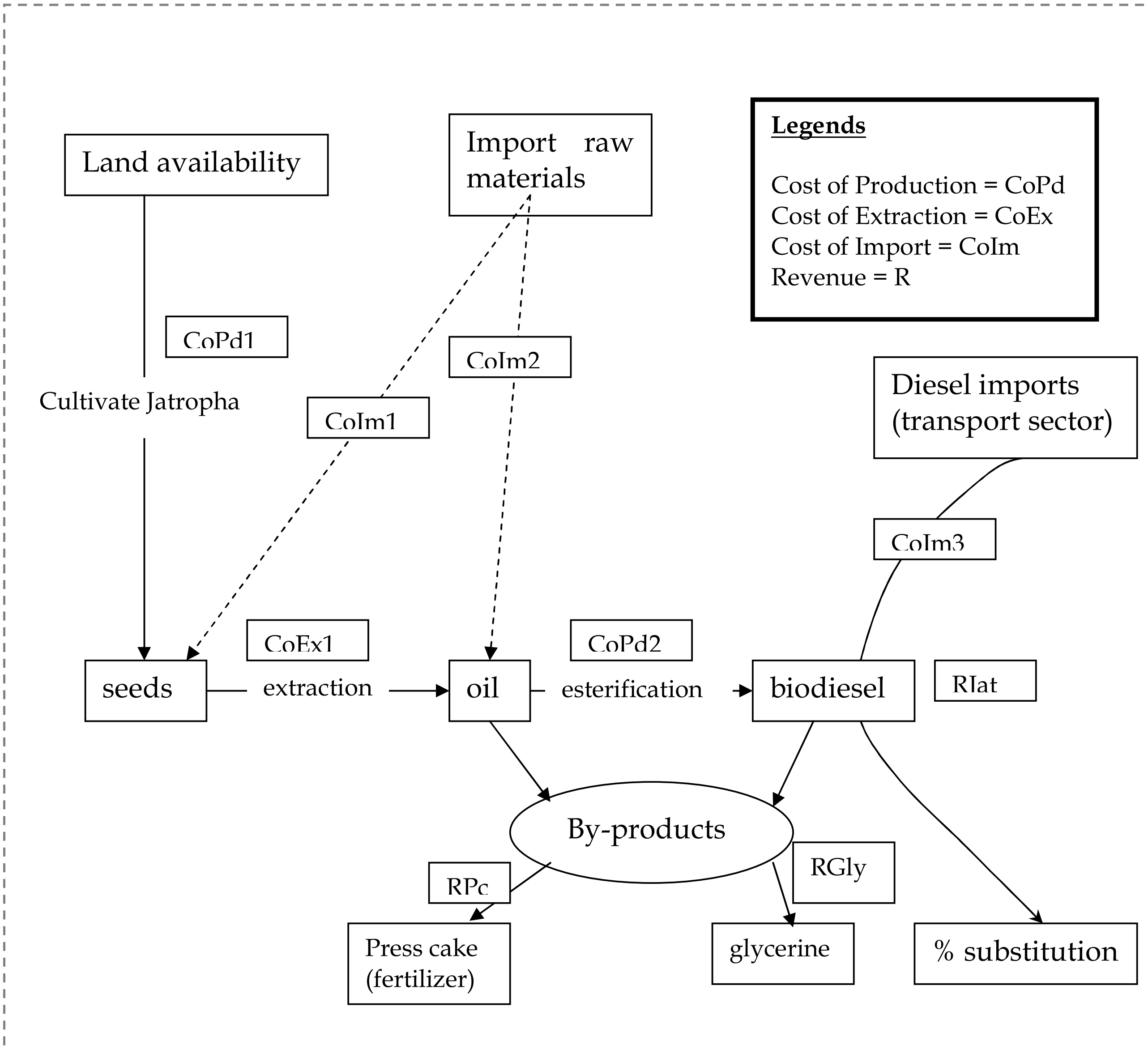

Figure 1. Flow chart summarising the two scenarios considered in this study.

METHODOLOGY

There are common features underlying the two scenarios, and this section provides their broad outlines. Specific details of the two scenarios are discussed at length below.

1. An initial Work Breakdown Structure (WBS) was performed and tasks assigned to different members of the team. The WBS covered the entire chain starting from identification of land for Jatropha cultivation biodiesel production. The outcome of this exercise is given in *Appendix 1*, from which data was used in scenario analyses;
2. Both straight vegetable oil (SVO) and biodiesel can be used as replacement for diesel oil. This study has concentrated on the substitution of diesel oil in the transport sector, which occupies almost 50% share of final energy consumption. This provides a baseline for scenario analysis. This decision, as opposed to using diesel in primary energy requirement, is justified below;
3. As far as practicable, this study has looked at the production of biofuel as an industry cluster, wherein the benefits of by-products such as press cake (used as fertilizer or for biogas production) and glycerine (a by-product of the trans-esterification process can be used to make soap) have been taken in account;[2]

A NOTE ON ASSUMPTIONS

Several assumptions have been made for each scenario. The validity of each assumption has been justified as far as practicable within the scope of a desk research. One or more of these assumptions may change depending on the dynamics of market forces. However, the models used here can be updated to accommodate these changes. The models can be further developed should the need arise in the future. It is pointed out here that the level of sophistication of models has been kept to the bare minimum required to investigate the central question addressed by each scenario.

[2] The medicinal uses of Jatropha oil were not considered in this study.

SCENARIO 1

Introduction

This scenario investigates the production of **biodiesel (biofuel) from Jatropha plants cultivated on marginal land in Mauritius**.

Assumptions

As1.1 Land type – Only marginal land was considered for cultivating Jatropha, because of the resilience of the plant to grow on such type of land. However, as mentioned at As1.2, not all of the marginal land may be suitable for planting Jatropha.

As1.2 Land availability – Detailed analysis would have required development of a Geographical Information System (GIS) for marginal land in Mauritius. This study has not developed a GIS. Rather it has assumed that land under sugar cane plantation will decrease from approximately 72,000 hectares in 2005 to approximately 65,000 hectares in 2015, and that the land liberated will be of marginal type. It is also assumed that the phasing out of sugar cane will proceed linearly at 630 hectares/annum starting at the end of 2006.

However, it should be noted that approximately 2600 hectares out of the 6300 hectares marginal land that will become available gradually as from 2006 are found in the super-humid zone (highlands). Prior to becoming cultivated with sugar cane, marginal land in the super-humid zone was under tea plantation. Further, part of the ~2600 hectares is also gently sloping. Jatropha plants have poor yield under such conditions, especially when annual rainfall exceeds 600mm in moderate climatic conditions and on slopes greater than 30°.[3]

Therefore, this scenario has provided for either 6300 hectares or 3780 hectares of land suitable for Jatropha plantation. In the latter case, and in the absence of complete information, it has been assumed that the most suitable land for cultivating Jatropha will become available first.

As1.3 Maturity of plants – Plants reach maximum yield in the fifth year after seeds are planted.

As1.4 Diesel displacement – Biodiesel produced from Jatropha oil can be used to replace imported diesel oil. Diesel oil is used in various sectors of the economy, including (1) manufacturing, (2) transport, (3) electricity production, and (4) agriculture. The transport sector holds by far the largest share (~50% in 2005) of

[3] S. Biswas, N. Kaushik and G. Srikanth, Biodiesel: Technology & Business Opportunities – An insight (http://www.tifac.org.in/news/Bioenergy_1.htm - accessed 11 July 2006)

final energy consumption, and consumption of diesel oil in this sector exhibits steadier trends than in a sector like electricity production. Hence, analysis of diesel substitution with biofuel has used the transport sector as a baseline.

As1.5 Valuation of by-products – The ongoing market prices of by-products have been used. The value of press cake as a fertilizer has been taken as Rs 2000/tonne, while that of glycerine has been taken as Euro 410/tonne.

As1.6 Price of biodiesel – In order to calculate revenue from the sale of biodiesel, the price of biodiesel has been taken to be equal to the price of diesel (by volume). Hence, the price used here is the revised price of Rs 30.2/litre. This amounts to Rs 34,318.2/tonne using an average density of 0.88 kg/litre for biodiesel. Typically, a price differential is established between biodiesel and diesel (through various types of subsidies on biodiesel) for the promotion of biofuels. Hence, the assumption that the price of biodiesel is pegged to the price of diesel (by volume) provides an upper limit to the price of the former.

As1.7 Price inflation of biodiesel – A price inflation of 6% has been assumed for biodiesel. This does not take into account the price volatility of diesel oil.

As1.8 Fuel economy of biodiesel – Biodiesel provides 5% less fuel economy than diesel. Given the very low levels of diesel substitution considered here, this difference has been assumed to be negligible.[4]

As1.9 Discount rate for calculating Net Present Value (NPV) – A discount rate of 10% has been used to calculate NPV.

Analysis (Scenario 1)

The physical layout of the Excel Spreadsheet used for modelling Scenario 1 is given in *Appendix 3*.

Area of land under Jatropha cultivation

There are two factors to consider regarding the productive area of land for producing Jatropha fruits (and oil-bearing seeds), namely (1) the phased availability of marginal land, and (2) that there is a delay of five years before plants become mature. Using the yield data given on page 28 of *Appendix 1* (i.e. OUTPUTS OBTAINED FROM JATROPHA CURCAS PLANTATION) and As1.2, the effective productive area of land has been calculated *(see Fig. 2).* In this scenario, plants become mature on the entire 6300 hectares of land only in 2020.

[4] This is a fair assumption for biodiesel/diesel mixtures containing less than 5% by volume of biodiesel (i.e. B5).

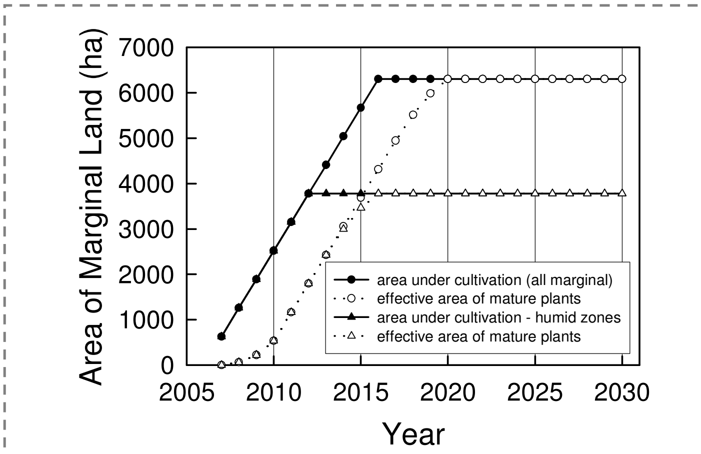

Figure 2. Comparison between area of land under cultivation and effective area coverage with mature plants.

However, only 3780 hectares of land becomes available in 2016 when marginal land found in super-humid and sloping zones are excluded from the analysis.

Import substitution of diesel oil

The percentage import substitution of diesel has been calculated for the transport sector under three different demand conditions. The projected annual increase in the demand for diesel oil has been based on 2-year (1.6%), 5-year (3.25%) and 10-year (5.1%) averages.

An energy context of 23100 kWh per hectare of mature Jatropha plants has been assumed.[5] *Figure 3* shows that the peak displacement, varying between ~1.8 – 3.0% occurs in 2020 corresponding to the year when 6300 hectares of mature plants are harvested. The level of import substitution falls to between ~ 1.4 and ~2.0% (peak in 2016) when considering suitability of only 3780 hectares of land for Jatropha plantation.

[5] The calorific value of diesel oil has been taken to be 12 kWh/kg. A 35wt% oil content in seeds and an 85% oil extraction efficiency have been assumed.

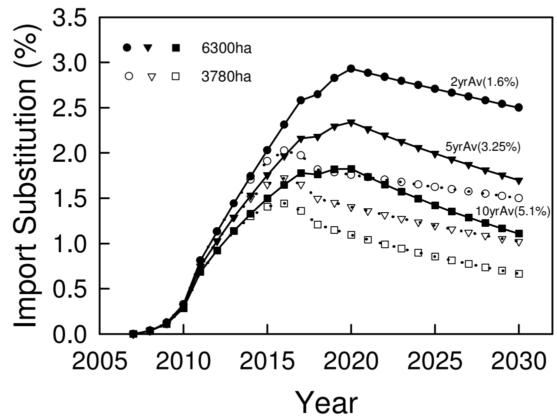

Figure 3. Percentage import substitution of diesel oil under different average growth in the demand of diesel oil in the transport sector. Data points shown in solid and open symbols corresponds to cultivation areas of 6300 ha and 3780 ha, respectively.

Value of diesel oil displaced

The value of diesel oil replaced by biodiesel produced from Jatropha is given in *Figure 4*. The curves shown in solid circles and open circles correspond to a total plantation area of 6300 hectares and 3780 hectares, respectively. The baseline cost of diesel has been taken as the average importation cost (inclusive of freight and insurance) of one tonne of diesel in 2005. Further a cost inflation of 6% per annum has been assumed.

The value of diesel oil displaced by biodiesel has to be qualified. First, the volatility of the price of oil may imply price inflation significantly different from 6% per annum. This was witnessed recently when the price of diesel oil (Rs/tonne) increased by 51% from 2004 to 2005. Second, the value of price of oil does not translate into net economic savings since capital investments have to be made in order to produce, store and distribute the biodiesel.

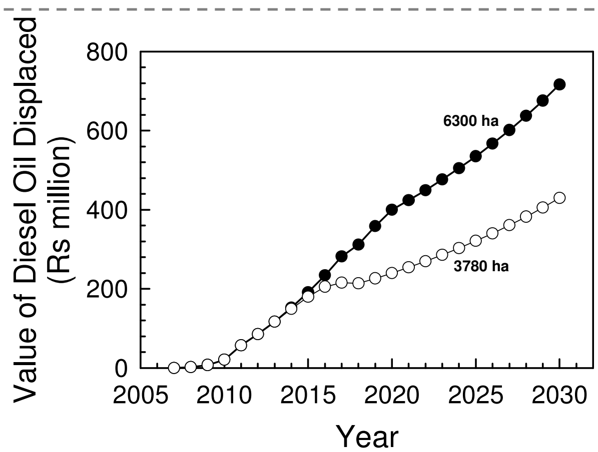

Figure 4. Value of diesel oil displaced by biodiesel.

Valuation of by-products

Two by-products – i.e. press cake and glycerine - have been investigated here. Press cake is the by-product of the oil extraction process, while glycerine (glycerol) is a by-product of the transesterification process of converting oil into biodiesel. Press cake obtained from Jatropha seeds cannot be used as animal feed because of its toxicity *(see Appendix 1)*. Here the value of press cake is taken to be Rs 2000/tonne (i.e. USD 60/kg),[6] while the price of glycerine is taken as Rs 16,400/tonne (i.e. Euro 410/tonne).[7] The revenue from these by-products is shown in *Figure 5*, inclusive of a price inflation rate of 6% per annum.

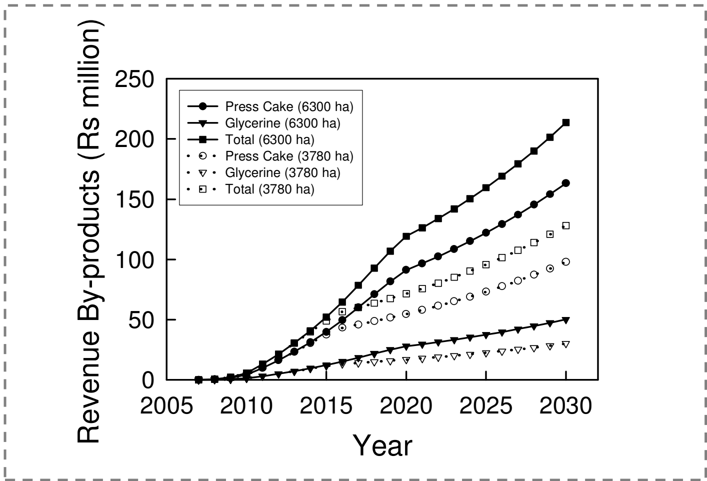

Figure 5. Revenue from by-products (press cake & glycerine). Data points shown in solid and open symbols correspond to a cultivation area of 6300 hectares and 3780 hectares, respectively.

Environmental benefits

Biodiesel provides several benefits, including lower emissions of particulate matter and being carbon-neutral.[8] The lower particulate emissions results in lower levels of air pollution that have positive impacts on health. For instance, pulmonary disorders and asthma are closely linked to air pollution. In this analysis, the health benefits accruing from the use of biodiesel have not been accounted for because it is difficult to quantify the decrease in air pollution through ~1.4 – 3% diesel oil substitution, and to link small improvements in air quality on population health.

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[6] Corresponds to rentability of mineral fertilizer (see Handbook of Jatropha Curcas at www.fact-fuels.org, pg. 13).
[7] Taken from Glycerine (Europe) Price Report – Chemical pricing information – ICIS Pricing (www.icispricing.com/il_shared/Samples/).
[8] Biodiesel usually has a higher CO_2 emission than diesel because of its higher oxygen content. However, this should not be taken into account since biodiesel production from oil-bearing plants is a C-neutral process. Further, the overall consumption can be considered as ~5% higher for biodiesel – i.e. lower calorific value of biodiesel. However, this difference becomes negligible when considering biodiesel: diesel blends.

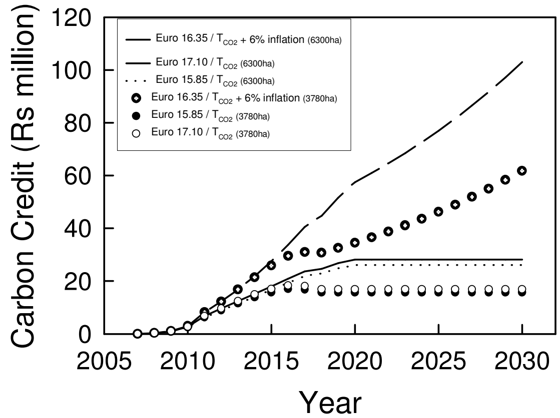

Figure 6. Carbon credit from diesel substitution. Curves shown in lines are for a cultivation area of 6300 hectares, while curves shown in symbols correspond to a plantation area of 3780 hectares.

Rather the carbon credit that can be obtained through CO_2 emissions trading has been computed for three situations *(see Figure 6)*.[9] The curves shown in lines are for an area of 6300 hectares, while data shown by symbols correspond to a cultivation area of 3780 hectares. The price of CO_2 on the EU market has fluctuated between ∊ 15.85 and ∊ 17.10 per tonne recently. Based on these values, and assuming no price inflation, credits amounting to Rs 26 - 28 million can be obtained per annum after 2020 from cultivation over 6300 hectares (Rs 15.8 – 17 million when area cultivated is 3780 hectares).[10] Assuming an initial price of ∊16.35/tonne CO_2 and a 6% price inflation per annum, the return from C-trading for cultivation on 6300 hectares may reach the Rs 100 million/year mark by 2030 (or Rs 61.8 million/year by 2030 for an area of 3780 hectares).[11]

Social benefits

The social benefits accruing from the plantation of Jatropha and production of biodiesel are direct and indirect. The direct benefits include the increased capacity for employees in the sector to meet their needs by earning disposable income. There are also secondary benefits that take a plethora of forms including, the increase of self-esteem by contributing positively to society, and the reduced likelihood of negative externalities such as thefts, alcoholism and drug abuse. Further, the worth to society on any enterprise will also depend on the objectives of that society – i.e. to what ends will the economic development of a country be put to – and examples

[9] The amount of CO_2 produced in the combustion of 1 litre of diesel is 2.698 kg CO_2 (0.73583tC/m^3 * 1m^3/1000L * 44tCO_2/12tC, where t = tonne), following the methodology used by the Intergovernmental Panel on Climate Change (IPCC).

[10] Data obtained from Point Carbon website (www.pointcarbon.com, accessed 18 September 2006). A further assumption is the invariable exchange rate between the Mauritius Rupee (MUR) and the Euro (Eur). Depreciation of MUR relative to Eur, with everything else being equal, will only increase the absolute values of C-credit given in Figure 5.

[11] Carbon trading is in its infancy, but it is generally recognised that the increasing pressure for greenhouse gas emissions abatement in order to mitigate climate change will become a significant driver for the price of carbon. The factors that influence the price of carbon are discussed at (www.pointcarbon.com/wimages/Carbon_Market_Analyst_special_Oct_823767.pdf).

could be the equitable distribution of wealth or further investment in the welfare state. Because of all of these considerations, a shadow price is used normally to evaluate social benefits. Given data concerning many of the above factors are incomplete, a shadow price of Rs 162.50 per person hour has been used here. This represents the average labour hour for men and women in the agricultural sector. An inflation rate of 6% has been given to the shadow price. The valuation of social benefits is given in *Figure 7*.

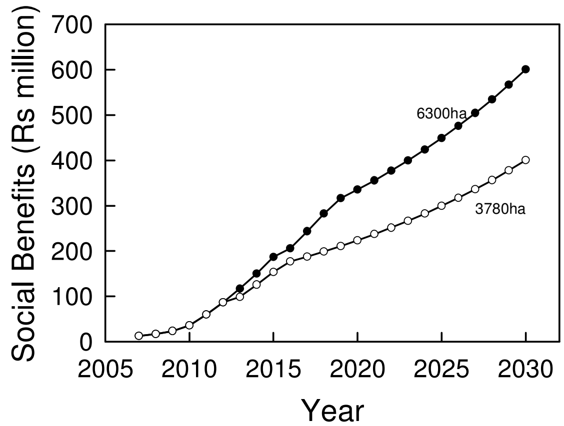

Figure 7. Social benefits from Jatropha cultivated over an area of 6300 hectares (solid circles) or 3780 hectares (open circles).

Net Present Valuation

The Net Present Value (NPV) and net cash flow from this scenario has been conducted under two conditions: (1) including only economic benefits, and (2) including economic, social and environmental benefits discussed above. The calculation of NPV uses a discount rate of 10% per annum.

The total cost of biodiesel production and the total revenue are the same in both cases. The total cost of biodiesel production includes capital and processing costs, as well as the opportunity cost of land and capital. Processing costs cover (1) cultivation of Jatropha, (2) extraction of oil from seeds, and (3) cost of biodiesel production. The opportunity cost of land has been taken as Rs 31,330/hectare, corresponding to an average of all types of agricultural land rent. Interest paid on capital has been taken as 7.5% per annum. Total revenue includes receipts from sale of biodiesel and all by-products (i.e. press cake and glycerine).

Economic Benefits *(with or without including the value of by-products)*

Figure 8 shows the time evolution of the Present Value – i.e. the difference between revenue and cost that has been discounted at a rate of 10% per annum – of producing biodiesel through cultivation of Jatropha without accounting for social and environmental benefits. The curves shown in solid and open symbols correspond to cultivation areas of 6300 hectares and 3780 hectares, respectively. The plots of economic benefits without the inclusion of the value of by-products (i.e. glycerine and press cake) are shown in triangles.

The Net Present Value (NPV) of producing biodiesel from Jatropha cultivation is ~Rs 127 million and ~Rs 181million for 6300 hectares and 3780 hectares, respectively, when the value of by-products is not included. The NPV is increased by approximately four times when the value of by-products is included. These results are summarized in *Tables 1* and *2*.

The positive NPVs reported here should not be regarded as sufficient to decide in favour of cultivating Jatropha in Mauritius for the reasons discussed under the section '**Discussions**'.

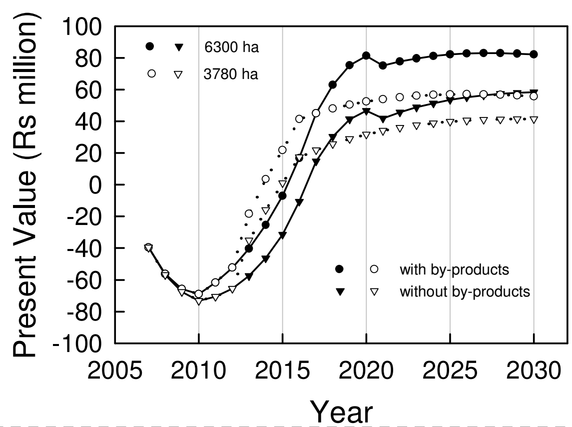

Figure 8. Present value of producing biodiesel from Jatropha cultivated in Mauritius without including social and environmental benefits. Data are given for cultivation areas of 6300 hectares and 3780 hectares, and with or without the inclusion of the value of by-products.

Economic + Social + Environmental benefits

The situation obviously changes when social and environmental benefits are included in the analysis *(Figure 9)*. Obviously, the NPVs increase quite significantly when the social and environmental benefits are accounted for. For instance, the inclusion of social and environmental benefits increases the NPV by a factor of 3.5-3.7 when the value of by-products is also included (or a factor of 11.5-11.9 when value of by-products are excluded) compared to the case when social and environmental benefits are not considered. Please see *Tables 1* and *2* for summary of results.

The fact that the NPVs (for both areas of land under cultivation) increase substantially when social and economic benefits are included should be further qualified. This is because private investors rarely make investment decisions based on the concept of the "common good" as will be further discussed below.

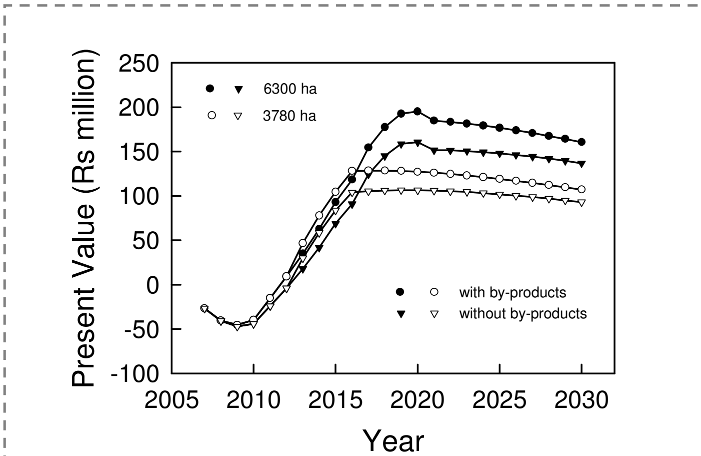

Figure 9. Present value of producing biodiesel from Jatropha cultivated in Mauritius after including social and environmental benefits.

Tables 1 and *2* summarize the NPV for the production of biodiesel up to 2030 both with or without social and environmental benefits, and with or without accounting for by-products for a cultivation area of 6300 hectares or 3780 hectares, respectively.

Table 1. Net Present Value for biodiesel production from Jatropha planted on 6300 hectares.

Social & Environmental benefits (included or excluded)	Value of by-products (included or excluded)	Net Present Value, NPV (Rs)
Excluded	Included	747,793,153
Included	Included	2,612,805,054
Included	Excluded	2,079,580,308
Excluded	Excluded	181,298,422

Table 2. Net Present Value for biodiesel production from Jatropha planted on 3780 hectares.

Social & Environmental benefits (included or excluded)	Value of by-products (included or excluded)	Net Present Value, NPV (Rs)
Excluded	Included	514,589,089
Included	Included	1,885,156,853
Included	Excluded	1,517,822,618
Excluded	Excluded	127,292,863

SCENARIO 2

Introduction

This scenario investigates the production of **biodiesel (biofuel) from importation of raw materials**.

Assumptions

As2.1 Raw materials – The scenario allows for the production of biodiesel from a combination of imported oil and Jatropha seeds from which oil is extracted locally.

As2.2 Equivalence between diesel and biodiesel – A factor of 0.7885 has been used to convert unit mass of biodiesel to diesel. This factor takes into account (1) conversion from volume to mass (density of diesel); (2) difference between densities of diesel and biodiesel; and (3) that fuel economy decreases by 5% when biodiesel is used.

As2.3 Value of by-products – These are the same as in Scenario 1.

As2.4 Cost of oil extraction and biodiesel processing – Same as in Scenario 1.

As2.5 Volatility of price of oil – Based on the previous trends, the price volatility of imported vegetable oil has been assumed to be insignificant. A price of Rs 18,500/tonne of oil has been used for the year 2007 (based on the average price of oil for 2005).

As2.6 Type of oil used for biodiesel production – It is assumed that a wide range of edible oil can be used as input to biodiesel production. In fact, there are flexible biodiesel plants that can accommodate a wide range of vegetable oil feedstocks.[12]

As2.7 Price of biodiesel – It is assumed that the biodiesel will sell at the ongoing market price of diesel oil – i.e. Rs 34,318/tonne.

[12] Philip Wood, Out of Africa – could Jatropha vegetable oil be Europe's biodiesel feedstock?, Refocus July/August 2005, pp.40-44.

Analysis (Scenario 2)

This analysis has been done for the year 2007 only. This is sufficient to demonstrate the pertinent aspects of biodiesel production from imported raw materials. Obviously, the model can be further developed to over the same time period as Scenario 1 if required.

The model allows for the production of biodiesel from a mixture of oil derived from (1) Jatropha seeds and (2) vegetable oil imported in 'ready-to-be-used' form (i.e. neat vegetable oil). Further, the percentage substitution of diesel in the transport sector can be varied. The physical layout of the Excel Spreadsheet used for modelling Scenario 2 is given in *Appendix IV*.

Producing biodiesel solely from imported vegetable oil

Breakeven price of imported vegetable oil

Parameters related to Jatropha seed are irrelevant in this situation. The breakeven price when revenue from sales of biodiesel is equal to its cost of production has been computed as a function of the percentage substitution of diesel. As expected, the breakeven price of oil is not sensitive to the percentage substitution of diesel. It is found to be around Rs 24,828/tonne of imported oil at current market price of diesel. Considering the cost of biodiesel production and the assumptions made above, it is viable to produce biodiesel so long that the price of imported oil is below this breakeven price. Obviously, the breakeven price of oil will increase if the price of diesel increases. *Figure 10* shows how the breakeven price of imported vegetable oil changes as a function of the cost of diesel oil.

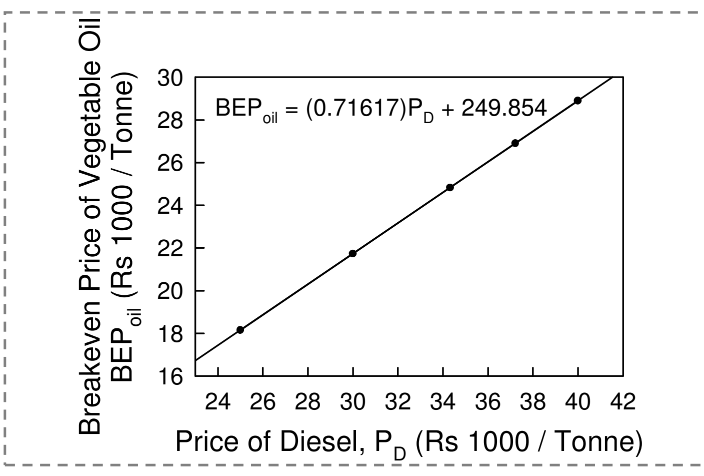

Figure 10. Variation of the breakeven price of imported vegetable oil as a function of the price of diesel.

Revenue minus cost of production

Table 3 summarises the difference between revenue (R) and cost (C) of biodiesel production for 2007 as a function of the percentage diesel oil substitution. There is a linear relationship between (R-C) and percentage diesel oil substitution – in fact, (R-C) = 30778402 x percentage diesel oil substitution.

Table 3. (R-C) as a function of percentage diesel oil substitution.

Diesel Substitution (%)	3	5	10	20
(R-C), Rs	92,335,207	153,892,012	307,784,024	615,568,047

Producing biodiesel from a mixture of imported vegetable oil & Jatropha seeds

Breakeven price of imported Jatropha seeds

The price of imported oil has been assumed to be fixed at Rs 18,500/tonne. The breakeven price of Jatropha seeds has been computed as a function of different ad-mixtures of vegetable oil/Jatropha oil extracted from imported Jatropha seeds, and for different prices of biodiesel (assuming that the price of biodiesel will be the same as the ongoing market price of diesel oil). The results are shown in *Figure 11*.

The breakeven price is sensitive to both the percentage of imported vegetable oil in the production of biodiesel and the price of diesel, especially at the higher percentage values of imported vegetable oil. The data points were not sensitive to the percentage substitution of diesel oil in the transport sector. The horizontal solid line represents a moderate market price quoted for Jatropha seeds.[13] It is not sensible to import Jatropha seeds for biodiesel production when the price of diesel reaches ~Rs 30,000/Tonne, which is already the case. The market price for Jatropha seeds could be even higher. A much higher price of US$ 380/50 kg (i.e. Rs 249,835/tonne) for Jatropha seeds has been used in Appendix I to calculate the cost of producing seeds from Jatropha plants in Mauritius.[14] The reason for this extremely high price of seeds could be because of high quality, high germination rate of seeds needed for cultivation purposes. Such high quality seeds may not be required for oil extraction and biodiesel production.

[13] A recent article has quoted a price on Jatropha seeds of Rs26/kg in India (www.thehindubusinessline.com/2006/09/06/stories/2006090603420800.htm). Until 2 years ago, the price of Jatropha seeds was around Rs 6/kg. The surge in the price of seeds reflects the shortage of seeds on the market. The solid line in Figure 2.1 corresponds to Rs 22,464/tonne of seeds. This value includes an additional 20% for c.i.f. and following an exchange rate of 0.72 between the Indian and Mauritian Rupees.

14 Private communication between AREU and Mr R Anand Kumaar, Jarveer Trader/Tao Media.

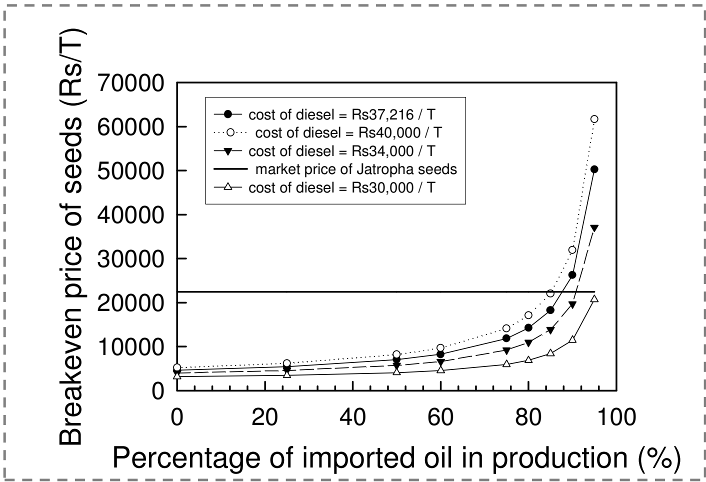

Figure 11. Breakeven price of imported Jatropha seeds as a function of the percentage of imported vegetable oil in the production process. The solid line represents the ongoing market price of Jatropha seeds.

DISCUSSIONS

Scenario 1

This study has found that the production of biodiesel from Jatropha plants (seeds) cultivated in Mauritius has a positive Net Present Value (NPV) (see values listed in *Tables 1 and 2*). **The positive NPV should not be taken as a forgone conclusion that the cultivation of Jatropha on marginal land for biodiesel production is viable**. The positive NPV reported here has to be further qualified.

1. This study has assumed an average maximum yield of seeds from Jatropha cultivations. Further, two areas of marginal land available for planting of Jatropha have been considered, giving upper (6300 hectares) and lower (3780 hectares) boundary situations. An accurate determination of yield of Jatropha seeds (and therefore oil) can only be made after establishing thoroughly the quality and topography of marginal land suitable for Jatropha plantation. This would require developing a dedicated Geographical Information System (GIS). Based purely on economic benefits (i.e. excluding social and environmental benefits), the NPV can vary from ~Rs 127 million to ~Rs 748 million, depending on whether the value of by-products is included or not. The inclusion of social and environmental benefits is further discussed at 6 below;

2. Before deciding whether Jatropha can or should be cultivated in Mauritius, **due consideration should be given to whether there are sustainable transport measures that can be implemented that would result in the reduction of energy consumption in the transport sector** (i.e. reduction between ~1.4% and ~3.0% of diesel consumption) without adversely affecting mobility and accessibility (leaving marginal land for other uses). This exercise would call for a review of the transport sector;

3. A ***critical factor*** that will have a significant bearing on NPV (i.e. the economic feasibility of scenario 1) is the ***opportunity cost of land*** (or rentability of land). A definitive answer to this can only be had after studying all the potential alternative uses of marginal land. **It is conceivable that there are other projects that provide higher opportunity costs of land than what has been used in this study**. The Integrated Resort Scheme (IRS) is such an example.

   Further, as far as biodiesel production is concerned, there could be **other options such as plantation of alternative oil-bearing fruits like pongamia or palms** that may potentially yield higher NPVs. Alternative uses of land for planting vegetables or setting up integrated farms should also be given due consideration. Recently, there has been a report that Japan has developed a new variety of sugarcane called the 'Monster Cane' that, compared to conventional cane varieties, increases yield more than two-fold. When processed, the 'Monster Cane' produces 7.1 tonnes of sugar, 4.3 kilolitres of ethanol, and 24 tonnes of bagasse compared to 6.9 tonnes of sugar, 1.4 kilolitres of ethanol and 7.8 tonnes of bagasse from conventional sugarcane.[15] The future introduction of such variety of cane on marginal land in Mauritius should not be ruled out.

   The opportunity cost of land is a critical parameter to consider. In order to illustrate this, *Table 4* illustrates the change in NPV when the opportunity cost of land is varied for Jatropha cultivation on 6300 hectares. The market price of diesel has been taken as Rs 34,318 / tonne. Under the assumptions used here, the NPV (considering only economic benefits) becomes negative when the annual cost of land per hectare exceeds Rs 65,674. The opportunity cost of land when NPV becomes zero has been called the "economic" value of land. Further, the variation of the "economic" value of land with changing price of diesel has been investigated as summarized in *Table 5*. As expected, an increase in the price of diesel increases the "economic" value of marginal land;

[15] Aya Takada, Japan brewer pursues 'Monster Cane' ethanol dream (http://news.yahoo.com/s/nm/energy_japan_biofuel_ethanol_dc;_ylt=AionZswLCfKnT.EFK4wiYjUbr7sF;_ylu=X3oDMTA0cDJlYmhvBHNlYwM – accessed 18 October 2006).

Table 4. NPV for different rentability of marginal land.

Cost of land (Rs / ha)	NPV (excluding social & environmental benefits) for 6300 ha, Rs million
31,330	747.8
45,000	450.2
65,674	~0
70,000	-94.2
100,000	-747.4

Table 5. "Economic" value of land and the price of diesel.

Price of diesel (Rs / tonne)	"Economic" value 6300 ha of land (Rs / ha)
25,000	13,055
30,000	41,287
34,318	64,674
40,000	97,752
45,000	125,984

4. The fact that a large proportion of marginal land is owned by numerous and geographically dispersed planters should add to the costs of producing biodiesel. Firstly, the transaction costs of dealing and obtaining consensus between these owners can be expected to be high. Secondly, the geographical spread of small plots of land will (1) increase transportation costs, and (2) place a limit on economies of scale. *These costs have not been included in this study*;

5. There is also the question of "who bears the burden of investing in a biodiesel plant?" that has to be answered;

6. Resilience will have to be built in the system to provide a guarantee to potential Jatropha planters to deal with adverse conditions like damage to crops by cyclones. Further, resilience will have to be built over the entire value chain. For instance, it will have to be made clear what will be the economic benefits to

planters, oil extractors, biodiesel producers, any other intermediaries and the consumers. For instance, it has been assumed here that the cost of biodiesel is equal to that of diesel by volume. This assumption yields maximum revenue for sales of biodiesel. However, the cost of biodiesel (and biofuels in general) is usually lower than that of diesel oil in order to reduce "switching costs" between the two liquid fuels. Schemes such as lower excise duty or subsidies on biodiesel are typically used for promoting the switch to biodiesel. The regulatory and policy frameworks for promoting biofuels are currently lacking in Mauritius;

7. It should be born in mind that entrepreneurs invest in projects that make economic sense, and, in general, do not do so for the common good – i.e. broader social and environmental benefits. To reap these additional benefits, which are mostly positive externalities, entrepreneurs or investors need to be given fiscal and economic incentives;

8. Mauritius has extensive grid coverage. Therefore, the requirement for local energy production from oil is not an imperative as it may be in rural areas of Africa and Asia. That is, the growing of Jatropha (or any other oil-bearing plant) for energy self-sufficiency at the local level is not what is being considered here; and

9. Since **this report is not a business plan**, items like constructions/buildings and cost of utilities, have not been taken into account.

Scenario 2

The results in *Figure 11* reveals that, based on the assumptions used in this report, the production of biodiesel from a mixture of imported vegetable oils and oil extracted from imported Jatropha seeds is economically viable when the percentage of vegetable oil in biodiesel production is above 88%, and as long as the price of diesel is above ~Rs 30,000/tonne. Considering the higher price of Jatropha seeds than imported vegetable oil, it is not economically viable to import the seeds for producing biodiesel. However, this conclusion will change according to the market price of seeds. The importation of Jatropha seeds will make economic sense when the total cost of producing Jatropha oil from imported seeds is less than Rs 18,500/tonne of Jatropha oil extracted.

Alternatively, producing biodiesel from purely imported neat vegetable oil is economically viable as long as the price of diesel is above ~Rs 25,500/tonne (see *Figure 10*).

Discussions

Based on the assumptions used in this study, the production of biodiesel from imported neat vegetable oil appears to be more favourable that either the local cultivation of Jatropha or the importation of Jatropha seeds for oil extraction in Mauritius. The production of biodiesel from imported Jatropha seeds will become viable only if a reliable and cheap source of seeds is secured, which does not appear to be the case from desk research.

One important consideration when making specific energy policies, such as the introduction of biofuels as an alternative to diesel oil in the transport sector, is the parallel focus on sustainable mobility measures aimed at enhancing the overall energy efficiency of the transport sector.

APPENDIX 1

This appendix describes the entire value chain for biodiesel production. It covers the cultivation of Jatropha to oil extraction to the transesterification process used for biodiesel production.

Cultivation of **Jatropha curcas**

Introduction

Jatropha is a plant of Latin American origin, which is now widespread throughout the arid and semi-arid tropical regions. It is a member of the Euphorbiaceae family. It is a plant that can grow almost anywhere even on gravelly, sandy, saline and marginal soils but not under waterlogged conditions. It has hardly any special requirements with regard to climate except that it is not adapted to cool and super-humid areas. It was originally grown for several reasons: firstly as a live fence to keep away animals from compounds and plantations, as they do not graze on the plant parts which are toxic. Secondly, it was used to stabilize soils in erosion-prone areas. Nowadays, it is being grown in a few countries for soap making and for bio-diesel production, with the aim of providing income to the rural poor. In Madagascar and previously in Mauritius, it is used as a support for vanilla.

Cultivation of Jatropha is however labour oriented. The major tasks for which a high intensity of labour is required are:

1) Plantation
2) Maintenance
3) Seed harvesting

An estimate of inputs required for the first five years of plantation is given in Tables below. Above 5 years, the costs of inputs are considered to be more or less stable as the yield stabilizes.

Plantation is started from seedlings instead of cuttings as pre-cultivation of Jatropha seedlings in poly-ethylene bags is stated to accelerate the establishment of a plantation by at least 3 months.

Inputs for Jatropha curcas/*hectare*

Assumptions:

1. 50 kg of jatropha seeds cost $380 USD
2. No of hours necessary to irrigate 3000 bags is 1 hour at nursery stage
3. Transplantation plots are rainfed
4. Weeding is done two times/year using herbicide Basta
5. No of hours necessary to harvest seeds is 125/tonne
6. An increase of 5% in price of herbicide & fertiliser per year

1st Year

In Nursery

Items/Operations	**Amount/ hectare**	**Cost/unit**	**No of mandays/ hectare**	**Total cost/ hectare**
Planting materials - Seed	5 kg	Rs 225/kg		Rs 1,125
Polyethylene bags	3000 units	Rs 1.15		Rs 3,450
Manure + transport	600 kg	Rs 100/tonne		Rs 400
Preparation of soil mixture + Filling of bags + Sowing of seeds	3000 bags	Rs 125/ womanday	15	Rs 1,875
Irrigation for 3 months	3000 bags	Rs 200/ manday	22.5	Rs 4,500
Weeding/month	3000 bags	Rs 125/ womanday	9	Rs 1,125
Total cost				**Rs 12,475**

In Transplantation plot (2500 plants/hectare)

Items/Operations	**Amount/ hectare**	**Cost/unit (Rs)**	**No of mandays/ hectare**	**Total cost per hectare**
Land preparation – leveling, staking	1 hectare	Rs 200/ manday	15	Rs 3,000
Digging of holes of 30 cm^3 size	2500 holes	Rs 200/ manday	25	Rs 5,000
Cost of fertilizer – 13:13:20:2 (50g/pit)	125 kg	Rs 425/50 kg		Rs 600
Top dressing with 25 Kg N/ha	50 kg	Rs 465/50 kg		Rs 465

No of womandays for application fertiliser		Rs 125/ womanday	3	Rs 375
Transportation of seedlings from nursery to field	2500			Rs 300
Mixing of manure, fertilisers, transplanting seedlings & refilling of pits	2500 seedlings	Rs 125/ womanday	25	Rs 3,125
Chemical weeding	3 lt/ hectare	Rs 335/lt		Rs 1005
No of mandays for application of herbicides		Rs 200/ manday	4	Rs 800
Total cost				**Rs 14,670**

Total cost for 1st year: 27,145

2nd Year

Items/Operations	**Amount/ hectare**	**Cost/unit (Rs)**	**No of mandays/ hectare**	**Total cost per hectare**
Cost of fertilizer – 13:13:20:2 (25 g/pit)	62.5 kg	Rs 446/50 kg		Rs 558
Top dressing with 25 Kg N/ha	50 kg	Rs 488/50 kg		Rs 488
No of womandays for application of fertiliser		Rs 125/ womanday	1	Rs 125
Pruning of plants	2500 plants	Rs 200/ manday	10	Rs 2000
Chemical weeding	3 lt/hectare	Rs 352/lt		Rs 1055
No of mandays for application of herbicides	1 hectare	Rs 200/ manday	4	Rs 800
Cost of harvesting seeds	500 kg	Rs 125/ womanday	16	Rs 2000
Total cost				**Rs 6234**

3rd Year

Items/Operations	Amount/ hectare	Cost/unit (Rs)	No of mandays/ hectare	Total cost per hectare
Cost of fertilizer – 13:13:20:2 (25 g/pit)	62.5 kg	Rs 468/50 kg		Rs 585
Top dressing with 25 Kg N/ha	50 kg	Rs 510/50 kg		Rs 510
No of womandays for application of fertiliser		Rs 125/ womanday	1	Rs 125
Chemical weeding	3 lt/hectare	Rs 370/lt		Rs 1110
No of mandays for application of herbicides	1 hectare	Rs 200/ manday	4	Rs 800
Cost of harvesting seeds	1250 kg	Rs 125/ womanday	39	Rs 4,875
Total cost				**Rs 7005**

4th Year

Items/Operations	Amount/ hectare	Cost/unit (Rs)	No of mandays/ hectare	Total cost per hectare
Cost of fertilizer – 13:13:20:2 (25 g/pit)	62.5 kg	Rs 490/50 kg		Rs 615
Top dressing with 25 Kg N/ha	50 kg	Rs 540/50 kg		Rs 540
No of womandays for application of manure and fertiliser		Rs 125/ womanday	1	Rs 125
Chemical weeding	3 lt/hectare	Rs 390/lt		Rs 1170
No of mandays for application of herbicides	1 hectare	Rs 200/ manday	4	Rs 800
Cost of harvesting seeds	2500 kg	Rs 125/ womanday	78	Rs 9,750
Total cost				**Rs 13,000**

5th Year

Items/Operations	**Amount /hectare**	**Cost/unit (Rs)**	**No of mandays/hectare**	**Total cost per hectare**
Cost of fertilizer – 13:13:20:2 (25 g/pit)	62.5 kg	Rs 516/50 kg		Rs 645
Top dressing with 25 Kg N/ha	50 kg	Rs 565/50 kg		Rs 565
No of womandays for application of manure and fertiliser		Rs 125/ womanday	1	Rs 125
Chemical weeding	3 lt/hectare	Rs 410/lt		Rs 1230
No of mandays for application of herbicides	1 hectare	Rs 200/ manday	4	Rs 800
Cost of harvesting seeds	5000 kg	Rs 125/ womanday	156	Rs 19,500
Total cost				**Rs 22,865**

Outputs obtained from **Jatropha curcas** *plantation*

Assumption: 3-4 kg of seed yields 1 kg of oil

Year	**Yield of seed (kg/hect)**	**Amount of oil extracted (kg)**	**Amount of press cake (kg)**	**Amount of glycerol (kg)**
1				
2	500	143	320	12
3	1250	357	800	30
4	2500	714	1600	60
5	5000	1429	3200	120
>5	5000	1429	3200	120

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Jatropha oil extraction

Outline of Process

Jatropha fruits

↓

Decorticator

Jatropha seeds

↓ ***Hand press/ oil press/ mechanic oil expeller***

Jatropha oil

↓ ***Biodiesel plant (mix with sodium methoxide to produce biodiesel)***

Biodiesel

Biology of Jatropha fruits and seeds

Fruits

After pollination, a trilocular ellipsoidal fruit is formed. The exocarp remains fleshy until the seeds are mature. Fruits are egg-shaped capsules, initially green but eventually turning dark brown or black. They split into three parts at maturity, releasing the seeds *(Ecoport website)*

Note: The fruits may be dried under full sun conditions to release the seeds for oil extraction at a later stage.

Seeds

The fruit releases three large black carunculate seeds (nuts), each about 2 cm long and 1 cm in diameter. The caruncule is rather small. Average 1000 seeds weigh 500g. The shell is about 43% of the seed and the kernel 57%, of which 30% is crude fat *(Ecoport website)*

Proximate analysis undertaken on local Jatropha curcas seeds by the Agricultural Chemistry Division, Min. of Agro-Industry, has revealed a % fat content of 31 – 33%.

Harvesting Jatropha fruits

Fruits (capsule) of Jatropha can be harvested at three stages of maturity: green [approaching to maturity, 47 days after anthesis (DAA)], yellow (mature, 57 DAA) and brownish black (ripened, 67 DAA). Storage period of the seeds (3 months) did not affect their germination percent and vigour index, implying the seeds are still viable after this period of time *(Kaushik, 2003)*.

In practice, black fruits are collected, dried until all fruits open and the seeds are then separated from the capsules. Alternatively, the unopened fruits can be placed in gunny/jut/raffia bags, on which one can step on repeatedly over a hard surface in order to release the seeds.

Fruit Decortication/Breaking

Decortication or dehulling is referred to as the separation of the oil bearing part of the plant be it a nut, fruit or seed from the non-oil bearing parts (shells/exocarp/capsules). Seeds with thin testa similar to rapeseeds can be processed without decortication *(FAO, 1992).*

In most cases of oil extraction, the oil-bearing materials (seeds) are often broken into smaller pieces by:

1) pounding in a pestle and mortar; or
2) motorised grinding

When motorised oil expellers are used decorticated or undecorticated materials can often be fed directly to the expeller *(FAO, 1992)*

Jatropha fruits (capsules), when black, can release the seeds readily after drying under sun. Please refer to section 2.0

Pre-treatment of seeds prior to oil extraction

To prepare seeds for oil extraction, they should be heated, either in full sunlight on a black plastic sheet for several hours or in a roasting pan for 10 mins. This process breaks the cells containing the oil, permitting an easy oil extraction. The heating process also liquefies the oil, which improves oil extraction *(Henning, 2000)*.

Locally, black plastic mulch sold by suppliers of hydroponics systems may be used in regions of high temperatures and high light intensity (Northern or Western parts of our island). Alternatively, low-cost ovens can be utilized.

Coming to the oil extraction process, a lever-operated press (manual) was used for oil extraction *(Henning, 2000).* The press consists of a hopper, piston, cage and an outlet. Full details of these are given in *Appendix 1*.

Other techniques for oil extraction

Suitable presses are not available for extraction of oil from Jatropha seeds *(Openshaw, 2000)*. Oil extraction though the use of organic solvents and water have been the main approaches.

Shah, Sharma and Gupta (2003) have reported on the extraction of oil from Jatropha curcas seeds by utilising a combination of ultrasonication and aqueous enzymatic oil extraction. Ultrasonication as a pre-treatment for 5 – 10 minutes at pH 9.0, before aqueous and enzymatic oil extraction resulted in high yield of oil (67 – 74% on a weight by weight basis). Ultrasonication also reduced process time from 18 h to 6 h. Use of aqueous oil extraction only at different temperatures resulted in an oil yield of 17 – 21 % (w/w).

While the work by *Shah et al (2003)* has focused on an advanced technique for oil extraction, the later method has to be further elaborated prior to commercial application. Commercially, traditional methods, as outlined above, are being used.

In contrast, *Henning (2000)* reported that Jatropha seeds contain 32 – 35% oil (methodology of extraction not detailed). In the same report, it was mentioned that using mechanic oil expellers such as the Sundhara press, 75 – 80% of the oil could be extracted (possibly 75 – 80% of the total oil content of the seeds). The Yenga hand press would result in about 60 – 65% yield of oil (5 kg of seeds will give about 1 litre of oil). Though the procedures, outlined in *Henning (2000)*, do not include enzymatic oil extraction and/or ultrasonication, high oil yield has been obtained (up to 80%) through simple methods.

Purification of oil

There are three ways to purify the oil:

- **Sedimentation**

  This is the easiest way to get clear oil, but it takes up to one week until the sediment is reduced to 20 - 25% of the volume of the raw oil.

- **Boiling with water**

  The purification process can be accelerated tremendously by boiling the oil with about 20% of water. The boiling should continue until the water has evaporated (no bubbles of water vapour anymore). After a short time (a few hours) the oil then becomes clear.

- **Filtering**

  Passing the raw oil through a filter is a very slow process and has no advantage in respect of sedimentation. It is not recommended.

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Production of Biodiesel

Biodiesel is the common name of product that has properties that are somewhat similar to that of and are compatible with fossil diesel. The technical definition of biodiesel – "a fuel comprised of non-alkyl esters of chain fatty acids derived from vegetable oil or 35 animal fats, designated as B100, and meeting the requirements of ASTM D 6751"(11). It is also referred to as Fatty Acid Methyl Ester (FAME**)** or Fatty Acid Ethyl Ester (FAEE) or in Europe Rape Methyl Ester (RME) when it is made from oil of rapeseed. Biodiesel can be used in neat (unblended) form in applications where diesel is used or blended with diesel by simple process of mixing in desirable ratios. A blend percentage of up to 20% is most common as various standards, oil companies and vehicle/engine and their component manufacturers accept it.

Technical advantages and benefits of biodiesel

Biodiesel has a high octane number that improves engine performance, high lubricity that reduces wear and tear, low content of sulphur, aromatics and other toxics. It reduces emissions of Carbon Monoxide, Hydrocarbons, Poly Aromatic Hydrocarbons (PAH), Particulate Matter, and Sulphur Dioxide etc. It mitigates the effects of climate change and green house gases (GHGs) by reducing the addition of Carbon Dioxides to the atmosphere thereby contributing to realization of goals of the Kyoto Protocol. Each tonne of biodiesel reduces Carbon Dioxide to the extent of 2.51 tonnes and thereby offering opportunity to trade in Carbon and earn foreign exchange (12).

Processes for the manufacture of biodiesel

There are a number of processes for undertaking transesterification of vegetable oil including:

- Alkaline Process
- Acid Process
- Catalyst free supercritical Process

The most popular commercial process followed at present is the alkaline process. In case the plant size is small it may be advisable to produce batch wise, which is easier to operate and is less automated but has higher manpower requirement. For larger plants continuous production is recommended in which continuous reaction takes place when producing biodiesel.

Process description in brief

The process of production of biodiesel involves reaction of vegetable oil with methanol or ethanol employing a catalyst such as sodium or potassium hydroxide. In this process the reaction that takes place is called transesterification, which results in formation or biodiesel and glycerol (glycerin). The methanol present in the glycerin phase is removed by distillation and glycerin concentrated by removal of water. The biodiesel is separated from the glycerin of higher density by settling or centrifuging. The glycerin in crude form 36 can be processed and distilled to make various grades of glycerin that can be sold to various consumers. A water wash may be given to biodiesel to remove impurities from it including methanol, catalyst and any remaining free glycerin. It is then distilled to remove the methanol and also to remove the water and final traces of glycerin. A simplified process flow diagram is given in *Figure 12*.

Although it is possible to manufacture biodiesel at a very small scale including at home it is not recommended because Methanol, normally non-renewable petrochemicals, used is highly toxic and has an adverse effect on human health. The biodiesel produced at such a small scale may not recover methanol from either the biodiesel or the glycerin. Any ingestion through contamination of water stream or even by inhalation may have adverse impact on health. Methanol, like Ethanol, is classified as a highly inflammable chemical under various laws and special procedure has to be followed in handling, transport, storage and use. On the other hand ethanol, a renewable biofuel, is not toxic but the transesterfication reaction with it is slower, the properties of biodiesel produced from it are slightly different.

Specifications and Quality Standards

Fuel used in engines must meet quality norms so that the engine operates as per its rating, endurance and has expected life span. In order to achieve these goals, it is necessary to set Standards of quality with detailed specifications. Approved standards are also necessary for the evaluation of health, safety, risks and environmental protection.

Standards are necessary for the approval and warrantee commitment for engine and vehicles by manufacturers and are, therefore, a pre-requisite for the market introduction and commercialization of biofuels.

In Europe biodiesel is predominantly made from rapeseed oil and most of the experience, information and data available are dealing with the rapeseed methyl ester (RME). EU has developed a common Standard for fatty acid methyl ester i.e. EN14214 that is more comprehensive than the ASTM standard. South Africa is reported to have developed its Biodiesel Standards.

Technologies

There are multiple operating options available for making biodiesel. Many of these technologies can be combined under various conditions and feedstocks in an infinite number of ways. The technology choice is a function of desired capacity, feedstock type and quality, alcohol recovery, and catalyst recovery. The dominant factor in biodiesel production is the feedstock cost, with capital cost contributing only about 7% of the final product cost.

Technologies used are:

1. Batch Processing
2. Continuous Process Systems
3. High Free Fatty Acid Systems
4. Non-catalyzed System-Biox Process
5. Non-catalyzed System-Supercritical Process

Cost estimates of producing biodiesel

Model	Country of Origin	Capacity	Input	Cost	Cost per capacity (Rs)
Tomsa Destil Ltd	Spain	60,000 MT/yr	Semi-refined vegetable oil	€4,334,471	4460/MT
Biofuels Canada Ltd	Canada	2,520 MT/yr	N/A	$110,000	1415/MT
Chemical Construction International Ltd	India	30,000 MT/yr	Purified Crude vegetable oil	$5,750,000	6214/MT
BioDiesel Technologies GmbH.,	Austria	8,000 MT/yr	Semi-refined vegetable oil	€1,500,000	11526/MT
Mike Pelly	USA	50,000 gallons per yr	N/A	$55,000	36/gallons
		300,000 gallons per yr	N/A	$170,000	18/gallons
BM Ingenieria Ltd	Spain	20,000 MT/yr	Semi-refined vegetable oil	€2,500,000	7684/MT
		10,000 MT/yr	Semi-refined vegetable oil	€1,050,00	645/MT

Life Cycle Assessment of biodiesel

LCA of biodiesel v/s petroleum diesel

The most reliable conclusions of this study are for overall energy balance and CO2 emissions. For these two measures, data are the most complete. More importantly, the sensitivity studies show that the estimates of CO2 emissions and energy requirements are very robust; that is, these results show little change in response to changes in key assumptions.

Life Cycle Energy and Environmental Flows

Major analytical results are presented below in order of decreasing confidence:

- *Energy Balance*

  Biodiesel and petroleum diesel have very similar energy efficiencies. The base case model estimates life cycle energy efficiencies of 80.55% for biodiesel versus 83.28% for petroleum diesel. The lower efficiency for biodiesel reflects slightly higher process energy requirements for converting the energy contained in soybean oil to fuel. In terms of effective use of fossil energy resources, biodiesel yields around 3.2 units of fuel product energy for every unit of fossil energy consumed in the life cycle. By contrast, petroleum diesel's life cycle yields only 0.83 units of fuel product energy per unit of fossil energy consumed. Such measures confirm the "renewable" nature of biodiesel. The life cycle for B20 has a proportionately lower fossil energy ratio (0.98 units of fuel product energy for every unit of fossil energy consumed). B20's fossil energy ratio reflects the impact of adding petroleum diesel into the blend.

- *CO2 Emissions*

  Given the low demand for fossil energy associated with biodiesel, it is not surprising that biodiesel's life cycle emissions of CO2 are substantially lower. Per unit of work delivered by a bus engine, B100 reduces net emissions of CO_2 by 78.45% compared to petroleum diesel. B20's life cycle CO2 emissions are 15.66% lower than those of petroleum diesel. Thus, use of biodiesel to displace petroleum diesel in urban buses is an extremely effective strategy for reducing CO2 emissions.

- *Total Particulate Matter (TPM) and Carbon Monoxide (CO) Emissions*

  The biodiesel (B100) life cycle produces less TPM and CO (32% and 35% reductions, respectively) than the petroleum diesel life cycle. Most of these reductions occur because of lower emissions at the tailpipe. PM10 emissions from an urban bus operating on biodiesel are 63% lower than the emissions from an urban bus operating on petroleum diesel. Biodiesel reduces tailpipe emissions of CO by 46%.

- *NOx Emissions*

  At the same time, NOx emissions are 13% higher for the B100 life cycle compared to the petroleum diesel life cycle. B20 has 2.67% higher life cycle emissions of NOx. Again, this increase is attributed to higher NOx emissions that occur at the tailpipe. An urban bus run on B100 has NOx emissions that are 8.89% higher than a bus operated on petroleum diesel.

- *Total Hydrocarbons (THC)*

  We also report 35% higher life cycle emissions of THC compared to petroleum diesel. Tailpipe emissions of THC are actually 37% lower for B100, compared to petroleum diesel. The increase in hydrocarbon emissions is due to release of hexane during soybean processing and to volatilization of agrochemicals applied on the farm. We have less confidence in the hydrocarbon air emissions results from this study. Air emissions data are often not reported on the same basis. For example, data run the gamut from specific hydrocarbon compounds such as CH_4 or benzene to broad measures of total hydrocarbons. The latter are not measured consistently, as well. Our data set includes numbers reported as "unspecified hydrocarbons" and as "non-methane hydrocarbons" (NMHC). Given these kinds of ambiguities in the data, results on hydrocarbon emissions need to be viewed with caution.

- *Water and Solid Waste*

  We report total wastewater and solid waste flows. Our results show that biodiesel has life cycle wastewater flows that are almost 80% lower than those of petroleum diesel. Hazardous waste generation is also much lower for biodiesel. Biodiesel generates only 5% of the amount of hazardous waste generated by petroleum diesel. However, we do not have a consistent basis for comparing these flows because their final disposition and composition are so different.

- *Water consumption*

  B100 uses water at a level that is three orders of magnitude higher than petroleum diesel, on a life cycle basis.

Cooper LCA

From the US Biodiesel LCA: -

- <u>*Reductions in petroleum and fossil energy consumption*</u>

  Substituting 100% biodiesel in buses reduces the life cycle consumption of petroleum by 95%.

- <u>*Particulates, Carbon monoxide and sulphur oxides*</u>

  Tailpipe emissions of particulates less than 10 microns in size are 68% lower for buses run on biodiesel as compared to petroleum diesel. In addition, tailpipe emissions of carbon monoxide are 46% lower for buses run on biodiesel (compared to petroleum diesel). Biodiesel completely eliminates emissions of sulphur oxides at the tail pipe. For B20, users can expect to see 20% of the reductions for biodiesel used in its neat form (B100).

The UK Biodiesel LCA: with impact assessment

- The use of low nitrogen methods of cultivation.
- The rapeseed straw can be used as an alternative heating fuel for drying, solvent extraction, refining and esterification process.
- It was found that for every ton of biodiesel produced, 916±52 kg CO_2 was released into the atmosphere. This dominates the greenhouse gas emissions: for each ton of biodiesel produced the equivalent of 1,516±88 kg of CO_2 are released, for petroleum.
- For every ton of biodiesel produced 16,269±896 MJ of energy is required.

The LCA of fossil fuel has been used to compare the energy demands of biodiesel, as follows:

- <u>*CO2 Emissions*</u>
  - For each MJ of biodiesel produced 0.025 kg of CO_2 is released
  - For each MJ of fossil diesel produced 0.087 kg of CO_2 is released

- <u>*GHG Emissions*</u>
  - For each MJ of biodiesel produced 0.041 kg of GHG CO2 equivalent is released
  - For each MJ of fossil diesel produced 0.095 kg of GHG CO2 equivalent is released

- *Energy Requirements*

  - For each MJ of biodiesel produced 0.45 MJ is required
  - For each MJ of fossil diesel produced 1.26 MJ is required

A review of all LCA's on biodiesels has indicated that it is impossible at this stage to deduce general conclusions as:

- there are several uncertainties linked to LCA especially in the waste management phase.
- the petroleum industry and technologies are more developed than the biofuel industry (still in early stage of development). The latter needs more research to have 'state-of-the-art knowledge' which would bring down costs as well.

Cost/Benefit Analysis

Economics:

- *Cost of production*

The table below shows a breakdown of the cost of Jatropha biofuel in India, as per Planning Commission Report on Bio-fuels, 2003. A third column has been added, where an estimate of the equivalent Mauritian cost is given.

Activities	**Indian Rate (Rs.(IRP)/Kg)**	**Mauritian Rate (Rs. (MRP) / Kg) - approximate**
Seed	5	7
Cost of plantation – assuming 3 tons of seeds are produced per hectare	8.33	16.67
Cost of collection & oil extraction	2.36	2
Less cake produced	1	1
Trans-esterification	6.67	5
Less cost of glycerin produced	40-60	30-55
Cost of bio-diesel	**19.52-17.52**	**13.02-11.69**
Cost of delivery & distribution	**-**	**0.50**

Table 6: Breakdown of cost of production of Jatropha biodiesel *(Source: http://www.pcra-biofuels.org/biodiesel.htm)*

- <u>*Additional Notes*</u>

1. Jatropha Curcas grows on non-arable land. Existing cultivations therefore do not have to be sacrificed for the cultivation of Jatropha Curcas. Moreover since prime land is not required, the cost of buying a plot of land to start the cultivation is not expected to be much.

2. Water requirement is known to be extremely low and the Jatropha plant can withstand long periods of drought. Cultivation of the plant will thus not be an additional burden to the water distribution system and our dry summer months will not be adverse to the business.

3. Because of the toxicity of the seed, they are not eaten and destroyed by animals. It can therefore accurately be predicted that 100% of the plant production will be yielded.

4. It has a high oil yield per hectare (around 5 tons of oil per cultivated hectare after three years).

5. The plants start yielding only one year after seedling.

6. Apart from it ability to produce biodiesel, the plant can also be used to produce other products. These are given below.

   a) Oil has a very high saponification value and is being extensively used for making soap in some countries,

   b) The latex of *Jatropha curcas* contains an alkaloid known as *jatrophine*, which is believed to have anti-cancerous properties. It is also used as an external application for skin diseases and rheumatism and for sores on domestic livestock. In addition, the tender twigs of the plant are used for cleaning teeth, while the juice of the leaf is used as an external application for piles. Finally, the roots are reported to be used as an antidote for snake-bites.

   c) The bark of *Jatropha curcas* yields a dark blue dye which is used for colouring cloth, fishing nets and lines.

   d) *Jatropha curcas* oil cake is rich in nitrogen, phosphorous and potassium and can be used as organic manure.

   e) The seeds are considered anthelimintic in Brazil, and the leaves are used for fumigating houses against bed-bugs. Also, the ether extract shows antibiotic activity against S*typhylococcus aureus* and *Escherichia coli.*

7. The use of bio-diesel will help reduce our import of fossil fuels and hence our dependence on foreign oils.

Social Benefits:

1. There are four business lines in the production of Jatropha biodiesel:

- Plantation of Jatropha curcas
- Collection of Oil bearing seeds
- Processing of seeds to produce oil and seed cake
- Manufacture of biodiesel and other by-products

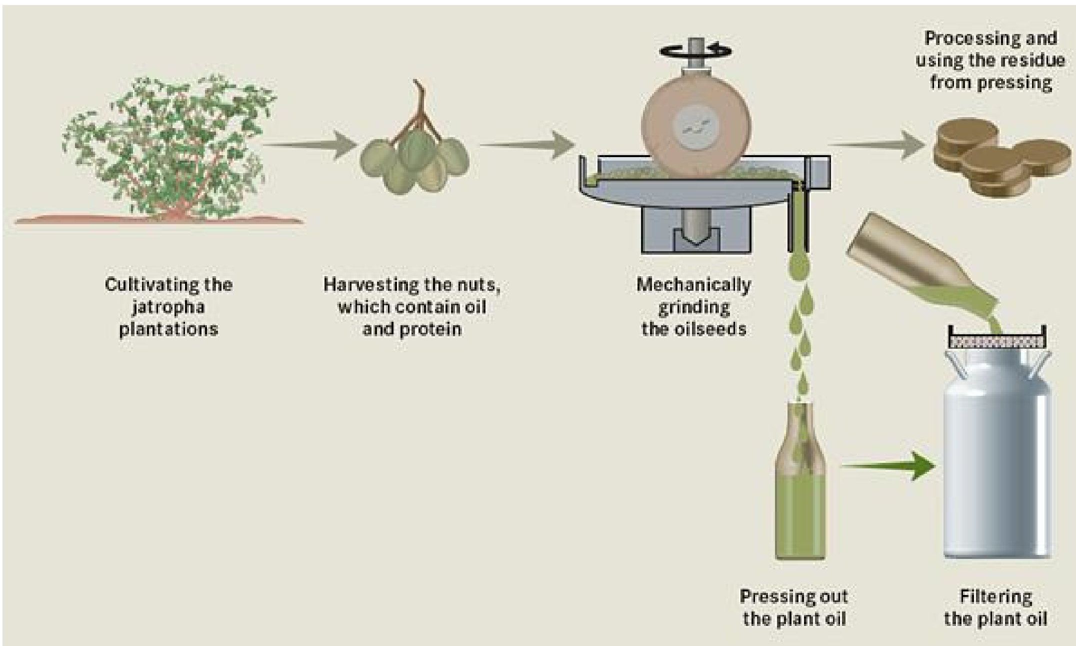


Figure 12: The different business lines in the production of Jatropha biodiesel *(Source: www.daimlerchrysler.com)*

The Jatropha cultivation is a very labour intensive process. It will therefore create jobs.

The following figures are estimated for the labour requirements for the plantation of an area of 1hectare. They are based on the figures obtained in India *(source: http://www.svlele.com/jatropha_plant.htm).*

Item	**Employment in person days / hectare**	
	Year	
	1st	**2nd**
Site preparation i.e. cleaning and leveling of field	15	

Alignment and staking	5	
Digging of pits (2500 Nos) of 30 Cm3 size @ 30 pits per Man Day	75	
Purchase and application of manure 2 Kg. per pits during 1st year (2 MT) 1 Kg. per pit during second year onwards	30	
Purchase and application of fertilizer @ Rs. 6 per kg (50 gm. Per plant during 1st year and 25 gm from 2nd year onward and 2 Man Days for each application.	3	2
Mixing of Manure, insecticides fertilizers and refilling of pits @100 pits per Man Day	35	
Planting (including carriage) 2500 Nos. during first year and 500 Nos. of plants during second year for replanting @ Rs. 4 per plant.	150	30
Planting and replanting cost 100 plants per Man Day	35	7
Irrigation - 3 irrigation during 1st and one irrigation during 2nd year	7	3
Weeding and soil working	30	30
Plant protection measure	1	

Table 7: Labour requirement for the plantation of 1hectare of land with Jatropha plants

2. The Jatropha business may promote setting up of small and medium enterprises for the plantation and collection business lines. The formation of clusters among the farmers and the enterprises could also present numerous advantages such as:

    a. Procurement of group loans from banks.
    b. Get more support to price and market their produce more easily.

3. It is however recommended that the oil extraction from the seed be centralised. This is because the oil is known to be carcinogenic and contact with the skin may cause skin cancer. It is therefore highly desirable to carry out the process in a controlled environment.

Environmental Issues:

1. Does not require much fertilizer since it grows in all types of soils and has low nutrient requirements. Moreover, the press cake obtained as by-product during oil extraction is rich in nutrients and can by itself be used as organic fertilizer.

2. Helps control soil erosion and improves the water retention ability of soils.
3. The potential invasiveness of the plant is still being studied. The impact of its cultivation on our ecosystem and our endemic plants should be carefully considered.
4. It is a renewable source of energy.
5. A mixture of 20% bio-diesel and 80% petroleum diesel is believed to reduce carbon dioxide emissions by 15% over petroleum diesel. Biodiesel also produces fewer particulate, carbon monoxide and sulfur dioxide emissions. The table below gives a comparison of bio-diesel and petroleum diesel.

Here the high carbon residue percentage indicates that the bio-fuel is less combustible than petroleum diesel and may produce soot on burning.

Property	**Jatropha curcas Oil**	**Diesel Oil**
Viscosity (cp) (30^{o}C)	5.51	3.60
Specific gravity (15^{o}C/4^{o}C)	0.917/ 0.923(0.881)	0.841 / 0.85
Solidifying Point (^{o}C)	2.0	0.14
Cetane Value	51.0	47.8 to 59
Flash Point (^{o}C)	110 / 340	80
Carbon Residue (%)	0.64	< 0.05 to < 0.15
Distillation (^{o}C)	284 to 295	< 350 to < 370
Sulfur (%)	0.13 to 0.16	< 1.0 to 1.2
Acid Value	1.0 to 38.2	
Saponification Value	188 to 198	
Iodine Value	90.8 to 112.5	
Refractive Index (30^{o}C)	1.47	

Table 8: Physical and chemical properties of Jatropha curcas oil and diesel fuel
(Source: http://www.svlele.com/jatropha_plant.htm).

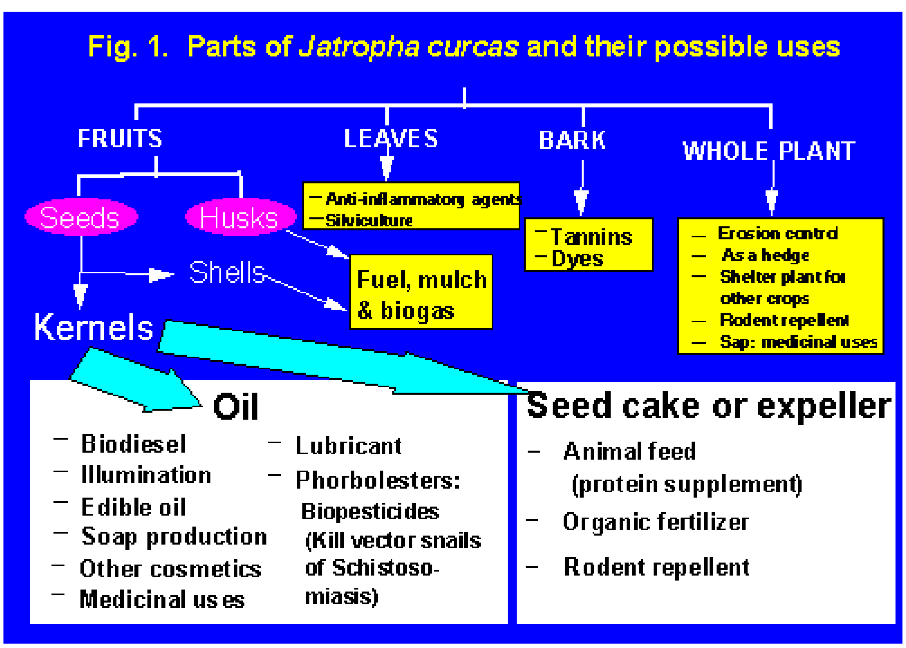
APPENDIX 2

Energy *(Source: James A. Duke. 1983. Handbook of Energy Crops. Unpublished).*

The clear oil expressed from the seed has been used for illumination and lubricating, and more recently has been suggested for energetic purposes, one ton of nuts yielding 70 kg refined petroleum, 40 kg "gasoil leger" (light fuel oil), 40 kg regular fuel oil, 34 kg dry tar/pitch/rosin, 270 kg coke-like char, and 200 kg ammoniacal water, natural gas, creosote, etc. In a startling study, *Gaydou et al. (1982)* compare several possible energy species with potential to grow in Malagasy. Oil palm was considered energetically most promising.

	Crop production MT/ha	Fuel production /ha	Energetic equivalent kwh/ha
Elaeis guineensis	18–20	3,600–4,000	33,900–37,700
Jatropha curcas	6–8	2,100–2,800	19,800–26,400
Aleurites fordii	4–6	1,800–2,700	17,000–25,500
Saccharum officinarum	35	2,450	16,000
Ricinus communis	3–5	1,200–2,000	11,300–18,900
Manihot eaculenta	6	1,020	6,600

The schematic below shows the alternative uses of Jatropha curcas and its by-products.



APPENDIX 3

SCENARIO 1

				0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
				2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
		Available marginal land	ha	630	1260	1890	2520	3150	3780	4410	5040	5670	6300	6300	6300	6300	6300	6300	6300	6300	6300	6300	6300	6300	6300	6300	6300
		Cost of jatropha biodiesel																									
		Yield																									
	yr 1	0.5	T/ha																								
	yr 2	1.25	T/ha																								
	yr 3	2.5	T/ha																								
	yr 4	5	T/ha																								
	yr 5	5	T/ha																								
		Cost of land																									
		31330	Rs/ha																								
		Cost of seed production w.o land																									
	yr 1	27145	Rs/ha																								
	yr 2	6234	Rs/ha																								
	yr 3	7005	Rs/ha																								
	yr 4	13000	Rs/ha																								
	yr 5	22865	Rs/ha																								
		Cost of seed production	ha	36839250	60504570	84655620	112583520	146726370	180869220	215012070	249154920	283297770	317440620	314744220	325221750	335213550	341428500										
	yr 1	58475	Rs/ha	36839250	60504570	84655620	112583520	146726370	180869220	215012070	249154920	283297770	317440620	314744220	325221750	335213550	341428500	341428500	341428500	341428500	341428500	341428500	341428500	341428500	341428500	341428500	341428500
	yr 2	37564	Rs/ha																								
	yr 3	38335	Rs/ha																								
	yr 4	44330	Rs/ha																								
	yr 5	54195	Rs/ha																								
		Seed production	T																								
				0	315	1102.5	2677.5	5827.5	8977.5	11812.5	14175	15750	15750	18900	22050	25200	28350	31500	31500	31500	31500	31500	31500	31500	31500	31500	31500
		Cost of seed production	Rs/T	36839250.00	203602.68	86275.79	50079.84	31786.99	26961.16	25820.00	26429.41	28668.80	34051.38	29823.23	27998.55	26766.49	25687.57	24505.94	25976.29	27534.87	29186.96	206808.12	32794.47	34762.14	36847.87	39058.74	41402.27
		1.06																									
		Cost of extraction	Rs																								
		4420	Rs/T	0	1475838	5475358.98	14095138.4	32518313.42	53101526.94	74062656	94207698.43	110955733.7	117613077.7	149603834.9	185010075.8	224126491.8	267270841.5	314785657.8	333672797.2	353693165.1	374914755	397409640.3	421254218.7	446529471.8	473321240.1	501720514.5	531823745.4
		Cost of transesterification	Rs																								
		5000	Rs/T	0	333900	1238769	3188945.34	7357084.484	12013920.12	17203090.53	22971711.28	29370635.39	36454732.24	44283186.42	52321854.01	60214979.42	67187240.19	71218474.61	75491583.08	80021078.07	84822342.75	89911683.32	95306384.32	101024767.4	107086253.4	113511428.6	120322114.3
		Cost of biodiesel production b4 capital		36839250.00	62314308.00	91369747.98	129867603.74	186601767.91	245984667.07	306277816.53	366334329.71	423624139.10	471508429.97	508631241.29	562553679.81	619555021.24	675886581.69	727432632.37	750592880.31	775142743.13	801165597.71	828749823.58	857989102.99	888982739.17	921835993.52	956660443.13	993574359.72
		Opportunity cost																									
		7.5	%	2762943.75	4673573.1	6852731.099	9740070.281	13995132.59	18448850.03	22970836.24	27475074.73	31771810.43	35363132.25	38147343.1	42191525.99	46466626.59	50691493.63	54557447.43	56294466.02	58135705.73	60087419.83	62156236.77	64349182.72	66673705.44	69137699.51	71749533.23	74518076.98
C		*Cost of biodiesel after accting for capital*		39602193.75	66987881.10	98222479.08	139607674.02	200596900.50	264433517.10	329248652.77	393809404.44	455395949.53	506871562.22	546778584.39	604745205.79	666021647.83	726578075.32	781990079.79	806887346.33	833278448.86	861253017.54	890906060.35	922338285.72	955656444.61	990973693.04	1028409976.37	1068092436.70
		Revenue from biodiesel and by-products					598.5	1512	2142	2772	3402	4032	4662	5292													
R		Oil production			63	220.5	535.5	1165.5	1795.5	2425.5	3055.5	3685.5	4315.5	4945.5	5512.5	5985	6300	6300	6300	6300							
	yr 2	0.1	x1		63	220.5	535.5	1165.5	1795.5	2425.5	3055.5	3685.5	4315.5	4945.5	5512.5	5985	6300	6300	6300	6300	6300	6300	6300	6300	6300	6300	6300
	yr 3	0.25	x2																								
	yr 4	0.5	x3																								
	yr 5	1	x4																								
		Diesel equivalent	T	0	121.275	424.4625	1030.8375	2243.5875	3456.3375	4669.0875	5881.8375	7094.5875	8307.3375	9520.0875	10611.5625	11521.125	12127.5	12127.5	12127.5	12127.5	12127.5	12127.5	12127.5	12127.5	12127.5	12127.5	12127.5
		Price of diesel equivalent	Rs/T	34319	36378.14	38560.8284	40874.4781	43326.94679	45926.5636	48682.15741	51603.08686	54699.27207	57981.22839	61460.1021	65147.70822	69056.57072	73199.96496	77591.96286	82247.48063	87182.32947	92413.26923	97958.06539	103835.5493	110065.6823	116669.6232	123669.8006	131089.9886
		Revenue from biodiesel	Rs	0	4411758.929	16367625.62	42134944.82	97207796.23	158737704	227301252.7	303520971.4	388068771.9	481669632.9	585105549.7	691318977.5	795609383.3	887732575.1	940996529.6	997456321.3	1057303701	1120741923	1187986438	1259265624	1334821562	1414910855	1499805507	1589793837
		Press cake production																									
	yr 2	0.32	T/ha		201.6	705.6	1713.6	3729.6	5745.6	7761.6	9777.6	11793.6	13809.6	15825.6	17640	19152	20160	20160	20160	20160	20160	20160	20160	20160	20160	20160	20160
	yr 3	0.8	T/ha																								
	yr 4	1.6	T/ha																								

				0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
	yr 5	3.2	T/ha																								
		Press cake	T	0	201.6	705.6	1713.6	3729.6	5745.6	7761.6	9777.6	11793.6	13809.6	15825.6	17640	19152	20160	20160	20160	20160	20160	20160	20160	20160	20160	20160	20160
R	2000	*Price of press cake fertiliser*	Rs/T	2120.00	2247.20	2382.03	2524.95	2676.45	2837.04	3007.26	3187.70	3378.96	3581.70	3796.60	4024.39	4265.86	4521.81	4793.12	5080.70	5385.55	5708.68	6051.20	6414.27	6799.13	7207.07	7639.50	8097.87
		Revenue from press cake fertiliser	Rs	0	453035.52	1680761.779	4326761.037	9982092.228	16300486.82	23341153.24	31168017.87	39850078.1	49461780.7	60083427.33	70990291.53	81699684.08	91159647.5	96629226.35	102426979.9	108572598.7	115086954.6	121992171.9	129311702.2	137070404.4	145294628.6	154012306.4	163253044.7
		1.06																									
		Glycerol production																									
	yr 2	0.012	kg/ha		7.56	26.46	64.26	139.86	215.46	291.06	366.66	442.26	517.86	593.46	661.5	718.2	756	756	756	756	756	756	756	756	756	756	756
	yr 3	0.03	kg/ha																								
	yr 4	0.06	kg/ha																								
	yr 5	0.12	kg/ha																								
		Glycerol	T	0	7.56	26.46	64.26	139.86	215.46	291.06	366.66	442.26	517.86	593.46	661.5	718.2	756	756	756	756	756	756	756	756	756	756	756
		Price of glycerol	Rs/T	17384.00	18427.04	19532.66	20704.62	21946.90	23263.71	24659.54	26139.11	27707.45	29369.90	31132.10	33000.02	34980.02	37078.82	39303.55	41661.77	44161.47	46811.16	49619.83	52597.02	55752.84	59098.01	62643.89	66402.53
R	16400	*Revenue from glycerol*	Rs	0	139308.4224	516834.2471	1330479.019	3069493.36	5012399.698	7177404.62	9584165.494	12253899.02	15209497.57	18475653.9	21829514.64	25122652.85	28031591.61	29713487.1	31496296.33	33386074.11	35389238.55	37512592.87	39763348.44	42149149.35	44678098.31	47358784.2	50200311.26
		1.06																									
	Conversion factor	1.925																									
		Total revenue b4 soc & ental benefits		0	5004102.871	18565221.65	47792184.88	110259381.8	180050590.5	257819810.5	344273154.8	440172749	546340911.2	663664631	784138783.7	902431720.2	1006923814	1067339243	1131379598	1199262373	1271218116	1347491203	1428340675	1514041115	1604883582	1701176597	1803247193
		Total revenue with soc & ental benefits		12859323.75	22486729.01	43219260.40	86450784.13	178231322.39	279090301.78	391410725.94	516204875.92	654565245.28	785944964.50	947738417.71	1111150583.43	1270384379.34	1399829644.24	1483819422.89	1572848588.26	1667219503.56	1767252673.78	1873287834.19	1985685104.25	2104826210.50	2231115783.14	2364982730.13	2506881693.92
		Social benefits																									
		Shadow benefits from labour																									
	yr 1	118.5	man hrs/ha	74655	94185	121905	173565	274995	376425	477855	579285	680715	707490	789390	863100	912870	912870	912870	912870	912870	912870	912870	912870	912870	912870	912870	912870
	yr 2	31	Rs	12859323.75	17196768.23	23593505.89	35607294.7	59800868.19	86769484.24	116759051.1	150034995.8	186883721.3	205888611	243505908.6	282218100.9	316401510.9	335385601.5	355508737.6	376839261.9	399449617.6	423416594.7	448821590.3	475750885.8	504295938.9	534553695.2	566626917	600624532
	yr 3	44																									
	yr 4	82																									
	yr 5	161																									
	162.5	1.06																	4								
		Environmental benefits																									
		Revenue from carbon displacement																									
			Rs	0.00	285857.91	1060532.86	3051304.54	8171072.38	12270227.02	16831864.35	21896725.36	27508774.97	33715442.32	40567878.16	44793698.80	51551148.22	57520228.55	60971442.26	64629728.79	68507512.52	72617963.27	76975041.06	81593543.53	86489156.14	91678505.51	97179215.85	103009968.78
		Cash flow at time t w.o soc & ental		-39602193.75	-61983778.23	-79657257.43	-91815489.14	-90337518.68	-84382926.57	-71428842.26	-49536249.68	-15223200.53	39469348.98	116886046.58	179393577.92	236410072.40	280345738.84	285349163.21	324492251.25	365983924.58	409965098.30	456585142.45	506002389.25	558384670.85	613909889.35	672766620.96	735154756.47
		Cash flow at time t with soc & ental		-26742870.00	-44501152.09	-55003218.68	-53156889.90	-22365578.11	14656784.69	62162073.17	122395471.48	199169295.75	279073402.29	400959833.32	506405377.64	604362731.51	673251568.92	701829343.10	765961241.93	833941054.70	905999656.23	982381773.85	1063346818.54	1149169765.90	1240142090.10	1336572753.77	1438789257.23
		Interest rate																									
		10	%																								
		Present value w.o soc & ental		-39602193.75	-56348889.3	-65832444.15	-68982335.95	-61701740.78	-52395158.41	-40319719.31	-25419928.67	-7101735.398	16738856.9	45064630.89	62876354.67	75327534.68	81206174.55	75141353.06	77680865.03	79648765.22	81109409.13	82120851.21	82735434.02	83000323.31	82957993.85	82646670.54	82100728.9
		Present value with soc & ental		-26742870	-40455592.81	-45457205.52	-39937558.15	-15275990.79	9100710.139	35088869.74	62808229.82	92913946.38	118354365.3	154587373.1	177491995.5	192568591.3	195016998.1	184813601.2	183365031.4	181489871	179247202	176689997.1	173865701.9	170816763.2	167581108.7	164192581.2	160681333.7
		Net present value w.o soc & ental		747793153.3																							
		Net present value with soc & ental		2612805054																							
		Diesel import substitution	T																								
	Increase 2 yrs ave	1.016	%	336765.392	342153.6383	347628.0965	353190.146	358841.1884	364582.6474	370415.9697	376342.6253	382364.1073	388481.933	394697.6439	401012.8062	407429.0111	413947.8753	420571.0413	427300.1779	434136.9808	441083.1725	448140.5032	455310.7513	462595.7233	469997.2549	477517.211	485157.4863
	Increase 5 yrs ave	1.0325	%	342234.515	353357.1367	364841.2437	376698.5841	388941.2881	401581.8799	414633.291	428108.873	442022.4114	456388.1397	471220.7543	486535.4288	502347.8302	518674.1347	535531.0441	552935.803	570906.2166	589460.6687	608618.1404	628398.23	648821.1724	669907.8605	691679.866	714159.4617
	Increase 10 yrs ave	1.051	%	348366.562	366133.2567	384806.0528	404431.1614	425057.1507	446735.0654	469518.5537	493463.9999	518630.6639	545080.8278	572879.95	602096.8275	632803.7657	665076.7577	698995.6723	734644.4516	772111.3187	811488.9959	852874.9347	896371.5564	942086.5058	990132.9176	1040629.696	1093701.811
		Diesel import substitution [2 yrs]	%		0.04	0.12	0.29	0.63	0.95	1.26	1.56	1.86	2.14	2.41	2.65	2.83	2.93	2.88	2.84	2.79	2.75	2.71	2.66	2.62	2.58	2.54	2.50
		Diesel import substitution [5 yrs]	%		0.03	0.12	0.27	0.58	0.86	1.13	1.37	1.61	1.82	2.02	2.18	2.29	2.34	2.26	2.19	2.12	2.06	1.99	1.93	1.87	1.81	1.75	1.70
		Diesel import substitution [10 yrs]	%		0.03	0.11	0.25	0.53	0.77	0.99	1.19	1.37	1.52	1.66	1.76	1.82	1.82	1.73	1.65	1.57	1.49	1.42	1.35	1.29	1.22	1.17	1.11
		Price of imported diesel	Rs/T	37216	39448.96	41815.8976	44324.85146	46984.34254	49803.4031	52791.60728	55959.10372	59316.64994	62875.64894	66648.18787	70647.07915	74885.9039	79379.05813	84141.80162	89190.30971	94541.7283	100214.232	106227.0859	112600.7111	119356.7537	126518.159	134109.2485	142155.8034
		1.06																									

SCENARIO 1 without by products

				0	1	2	3	4	5	6	7	8	9	10	11
				2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
		Available marginal land	ha	630	1260	1890	2520	3150	3780	4410	5040	5670	6300	6300	6300
		Cost of jatropha biodiesel													
		Yield													
	yr 1	0.5	T/ha												
	yr 2	1.25	T/ha												
	yr 3	2.5	T/ha												
	yr 4	5	T/ha												
	yr 5	5	T/ha												
		Cost of land													
		31330	Rs/ha												
		Cost of seed production w.o land													
	yr 1	27145	Rs/ha												
	yr 2	6234	Rs/ha												
	yr 3	7005	Rs/ha												
	yr 4	13000	Rs/ha												
	yr 5	22865	Rs/ha												
		Cost of seed production	ha												
	yr 1	58475	Rs/ha	36839250	60504570	84655620	112583520	146726370	180869220	215012070	249154920	283297770	317440620	314744220	325221750
	yr 2	37564	Rs/ha												
	yr 3	38335	Rs/ha												
	yr 4	44330	Rs/ha												
	yr 5	54195	Rs/ha												
		Seed production	T												
				0	315	1102.5	2677.5	5827.5	8977.5	11812.5	14175	15750	15750	18900	22050
		Cost of seed production	Rs/T	36839250.00	203602.68	86275.79	50079.84	31786.99	26961.16	25820.00	26429.41	28668.80	34051.38	29823.23	27998.55
		1.06													
		Cost of extraction	Rs												
		4420	Rs/T	0	1475838	5475358.98	14095138.4	32518313.42	53101526.94	74062656	94207698.43	110955733.7	117613077.7	149603834.9	185010075.8
		Cost of transesterification	Rs												
		5000	Rs/T	0	333900	1238769	3188945.34	7357084.484	12013920.12	17203090.53	22971711.28	29370635.39	36454732.24	44283186.42	52321854.01
		Cost of biodiesel production b4 capital		36839250.00	62314308.00	91369747.98	129867603.74	186601767.91	245984667.07	306277816.53	366334329.71	423624139.10	471508429.97	508631241.29	562553679.81
		Opportunity cost													
		7.5	%	2762943.75	4673573.1	6852731.099	9740070.281	13995132.59	18448850.03	22970836.24	27475074.73	31771810.43	35363132.25	38147343.1	42191525.99
C		*Cost of biodiesel after accting for capital*		39602193.75	66987881.10	98222479.08	139607674.02	200596900.50	264433517.10	329248652.77	393809404.44	455395949.53	506871562.22	546778584.39	604745205.79
		Revenue from biodiesel and by-products					598.5	1512	2142	2772	3402	4032	4662	5292	
R		Oil production			63	220.5	535.5	1165.5	1795.5	2425.5	3055.5	3685.5	4315.5	4945.5	5512.5
	yr 2	0.1	x1		63	220.5	535.5	1165.5	1795.5	2425.5	3055.5	3685.5	4315.5	4945.5	5512.5
	yr 3	0.25	x2												
	yr 4	0.5	x3												
	yr 5	1	x4												
		Diesel equivalent	T	0	121.275	424.4625	1030.8375	2243.5875	3456.3375	4669.0875	5881.8375	7094.5875	8307.3375	9520.0875	10611.5625
		Price of diesel equivalent	Rs/T	34319	36378.14	38560.8284	40874.4781	43326.94679	45926.5636	48682.15741	51603.08686	54699.27207	57981.22839	61460.1021	65147.70822
		Revenue from biodiesel	Rs	0	4411758.929	16367625.62	42134944.82	97207796.23	158737704	227301252.7	303520971.4	388068771.9	481669632.9	585105549.7	691318977.5
		Press cake production													
	yr 2	0.32	T/ha		201.6	705.6	1713.6	3729.6	5745.6	7761.6	9777.6	11793.6	13809.6	15825.6	17640
	yr 3	0.8	T/ha												
	yr 4	1.6	T/ha												
	yr 5	3.2	T/ha												
		Press cake	T	0	201.6	705.6	1713.6	3729.6	5745.6	7761.6	9777.6	11793.6	13809.6	15825.6	17640
R	2000	*Price of press cake fertiliser*	Rs/T	2120.00	2247.20	2382.03	2524.95	2676.45	2837.04	3007.26	3187.70	3378.96	3581.70	3796.60	4024.39
		Revenue from press cake fertiliser	Rs	0	0	0	0	0	0	0	0	0	0	0	0
		1.06													

				12	13	14	15	16	17	18	19	20	21	22	23
				2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
		Available marginal land	ha	6300	6300	6300	6300	6300	6300	6300	6300	6300	6300	6300	6300
		Cost of jatropha biodiesel													
		Yield													
	yr 1	0.5	T/ha												
	yr 2	1.25	T/ha												
	yr 3	2.5	T/ha												
	yr 4	5	T/ha												
	yr 5	5	T/ha												
		Cost of land													
		31330	Rs/ha												
		Cost of seed production w.o land													
	yr 1	27145	Rs/ha												
	yr 2	6234	Rs/ha												
	yr 3	7005	Rs/ha												
	yr 4	13000	Rs/ha												
	yr 5	22865	Rs/ha												
		Cost of seed production	ha												
	yr 1	58475	Rs/ha	335213550	341428500	341428500	341428500	341428500	341428500	341428500	341428500	341428500	341428500	341428500	341428500
	yr 2	37564	Rs/ha												
	yr 3	38335	Rs/ha												
	yr 4	44330	Rs/ha												
	yr 5	54195	Rs/ha												
		Seed production	T												
				25200	28350	31500	31500	31500	31500	31500	31500	31500	31500	31500	31500
		Cost of seed production	Rs/T	26766.49	25687.57	24505.94	25976.29	27534.87	29186.96	206808.12	32794.47	34762.14	36847.87	39058.74	41402.27
		1.06													
		Cost of extraction	Rs												
		4420	Rs/T	224126491.8	267270841.5	314785657.8	333672797.2	353693165.1	374914755	397409640.3	421254218.7	446529471.8	473321240.1	501720514.5	531823745.4
		Cost of transesterification	Rs												
		5000	Rs/T	60214979.42	67187240.19	71218474.61	75491583.08	80021078.07	84822342.75	89911683.32	95306384.32	101024767.4	107086253.4	113511428.6	120322114.3
		Cost of biodiesel production b4 capital		619555021.24	675886581.69	727432632.37	750592880.31	775142743.13	801165597.71	828749823.58	857989102.99	888982739.17	921835993.52	956660443.13	993574359.72
		Opportunity cost													
		7.5	%	46466626.59	50691493.63	54557447.43	56294466.02	58135705.73	60087419.83	62156236.77	64349182.72	66673705.44	69137699.51	71749533.23	74518076.98
C		*Cost of biodiesel after accting for capital*		666021647.83	726578075.32	781990079.79	806887346.33	833278448.86	861253017.54	890906060.35	922338285.72	955656444.61	990973693.04	1028409976.37	1068092436.70
		Revenue from biodiesel and by-products													
R		Oil production		5985	6300	6300	6300	6300							
	yr 2	0.1	x1	5985	6300	6300	6300	6300	6300	6300	6300	6300	6300	6300	6300
	yr 3	0.25	x2												
	yr 4	0.5	x3												
	yr 5	1	x4												
		Diesel equivalent	T	11521.125	12127.5	12127.5	12127.5	12127.5	12127.5	12127.5	12127.5	12127.5	12127.5	12127.5	12127.5
		Price of diesel equivalent	Rs/T	69056.57072	73199.96496	77591.96286	82247.48063	87182.32947	92413.26923	97958.06539	103835.5493	110065.6823	116669.6232	123669.8006	131089.9886
		Revenue from biodiesel	Rs	795609383.3	887732575.1	940996529.6	997456321.3	1057303701	1120741923	1187986438	1259265624	1334821562	1414910855	1499805507	1589793837
		Press cake production													
	yr 2	0.32	T/ha	19152	20160	20160	20160	20160	20160	20160	20160	20160	20160	20160	20160
	yr 3	0.8	T/ha												
	yr 4	1.6	T/ha												
	yr 5	3.2	T/ha												
		Press cake	T	19152	20160	20160	20160	20160	20160	20160	20160	20160	20160	20160	20160
R	2000	*Price of press cake fertiliser*	Rs/T	4265.86	4521.81	4793.12	5080.70	5385.55	5708.68	6051.20	6414.27	6799.13	7207.07	7639.50	8097.87
		Revenue from press cake fertiliser	Rs	0	0	0	0	0	0	0	0	0	0	0	0
		1.06													

					0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
		Glycerol production																										
	yr 2		0.012	kg/ha		7.56	26.46	64.26	139.86	215.46	291.06	366.66	442.26	517.86	593.46	661.5	718.2	756	756	756	756	756	756	756	756	756	756	756
	yr 3		0.03	kg/ha																								
	yr 4		0.06	kg/ha																								
	yr 5		0.12	kg/ha																								
		Glycerol		T	0	7.56	26.46	64.26	139.86	215.46	291.06	366.66	442.26	517.86	593.46	661.5	718.2	756	756	756	756	756	756	756	756	756	756	756
		Price of glycerol		Rs/T	17384.00	18427.04	19532.66	20704.62	21946.90	23263.71	24659.54	26139.11	27707.45	29369.90	31132.10	33000.02	34980.02	37078.82	39303.55	41661.77	44161.47	46811.16	49619.83	52597.02	55752.84	59098.01	62643.89	66402.53
R	16400	*Revenue from glycerol*		Rs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			1.06																									
	Conversion factor		1.925																									
		Total revenue b4 soc & ental benefits			0	4411758.929	16367625.62	42134944.82	97207796.23	158737704	227301252.7	303520971.4	388068771.9	481669632.9	585105549.7	691318977.5	795609383.3	887732575.1	940996529.6	997456321.3	1057303701	1120741923	1187986438	1259265624	1334821562	1414910855	1499805507	1589793837
		Total revenue with soc & ental benefits			12859323.75	21894385.07	41021664.38	80793544.07	165179736.80	257777415.26	360892168.09	475452692.56	602461268.16	721273686.24	869179336.47	1018330777.26	1163562042.41	1280638405.14	1357476709.45	1438925312.00	1525260830.73	1616776480.58	1713783069.40	1816610053.57	1925606656.79	2041143056.20	2163611639.57	2293428337.93
		Social benefits																										
		Shadow benefits from labour																										
	yr 1		118.5	man hrs/ha	74655	94185	121905	173565	274995	376425	477855	579285	680715	707490	789390	863100	912870	912870	912870	912870	912870	912870	912870	912870	912870	912870	912870	912870
	yr 2		31	Rs	12859323.75	17196768.23	23593505.89	35607294.7	59800868.19	86769484.24	116759051.1	150034995.8	186883721.3	205888611	243505908.6	282218100.9	316401510.9	335385601.5	355508737.6	376839261.9	399449617.6	423416594.7	448821590.3	475750885.8	504295938.9	534553695.2	566626917	600624532
	yr 3		44																									
	yr 4		82																									
	yr 5		161																									
	162.5		1.06																									
		Environmental benefits																										
		Revenue from carbon displacement																										
				Rs	0.00	285857.91	1060532.86	3051304.54	8171072.38	12270227.02	16831864.35	21896725.36	27508774.97	33715442.32	40567878.16	44793698.80	51551148.22	57520228.55	60971442.26	64629728.79	68507512.52	72617963.27	76975041.06	81593543.53	86489156.14	91678505.51	97179215.85	103009968.78
		Cash flow at time t w.o soc & ental			-39602193.75	-62576122.17	-81854853.45	-97472729.20	-103389104.27	-105695813.09	-101947400.12	-90288433.04	-67327177.65	-25201929.28	38326965.34	86573771.75	129587735.47	161154499.74	159006449.76	190568975.00	224025251.75	259488905.10	297080377.66	336927338.57	379165117.13	423937162.41	471395530.40	521701400.48
		Cash flow at time t with soc & ental			-26742870.00	-45093496.03	-57200814.70	-58814129.95	-35417163.70	-6656101.83	31643515.31	81643288.12	147065318.63	214402124.02	322400752.09	413585571.47	497540394.58	554060329.82	575486629.65	632037965.67	691982381.87	755523463.04	822877009.06	894271767.86	969950212.18	1050169363.16	1135201663.21	1225335901.23
		Interest rate																										
		10		%																								
		Present value w.o soc & ental			-39602193.75	-56887383.79	-67648639.22	-73232704.13	-70616149.35	-65628784.1	-57546649.61	-46332242.4	-31408625.26	-10688078.19	14776704.29	30343578.85	41290646.12	46680718.21	41871367.86	45620697.47	48754421.93	51338496.51	53432517.23	55090312.18	56360478.63	57286870.8	57909042.87	58262651.32
		Present value with soc & ental			-26742870	-40994087.3	47273400.58	-44187926.34	-24190399.36	-4132915.558	17861939.45	41895916.1	68607056.51	90927430.17	124299446.5	144959219.7	158531702.8	160491541.8	151543616	151304863.9	150595527.7	149476289.4	148001663.1	146220580	144176918.5	141909985.6	139454953.5	136843256.1
		Net present value w.o soc & ental			181298422.3																							
		Net present value with soc & ental			2079580308																							
		Diesel import substitution		T																								
	Increase 2 yrs ave		1.016	%	336765.392	342153.6383	347628.0965	353190.146	358841.1884	364582.6474	370415.9697	376342.6253	382364.1073	388481.933	394697.6439	401012.8062	407429.0111	413947.8753	420571.0413	427300.1779	434136.9808	441083.1725	448140.5032	455310.7513	462595.7233	469997.2549	477517.211	485157.4863
	Increase 5 yrs ave		1.0325	%	342234.515	353357.1367	364841.2437	376698.5841	388941.2881	401581.8799	414633.291	428108.873	442022.4114	456388.1397	471220.7543	486535.4288	502347.8302	518674.1347	535531.0441	552935.803	570906.2166	589460.6687	608618.1404	628398.23	648821.1724	669907.8605	691679.866	714159.4617
	Increase 10 yrs ave		1.051	%	348366.562	366133.2567	384806.0528	404431.1614	425057.1507	446735.0654	469518.5537	493463.9999	518630.6639	545080.8278	572879.95	602096.8275	632803.7657	665076.7577	698995.6723	734644.4516	772111.3187	811488.9959	852874.9347	896371.5564	942086.5058	990132.9176	1040629.696	1093701.811
		Diesel import substitution [2 yrs]		%		0.04	0.12	0.29	0.63	0.95	1.26	1.56	1.86	2.14	2.41	2.65	2.83	2.93	2.88	2.84	2.79	2.75	2.71	2.66	2.62	2.58	2.54	2.50
		Diesel import substitution [5 yrs]		%		0.03	0.12	0.27	0.58	0.86	1.13	1.37	1.61	1.82	2.02	2.18	2.29	2.34	2.26	2.19	2.12	2.06	1.99	1.93	1.87	1.81	1.75	1.70
		Diesel import substitution [10 yrs]		%		0.03	0.11	0.25	0.53	0.77	0.99	1.19	1.37	1.52	1.66	1.76	1.82	1.82	1.73	1.65	1.57	1.49	1.42	1.35	1.29	1.22	1.17	1.11
		Price of imported diesel		Rs/T	37216	39448.96	41815.8976	44324.85146	46984.34254	49803.4031	52791.60728	55959.10372	59316.64994	62875.64894	66648.18787	70647.07915	74885.9039	79379.05813	84141.80162	89190.30971	94541.7283	100214.232	106227.0859	112600.7111	119356.7537	126518.159	134109.2485	142155.8034
			1.06																									

SCENARIO 1 marginal lands

				0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
				2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
		Available marginal land	ha	630	1260	1890	2520	3150	3780	3780	3780	3780	3780	3780	3780	3780	3780	3780	3780	3780	3780	3780	3780	3780	3780	3780	3780
		Cost of jatropha biodiesel																									
		Yield																									
	yr 1	0.5	T/ha																								
	yr 2	1.25	T/ha																								
	yr 3	2.5	T/ha																								
	yr 4	5	T/ha																								
	yr 5	5	T/ha																								
		Cost of land																									
		31330	Rs/ha																								
		Cost of seed production w.o land																									
	yr 1	27145	Rs/ha																								
	yr 2	6234	Rs/ha																								
	yr 3	7005	Rs/ha																								
	yr 4	13000	Rs/ha																								
	yr 5	22865	Rs/ha																								
		Cost of seed production	ha		60504570	84655620	112583520	146726370	180869220	178172820	188650350	198642150	204857100	204857100	204857100	204857100	204857100	204857100	204857100	204857100	204857100	204857100	204857100	204857100	204857100	204857100	204857100
	yr 1	58475	Rs/ha	36839250	60504570	84655620	112583520	146726370	180869220	178172820	188650350	198642150	204857100	204857100	204857100	204857100	204857100	204857100	204857100	204857100	204857100	204857100	204857100	204857100	204857100	204857100	204857100
	yr 2	37564	Rs/ha																								
	yr 3	38335	Rs/ha																								
	yr 4	44330	Rs/ha																								
	yr 5	54195	Rs/ha																								
		Seed production	T	0	315	1102.5	2677.5	5827.5	8977.5	11812.5	14175	15750	15750	18900	22050	25200	28350	31500	31500	31500	31500	31500	31500	31500	31500	31500	31500
				0	315	1102.5	2677.5	5827.5	8977.5	11812.5	14175	15750	15750	15750	15750	15750	15750	15750	15750	15750	15750	15750	15750	15750	15750	15750	15750
		Cost of seed production	Rs/T	36839250.00	203602.68	86275.79	50079.84	31786.99	26961.16	21396.11	20011.31	20101.93	21974.71	23293.20	24690.79	26172.24	27742.57	29407.13	31171.55	33041.85	35024.36	248169.74	39353.37	41714.57	44217.44	46870.49	49682.72
		1.06																									
		Cost of extraction	Rs																								
		4420	Rs/T	0	1475838	5475358.98	14095138.4	32518313.42	53101526.94	74062656	94207698.43	110955733.7	117613077.7	124669862.4	132150054.1	140079057.4	148483800.8	157392828.9	166836398.6	176846582.5	187457377.5	198704820.1	210627109.3	223264735.9	236660620.1	250860257.3	265911872.7
		Cost of transesterification	Rs																								
		5000	Rs/T	0	333900	1238769	3188945.34	7357084.484	12013920.12	17203090.53	22498067.75	27613417.89	31931152.33	33847021.46	35877842.75	38030513.32	40312344.12	42731084.76	45294949.85	48012646.84	50893405.65	53947009.99	57183830.59	60614860.42	64251752.05	68106857.17	72193268.6
		Cost of biodiesel production b4 capital		36839250.00	62314308.00	91369747.98	129867603.74	186601767.91	245984667.07	269438566.53	305356116.18	337211301.60	354401330.06	363373983.86	372884996.89	382966670.70	393653244.95	404981013.64	416988448.46	429716329.37	443207883.13	457508930.12	472668039.93	488736696.32	505769472.10	523824214.43	542962241.29
		Opportunity cost																									
		7.5	%	2762943.75	4673573.1	6852731.099	9740070.281	13995132.59	18448850.03	20207892.49	22901708.71	25290847.62	26580099.75	27253048.79	27966374.77	28722500.3	29523993.37	30373576.02	31274133.63	32228724.7	33240591.23	34313169.76	35450102.99	36655252.22	37932710.41	39286816.08	40722168.1
C		*Cost of biodiesel after accting for capital*		39602193.75	66987881.10	98222479.08	139607674.02	200596900.50	264433517.10	289646459.02	328257824.90	362502149.22	380981429.81	390627032.65	400851371.66	411689171.01	423177238.32	435354589.67	448262582.10	461945054.07	476448474.37	491822099.88	508118142.92	525391948.55	543702182.51	563111030.51	583684409.39
		Revenue from biodiesel and by-products																									
R		Oil production					598.5	1512	2142	2772	3402	4032	4662	5292													
	yr 2	0.1	x1		63	220.5	535.5	1165.5	1795.5	2425.5	2992.5	3465	3780	3780	3780	3780	3780	3780	3780	3780	3780	3780	3780	3780	3780	3780	3780
	yr 3	0.25	x2		63	220.5	535.5	1165.5	1795.5	2425.5	3055.5	3685.5	4315.5	4945.5	5512.5	5985	6300	6300	6300	6300	6300	6300	6300	6300	6300	6300	6300
	yr 4	0.5	x3																								
	yr 5	1	x4																								
		Diesel equivalent	T	0	121.275	424.4625	1030.8375	2243.5875	3456.3375	4669.0875	5760.5625	6670.125	7276.5	7276.5	7276.5	7276.5	7276.5	7276.5	7276.5	7276.5	7276.5	7276.5	7276.5	7276.5	7276.5	7276.5	7276.5
		Price of diesel equivalent	Rs/T	34319	36378.14	38560.8284	40874.4781	43326.94679	45926.5636	48682.15741	51603.08686	54699.27207	57981.22839	61460.1021	65147.70822	69056.57072	73199.96496	77591.96286	82247.48063	87182.32947	92413.26923	97958.06539	103835.5493	110065.6823	116669.6232	123669.8006	131089.9886
		Revenue from biodiesel	Rs	0	4411758.929	16367625.62	42134944.82	97207796.23	158737704	227301252.7	297262807	364850982.1	421900408.4	447214432.9	474047298.9	502490136.8	532639545	564597917.7	598473792.8	634382220.4	672445153.6	712791862.8	755559374.6	800892937	848946513.3	899883304.1	953876302.3
		Press cake production																									
	yr 2	0.32	T/ha		201.6	705.6	1713.6	3729.6	5745.6	7560	9072	10080	12096	12096	12096	12096	12096	12096	12096	12096	12096	12096	12096	12096	12096	12096	12096
	yr 3	0.8	T/ha		201.6	705.6	1713.6	3729.6	5745.6	7761.6	9777.6	11793.6	13809.6	15825.6	17640	19152	20160	20160	20160	20160	20160	20160	20160	20160	20160	20160	20160
	yr 4	1.6	T/ha																								
	yr 5	3.2	T/ha																								
		Press cake	T	0	201.6	705.6	1713.6	3729.6	5745.6	7560	9072	10080	12096	12096	12096	12096	12096	12096	12096	12096	12096	12096	12096	12096	12096	12096	12096
R	2000	*Price of press cake fertiliser*	Rs/T	2120.00	2247.20	2382.03	2524.95	2676.45	2837.04	3007.26	3187.70	3378.96	3581.70	3796.60	4024.39	4265.86	4521.81	4793.12	5080.70	5385.55	5708.68	6051.20	6414.27	6799.13	7207.07	7639.50	8097.87
		Revenue from press cake fertiliser	Rs	0	453035.52	1680761.779	4326761.037	9982092.228	16300486.82	22734889.52	28918779.46	34059895.81	43324187.47	45923638.72	48679057.05	51599800.47	54695788.5	57977535.81	61456187.96	65143559.23	69052172.79	73195303.15	77587021.34	82242242.62	87176777.18	92407383.81	97951826.84
		1.06																									

				0	1	2	3	4	5	6	7	8	9	10	11
		Glycerol production													
	yr 2	0.012	kg/ha		7.56	26.46	64.26	139.86	215.46	283.5	340.2	378	453.6	453.6	453.6
	yr 3	0.03	kg/ha						215.46	291.06	366.66	442.26	517.86	593.46	661.5
	yr 4	0.06	kg/ha												
	yr 5	0.12	kg/ha												
		Glycerol	T	0	7.56	26.46	64.26	139.86	215.46	283.5	340.2	378	453.6	453.6	453.6
		Price of glycerol	Rs/T	17384.00	18427.04	19532.66	20704.62	21946.90	23263.71	24659.54	26139.11	27707.45	29369.90	31132.10	33000.02
R	16400	*Revenue from glycerol*	Rs	0	139308.4224	516834.2471	1330479.019	3069493.36	5012399.698	6990978.526	8892524.685	10473417.96	13322187.65	14121518.91	14968810.04
		1.06													
	Conversion factor	1.925													
		Total revenue b4 soc & ental benefits		0	5004102.871	18565221.65	47792184.88	110259381.8	180050590.5	257027120.7	335074111.2	409384295.9	478546783.5	507259590.5	537695166
		Total revenue with soc & ental benefits		12859323.75	22486729.01	43219260.40	86450784.13	178231322.39	279090301.78	372376839.62	479976171.01	586440531.66	682988168.47	723967458.58	767405506.09
		Social benefits													
		Shadow benefits from labour							376425	477855	579285	680715	707490	789390	863100
	yr 1	118.5	man hrs/ha	74655	94185	121905	173565	274995	376425	403200	485100	558810	608580	608580	608580
	yr 2	31	Rs	12859323.75	17196768.23	23593505.89	35607294.7	59800868.19	86769484.24	98517854.57	125641051.4	153415882.3	177104539.8	187730812.2	198994660.9
	yr 3	44													
	yr 4	82													
	yr 5	161													
	162.5	1.06													
		Environmental benefits													
		Revenue from carbon displacement		0	285857.9137	1060532.86	3051304.542	8171072.376	12270227.02	16831864.35	19261008.42	23640353.49	27336845.12	28977055.83	30715679.18
			Rs	0	285857.9137	1060532.86	3051304.542	8171072.376	12270227.02	16831864.35	19261008.42	23640353.49	27336845.12	28977055.83	30715679.18
		Cash flow at time t w.o soc & ental		-39602193.75	-61983778.23	-79657257.43	-91815489.14	-90337518.68	-84382926.57	-32619338.33	6816286.29	46882146.67	97565353.72	116632557.90	136843794.32
		Cash flow at time t with soc & ental		-26742870.00	-44501152.09	-55003218.68	-53156889.90	-22365578.11	14656784.69	82730380.59	151718346.12	223938382.44	302006738.66	333340425.93	366554134.43
		Interest rate													
		10	%												
		Present value w.o soc & ental		-39602193.75	-56348889.3	-65832444.15	-68982335.95	-61701740.78	-52395158.41	-18412766.1	3497832.648	21870867.42	41377234.15	44966900.03	47962915.09
		Present value with soc & ental		-26742870	-40455592.81	-45457205.52	-39937558.15	-15275990.79	9100710.139	46699143.07	77855500.99	104468908.1	128080338.6	128517164.3	128474987.9
		Net present value w.o soc & ental		514589088.6											
		Net present value with soc & ental		1885156853											
		Diesel import substitution	T												
	Increase 2 yrs ave	1.016	%	336765.392	342153.6383	347628.0965	353190.146	358841.1884	364582.6474	370415.9697	376342.6253	382364.1073	388481.933	394697.6439	401012.8062
	Increase 5 yrs ave	1.0325	%	342234.515	353357.1367	364841.2437	376698.5841	388941.2881	401581.8799	414633.291	428108.873	442022.4114	456388.1397	471220.7543	486535.4288
	Increase 10 yrs ave	1.051	%	348366.562	366133.2567	384806.0528	404431.1614	425057.1507	446735.0654	469518.5537	493463.9999	518630.6639	545080.8278	572879.95	602096.8275
		Diesel import substitution [2 yrs]	%		0.04	0.12	0.29	0.63	0.95	1.26	1.53	1.74	1.87	1.84	1.81
		Diesel import substitution [5 yrs]	%		0.03	0.12	0.27	0.58	0.86	1.13	1.35	1.51	1.59	1.54	1.50
		Diesel import substitution [10 yrs]	%		0.03	0.11	0.25	0.53	0.77	0.99	1.17	1.29	1.33	1.27	1.21
		Price of imported diesel	Rs/T	37216	39448.96	41815.8976	44324.85146	46984.34254	49803.4031	52791.60728	55959.10372	59316.64994	62875.64894	66648.18787	70647.07915
		1.06													

				12	13	14	15	16	17	18	19	20	21	22	23
		Glycerol production													
	yr 2	0.012	kg/ha	453.6	453.6	453.6	453.6	453.6	453.6	453.6	453.6	453.6	453.6	453.6	453.6
	yr 3	0.03	kg/ha	718.2	756	756	756	756	756	756	756	756	756	756	756
	yr 4	0.06	kg/ha												
	yr 5	0.12	kg/ha												
		Glycerol	T	453.6	453.6	453.6	453.6	453.6	453.6	453.6	453.6	453.6	453.6	453.6	453.6
		Price of glycerol	Rs/T	34980.02	37078.82	39303.55	41661.77	44161.47	46811.16	49619.83	52597.02	55752.84	59098.01	62643.89	66402.53
R	16400	*Revenue from glycerol*	Rs	15866938.64	16818954.96	17828092.26	18897777.8	20031644.46	21233543.13	22507555.72	23858009.06	25289489.61	26806858.98	28415270.52	30120186.75
		1.06													
	Conversion factor	1.925													
		Total revenue b4 soc & ental benefits		569956875.9	604154288.5	640403545.8	678827758.5	719557424.1	762730869.5	808494721.7	857004405	908424669.3	962930149.4	1020705958	1081948316
		Total revenue with soc & ental benefits		813449836.46	862256826.65	913992236.24	968831770.41	1026961676.64	1088579377.24	1153894139.87	1223127788.27	1296515455.56	1374306382.90	1456764765.88	1544170651.82
		Social benefits													
		Shadow benefits from labour		912870	912870	912870	912870	912870	912870	912870	912870	912870	912870	912870	912870
	yr 1	118.5	man hrs/ha	608580	608580	608580	608580	608580	608580	608580	608580	608580	608580	608580	608580
	yr 2	31	Rs	210934340.6	223590401	237005825.1	251226174.6	266299745.1	282277729.8	299214393.6	317167257.2	336197292.6	356369130.2	377751278	400416354.6
	yr 3	44													
	yr 4	82													
	yr 5	161													
	162.5	1.06													
		Environmental benefits													
		Revenue from carbon displacement		32558619.93	34512137.13	36582865.36	38777837.27	41104507.51	43570777.96	46185024.64	48956126.12	51893493.68	55007103.31	58307529.51	61805981.27
			Rs	32558619.93	34512137.13	36582865.36	38777837.27	41104507.51	43570777.96	46185024.64	48956126.12	51893493.68	55007103.31	58307529.51	61805981.27
		Cash flow at time t w.o soc & ental		158267704.93	180977050.17	205048956.13	230565176.45	257612369.99	286282395.14	316672621.80	348886262.05	383032720.73	419227966.92	457594927.89	498263906.51
		Cash flow at time t with soc & ental		401760665.45	439079588.33	478637646.58	520569188.32	565016622.57	612130902.88	662072039.99	715009645.35	771123507.02	830604200.39	893653735.37	960486242.43
		Interest rate													
		10	%												
		Present value w.o soc & ental		50428968.24	52422604.99	53995798.81	55195470.1	56063957.45	56639445.68	56956354.55	57045691.74	56935373.26	56650514.52	56213694.42	55645195.17
		Present value with soc & ental		128013329.4	127185716.6	126040251.8	124620124.8	122964079.3	121106835.8	119079475.9	116909790.5	114622595.7	112240019.8	109781763.2	107265334.1
		Diesel import substitution	T												
	Increase 2 yrs ave	1.016	%	407429.0111	413947.8753	420571.0413	427300.1779	434136.9808	441083.1725	448140.5032	455310.7513	462595.7233	469997.2549	477517.211	485157.4863
	Increase 5 yrs ave	1.0325	%	502347.8302	518674.1347	535531.0441	552935.803	570906.2166	589460.6687	608618.1404	628398.23	648821.1724	669907.8605	691679.866	714159.4617
	Increase 10 yrs ave	1.051	%	632803.7657	665076.7577	698995.6723	734644.4516	772111.3187	811488.9959	852874.9347	896371.5564	942086.5058	990132.9176	1040629.696	1093701.811
		Diesel import substitution [2 yrs]	%	1.79	1.76	1.73	1.70	1.68	1.65	1.62	1.60	1.57	1.55	1.52	1.50
		Diesel import substitution [5 yrs]	%	1.45	1.40	1.36	1.32	1.27	1.23	1.20	1.16	1.12	1.09	1.05	1.02
		Diesel import substitution [10 yrs]	%	1.15	1.09	1.04	0.99	0.94	0.90	0.85	0.81	0.77	0.73	0.70	0.67
		Price of imported diesel	Rs/T	74885.9039	79379.05813	84141.80162	89190.30971	94541.7283	100214.232	106227.0859	112600.7111	119356.7537	126518.159	134109.2485	142155.8034
		1.06													

SCENARIO 1 marginal lands without by-product

				0	1	2	3	4	5	6	7	8	9	10	11
				2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
		Available marginal land	ha	630	1260	1890	2520	3150	3780	3780	3780	3780	3780	3780	3780
		Cost of jatropha biodiesel													
		Yield													
	yr 1	0.5	T/ha												
	yr 2	1.25	T/ha												
	yr 3	2.5	T/ha												
	yr 4	5	T/ha												
	yr 5	5	T/ha												
		Cost of land													
		31330	Rs/ha												
		Cost of seed production w.o land													
	yr 1	27145	Rs/ha												
	yr 2	6234	Rs/ha												
	yr 3	7005	Rs/ha												
	yr 4	13000	Rs/ha												
	yr 5	22865	Rs/ha												
		Cost of seed production	ha												
	yr 1	58475	Rs/ha	36839250	60504570	84655620	112583520	146726370	180869220	178172820	188650350	198642150	204857100	204857100	204857100
	yr 2	37564	Rs/ha												
	yr 3	38335	Rs/ha												
	yr 4	44330	Rs/ha												
	yr 5	54195	Rs/ha												
		Seed production	T	0	315	1102.5	2677.5	5827.5	8977.5	11812.5	14175	15750	15750	18900	22050
				0	315	1102.5	2677.5	5827.5	8977.5	11812.5	14175	15750	15750	15750	15750
		Cost of seed production	Rs/T	36839250.00	203602.68	86275.79	50079.84	31786.99	26961.16	21396.11	20011.31	20101.93	21974.71	23293.20	24690.79
		1.06													
		Cost of extraction	Rs												
		4420	Rs/T	0	1475838	5475358.98	14095138.4	32518313.42	53101526.94	74062656	94207698.43	110955733.7	117613077.7	124669862.4	132150054.1
		Cost of transesterification	Rs												
		5000	Rs/T	0	333900	1238769	3188945.34	7357084.484	12013920.12	17203090.53	22498067.75	27613417.89	31931152.33	33847021.46	35877842.75
		Cost of biodiesel production b4 capital		36839250.00	62314308.00	91369747.98	129867603.74	186601767.91	245984667.07	269438566.53	305356116.18	337211301.60	354401330.06	363373983.86	372884996.89
		Opportunity cost													
		7.5	%	2762943.75	4673573.1	6852731.099	9740070.281	13995132.59	18448850.03	20207892.49	22901708.71	25290847.62	26580099.75	27253048.79	27966374.77
C		*Cost of biodiesel after accting for capital*		39602193.75	66987881.10	98222479.08	139607674.02	200596900.50	264433517.10	289646459.02	328257824.90	362502149.22	380981429.81	390627032.65	400851371.66
		Revenue from biodiesel and by-products													
R		Oil production					598.5	1512	2142	2772	3402	4032	4662	5292	
	yr 2	0.1	x1		63	220.5	535.5	1165.5	1795.5	2425.5	2992.5	3465	3780	3780	3780
	yr 3	0.25	x2		63	220.5	535.5	1165.5	1795.5	2425.5	3055.5	3685.5	4315.5	4945.5	5512.5
	yr 4	0.5	x3												
	yr 5	1	x4												
		Diesel equivalent	T	0	121.275	424.4625	1030.8375	2243.5875	3456.3375	4669.0875	5760.5625	6670.125	7276.5	7276.5	7276.5
		Price of diesel equivalent	Rs/T	34319	36378.14	38560.8284	40874.4781	43326.94679	45926.5636	48682.15741	51603.08686	54699.27207	57981.22839	61460.1021	65147.70822
		Revenue from biodiesel	Rs	0	4411758.929	16367625.62	42134944.82	97207796.23	158737704	227301252.7	297262807	364850982.1	421900408.4	447214432.9	474047298.9

				12	13	14	15	16	17	18	19	20	21	22	23
				2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
		Available marginal land	ha	3780	3780	3780	3780	3780	3780	3780	3780	3780	3780	3780	3780
		Cost of jatropha biodiesel													
		Yield													
	yr 1	0.5	T/ha												
	yr 2	1.25	T/ha												
	yr 3	2.5	T/ha												
	yr 4	5	T/ha												
	yr 5	5	T/ha												
		Cost of land													
		31330	Rs/ha												
		Cost of seed production w.o land													
	yr 1	27145	Rs/ha												
	yr 2	6234	Rs/ha												
	yr 3	7005	Rs/ha												
	yr 4	13000	Rs/ha												
	yr 5	22865	Rs/ha												
		Cost of seed production	ha												
	yr 1	58475	Rs/ha	204857100	204857100	204857100	204857100	204857100	204857100	204857100	204857100	204857100	204857100	204857100	204857100
	yr 2	37564	Rs/ha												
	yr 3	38335	Rs/ha												
	yr 4	44330	Rs/ha												
	yr 5	54195	Rs/ha												
		Seed production	T	25200	28350	31500	31500	31500	31500	31500	31500	31500	31500	31500	31500
				15750	15750	15750	15750	15750	15750	15750	15750	15750	15750	15750	15750
		Cost of seed production	Rs/T	26172.24	27742.57	29407.13	31171.55	33041.85	35024.36	248169.74	39353.37	41714.57	44217.44	46870.49	49682.72
		1.06													
		Cost of extraction	Rs												
		4420	Rs/T	140079057.4	148483800.8	157392828.9	166836398.6	176846582.5	187457377.5	198704820.1	210627109.3	223264735.9	236660620.1	250860257.3	265911872.7
		Cost of transesterification	Rs												
		5000	Rs/T	38030513.32	40312344.12	42731084.76	45294949.85	48012646.84	50893405.65	53947009.99	57183830.59	60614860.42	64251752.05	68106857.17	72193268.6
		Cost of biodiesel production b4 capital		382966670.70	393653244.95	404981013.64	416988448.46	429716329.37	443207883.13	457508930.12	472668039.93	488736696.32	505769472.10	523824214.43	542962241.29
		Opportunity cost													
		7.5	%	28722500.3	29523993.37	30373576.02	31274133.63	32228724.7	33240591.23	34313169.76	35450102.99	36655252.22	37932710.41	39286816.08	40722168.1
C		*Cost of biodiesel after accting for capital*		411689171.01	423177238.32	435354589.67	448262582.10	461945054.07	476448474.37	491822099.88	508118142.92	525391948.55	543702182.51	563111030.51	583684409.39
		Revenue from biodiesel and by-products													
R		Oil production													
	yr 2	0.1	x1	3780	3780	3780	3780	3780	3780	3780	3780	3780	3780	3780	3780
	yr 3	0.25	x2	5985	6300	6300	6300	6300	6300	6300	6300	6300	6300	6300	6300
	yr 4	0.5	x3												
	yr 5	1	x4												
		Diesel equivalent	T	7276.5	7276.5	7276.5	7276.5	7276.5	7276.5	7276.5	7276.5	7276.5	7276.5	7276.5	7276.5
		Price of diesel equivalent	Rs/T	69056.57072	73199.96496	77591.96286	82247.48063	87182.32947	92413.26923	97958.06539	103835.5493	110065.6823	116669.6232	123669.8006	131089.9886
		Revenue from biodiesel	Rs	502490136.8	532639545	564597917.7	598473792.8	634382220.4	672445153.6	712791862.8	755559374.6	800892937	848946513.3	899883304.1	953876302.3

				0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
		Press cake production																									
	yr 2	0.32	T/ha		201.6	705.6	1713.6	3729.6	5745.6	7560	9072	10080	12096	12096	12096	12096	12096	12096	12096	12096	12096	12096	12096	12096	12096	12096	12096
	yr 3	0.8	T/ha		201.6	705.6	1713.6	3729.6	5745.6	7761.6	9777.6	11793.6	13809.6	15825.6	17640	19152	20160	20160	20160	20160	20160	20160	20160	20160	20160	20160	20160
	yr 4	1.6	T/ha																								
	yr 5	3.2	T/ha																								
		Press cake	T	0	201.6	705.6	1713.6	3729.6	5745.6	7560	9072	10080	12096	12096	12096	12096	12096	12096	12096	12096	12096	12096	12096	12096	12096	12096	12096
R	2000	*Price of press cake fertiliser*	Rs/T	2120.00	2247.20	2382.03	2524.95	2676.45	2837.04	3007.26	3187.70	3378.96	3581.70	3796.60	4024.39	4265.86	4521.81	4793.12	5080.70	5385.55	5708.68	6051.20	6414.27	6799.13	7207.07	7639.50	8097.87
		Revenue from press cake fertiliser	Rs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		1.06																									
		Glycerol production																									
	yr 2	0.012	kg/ha		7.56	26.46	64.26	139.86	215.46	283.5	340.2	378	453.6	453.6	453.6	453.6	453.6	453.6	453.6	453.6	453.6	453.6	453.6	453.6	453.6	453.6	453.6
	yr 3	0.03	kg/ha						215.46	291.06	366.66	442.26	517.86	593.46	661.5	718.2	756	756	756	756	756	756	756	756	756	756	756
	yr 4	0.06	kg/ha																								
	yr 5	0.12	kg/ha																								
		Glycerol	T	0	7.56	26.46	64.26	139.86	215.46	283.5	340.2	378	453.6	453.6	453.6	453.6	453.6	453.6	453.6	453.6	453.6	453.6	453.6	453.6	453.6	453.6	453.6
		Price of glycerol	Rs/T	17384.00	18427.04	19532.66	20704.62	21946.90	23263.71	24659.54	26139.11	27707.45	29369.90	31132.10	33000.02	34980.02	37078.82	39303.55	41661.77	44161.47	46811.16	49619.83	52597.02	55752.84	59098.01	62643.89	66402.53
R	16400	*Revenue from glycerol*	Rs	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		1.06																									
	Conversion factor	1.925																									
		Total revenue b4 soc & ental benefits		0	4411758.929	16367625.62	42134944.82	97207796.23	158737704	227301252.7	297262807	364850982.1	421900408.4	447214432.9	474047298.9	502490136.8	532639545	564597917.7	598473792.8	634382220.4	672445153.6	712791862.8	755559374.6	800892937	848946513.3	899883304.1	953876302.3
		Total revenue with soc & ental benefits		12859323.75	21894385.07	41021664.38	80793544.07	165179736.80	257777415.26	342650971.58	442164866.86	541907217.88	626341793.35	663922300.95	703757639.00	745983097.34	790742083.19	838186608.18	888477804.66	941786472.95	998293661.32	1058191281.00	1121682757.86	1188983723.33	1260322746.73	1335942111.54	1416098638.22
		Social benefits																									
		Shadow benefits from labour							376425	477855	579285	680715	707490	789390	863100	912870	912870	912870	912870	912870	912870	912870	912870	912870	912870	912870	912870
	yr 1	118.5	man hrs/ha	74655	94185	121905	173565	274995	376425	403200	485100	558810	608580	608580	608580	608580	608580	608580	608580	608580	608580	608580	608580	608580	608580	608580	608580
	yr 2	31	Rs	12859323.75	17196768.23	23593505.89	35607294.7	59800868.19	86769484.24	98517854.57	125641051.4	153415882.3	177104539.8	187730812.2	198994660.9	210934340.6	223590401	237005825.1	251226174.6	266299745.1	282277729.8	299214393.6	317167257.2	336197292.6	356369130.2	377751278	400416354.6
	yr 3	44																									
	yr 4	82																									
	yr 5	161																									
	162.5	1.06																									
		Environmental benefits																									
		Revenue from carbon displacement		0	285857.9137	1060532.86	3051304.542	8171072.376	12270227.02	16831864.35	19261008.42	23640353.49	27336845.12	28977055.83	30715679.18	32558619.93	34512137.13	36582865.36	38777837.27	41104507.51	43570777.96	46185024.64	48956126.12	51893493.68	55007103.31	58307529.51	61805981.27
			Rs	0	285857.9137	1060532.86	3051304.542	8171072.376	12270227.02	16831864.35	19261008.42	23640353.49	27336845.12	28977055.83	30715679.18	32558619.93	34512137.13	36582865.36	38777837.27	41104507.51	43570777.96	46185024.64	48956126.12	51893493.68	55007103.31	58307529.51	61805981.27
		Cash flow at time t w.o soc & ental		-39602193.75	62576122.17	81854853.45	-97472729.20	-103389104.27	-105695813.09	-62345206.37	-30995017.86	2348832.90	40918978.60	56587400.26	73195927.23	90800965.81	109462306.71	129243328.07	150211210.70	172437166.29	195996679.22	220969762.92	247441231.65	275500988.50	305244330.76	336772273.55	370191892.92
		Cash flow at time t with soc & ental		-26742870.00	45093496.03	57200814.70	-58814129.95	-35417163.70	-6656101.83	53004512.55	113907041.97	179405068.66	245360363.54	273295268.30	302906267.35	334293926.34	367564844.87	402832018.51	440215222.56	479841418.87	521845186.96	566369181.12	613564614.94	663591774.78	716620564.22	772831081.03	832414228.83
		Interest rate																									
		10	%																								
		Present value w.o soc & ental		39602193.75	56887383.79	67648639.22	-73232704.13	-70616149.35	-65628784.1	-35192243.66	-15905345.04	1095747.88	17353641.37	21816892.44	25654725.96	28931985.99	31707331.18	34033807.69	35959369.57	37527351.48	38776898.11	39743354.17	40458618.63	40951466.45	41247840.69	41371117.82	41342348.63
		Present value with soc & ental		-26742870	-40994087.3	47273400.58	-44187926.34	-24190399.36	-4132915.558	29919665.51	58452323.31	83693788.58	104056745.8	105367156.7	106166798.8	106516347.1	106470442.8	106078260.7	105384024.3	104427473.3	103244288.2	101866475.6	100322717.4	98638688.93	96837345.98	94939186.56	92962487.6
		Net present value w.o soc & ental		127292862.7																							
		Net present value with soc & ental		1517822618																							
		Diesel import substitution	T																								
	Increase 2 yrs ave	1.016	%	336765.392	342153.6383	347628.0965	353190.146	358841.1884	364582.6474	370415.9697	376342.6253	382364.1073	388481.933	394697.6439	401012.8062	407429.0111	413947.8753	420571.0413	427300.1779	434136.9808	441083.1725	448140.5032	455310.7513	462595.7233	469997.2549	477517.211	485157.4863
	Increase 5 yrs ave	1.0325	%	342234.515	353357.1367	364841.2437	376698.5841	388941.2881	401581.8799	414633.291	428108.873	442022.4114	456388.1397	471220.7543	486535.4288	502347.8302	518674.1347	535531.0441	552935.803	570906.2166	589460.6687	608618.1404	628398.23	648821.1724	669907.8605	691679.866	714159.4617
	Increase 10 yrs ave	1.051	%	348366.562	366133.2567	384806.0528	404431.1614	425057.1507	446735.0654	469518.5537	493463.9999	518630.6639	545080.8278	572879.95	602096.8275	632803.7657	665076.7577	698995.6723	734644.4516	772111.3187	811488.9959	852874.9347	896371.5564	942086.5058	990132.9176	1040629.696	1093701.811
		Diesel import substitution [2 yrs]	%		0.04	0.12	0.29	0.63	0.95	1.26	1.53	1.74	1.87	1.84	1.81	1.79	1.76	1.73	1.70	1.68	1.65	1.62	1.60	1.57	1.55	1.52	1.50
		Diesel import substitution [5 yrs]	%		0.03	0.12	0.27	0.58	0.86	1.13	1.35	1.51	1.59	1.54	1.50	1.45	1.40	1.36	1.32	1.27	1.23	1.20	1.16	1.12	1.09	1.05	1.02
		Diesel import substitution [10 yrs]	%		0.03	0.11	0.25	0.53	0.77	0.99	1.17	1.29	1.33	1.27	1.21	1.15	1.09	1.04	0.99	0.94	0.90	0.85	0.81	0.77	0.73	0.70	0.67
		Price of imported diesel	Rs/T	37216	39448.96	41815.8976	44324.85146	46984.34254	49803.4031	52791.60728	55959.10372	59316.64994	62875.64894	66648.18787	70647.07915	74885.9039	79379.05813	84141.80162	89190.30971	94541.7283	100214.232	106227.0859	112600.7111	119356.7537	126518.159	134109.2485	142155.8034
		1.06																									

APPENDIX 4

SCENARIO 2

			2007			
	Rates	Units	Quantity	Cost	Revenue	
Diesel demand		T	348366			
Diesel Substitution		T	17418			
at	5	%				
Equivalence biodiesel & diesel						
at	0.7885					
Revenue from biodiesel	37216	Rs/T			648239452.8	
Glycerine		T	7345			
at	0.302					
Price of glycerine	17384	Rs/T			127687400	
Presscake		T	54464		115463574	
at	0.64					
Price of presscake	2120	Rs/T				
Oil for biodiesel		T	24322			
at	1.101					
Cost of transeterification	5000	Rs/T		121607789		
Oil from jatropha		T	24322			
Seed for oil		T	85100			
	0.2858					
at	100	%				
Extraction cost	4420	Rs/T		376141656		
Import cost for seed	4600	Rs/T		391459642.2		
Import oil for oil		T	0			
at	0	%				
Import cost for oil	18500	Rs/T		0		
Sub-total		Rs		889209087.2	891390427.2	
Revenue-Cost		Rs				2181340.065