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Vegetable Oil Based Biofuels in India: An Overview of the Value Chain and Analysis of Biofuels' Pro-Poor Potential

Nicholas Kukrika

Environment and Natural Resources Program
Belfer Center for Science and International Affairs

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An overview of the value chain and analysis of biofuels' pro-poor potential

Nicholas Kukrika*

* Nicholas Kukrika, Master in Public Policy, John F. Kennedy School of Government, Harvard University 2007

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FOREWORD

This paper was originally submitted as a Policy Analysis Exercise (Harvard University's John F. Kennedy School of Government's Masters Thesis). While I oversaw the development of both the PAE and the paper, Jay Rosengard (KSG), and Brian Trelstad (Acumen Fund) also contributed significantly to this effort.

Prior to attending the Kennedy School, Nicholas Kukrika was chief financial officer for United Biofuels, a biodiesel production company in Pennsylvania. He now works for Generation Investment Management in London.

This paper addresses two key questions: 1) What is the economic potential of biofuel development in India? And 2) What are the obstacles to this development? Kukrika's ability to obtain actual data and to trace the economics at each stage in the production chain – from harvesting to processing to transportation – makes this paper both timely and valuable.

This discussion paper is an important part of the KSG's ongoing work in the Bioenergy and Trade Project.

Henry Lee

Jassim M. Jaidah Family Director
Environment and Natural Resources Program
John F. Kennedy School of Government

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EXECUTIVE SUMMARY

***Key Conclusions about the Investment Climate*:**

A review of the industry economics and value chain below demonstrates that biofuels in India can provide substantial benefits for the rural poor by:

1. *Delivering lower cost energy: Biofuels can be 12-32% less expensive, offering substantial savings to consumers who use conventional diesel.* For example, farmers using diesel irrigation pumps could save as much as RS 1,500 for each acre of irrigated land
2. *Generating earnings of RS 5,000-10,000 per acre in peak cash profits for smallholder growers and up to 325,000 person days of work for every 5,000 hectares of feedstock grown.*
3. *Improving the rural environment / air quality and thereby reducing the number of respiratory illnesses caused by harmful emissions.*

Yet significant risks exist at both the industry and company level:

Industry level concerns:

1. *A recent government mandate fixed the price of biodiesel below the industry's current cost of production, stalling all sales of biodiesel.* There is no clarity on when the mandate may be relaxed or if it may applied to other types of biofuels such as straight vegetable oil.
2. *Demand for vegetable oil feedstocks from export markets could limit the availability of feedstocks to producers serving the domestic fuel market.*
3. *Widespread development of the biofuels sector could diminish important resources for food-based agriculture, including land and water.*

Company level concerns:

1. *All of the firms in the sector are still in the start-up / development stage and many have yet to prove their capability to achieve the necessary crop yields and quality of end-products that will be essential to financial sustainability.*

2. *Most of the start-up companies interviewed for this report have not developed a compelling plan for how they will serve the base of the pyramid and most have not developed a complete distribution strategy for their end products.*

INTRODUCTION

Amidst rising energy prices and on-going threats to the global environment, consumers, producers and governments across the world are searching for viable alternative sources of energy. Biofuels represent one such alternative. Biofuels are substitutes for fossil-based liquid fuels typically produced from agricultural crops. The two main types of biofuels, ethanol (a substitute for gasoline) and biodiesel (a substitute for diesel) have gained widespread acceptance in developed country markets, particularly the US and European Union.

In early 2003, the Indian National Planning Commission launched an ambitious program to foster development of vegetable oil based biofuels, in its "Report of the Committee on Development of Biofuel."[1] The Planning Commission cited several broad national challenges which it believed its program would address:

- **Energy access:** Approximately 57% of rural Indian households are still not connected to the formal power grid.[2] While centralized power generation and grid distribution are still the most economically viable sources of energy, progress on extending the grid to rural areas in India is slow. As a result, distributed approaches to energy production are common. Such approaches include millions of businesses and households which use diesel (or kerosene) powered generator sets to compensate for the inadequate or inconsistent grid access.
- **Energy security:** India currently imports 75% of their total petroleum consumption, with imports set to rise to as much as 94% in the next two decades.[3] Such high levels of oil imports place considerable risk on those consumers who use petroleum based products for their basic energy needs, including electricity generation, basic lighting (e.g. lanterns) and transportation.
- **Environmental degradation:** India is the world's fifth largest emitter of carbon dioxide and per capita emissions are projected to increase from 1.0 to 1.6 tons by 2030. In

[1] Indian National Planning Commission. Government of India, New Delhi. Report available at: http://planningcommission.nic.in/reports/genrep/cmtt_bio.pdf

[2] Ailawadi VS, Battacharyya, Subhes. "Access to energy services by the poor in India. Current situation and need for alternative strategies." Blackwell Publishing Ltd., 2006.

[3] Misra, Neha. Petroleum Pricing in India: Balancing Efficiency and Equity. TERI, 2005. Page 6

addition, soot, sulfur and other harmful emissions have been attributed to a higher incidence of respiratory illness.[4]

The Commission responded to these challenges with a "National Mission on Biodiesel." It advocated widespread planting of an inedible, but high-yielding and hearty tree-born oilseed known as *jatropha curcas* (jatropha) that would serve as the primary feedstock for the production of vegetable oil based biofuels. More specifically, the Commission recommended that 11.2 million hectares of jatropha be cultivated on marginal waste-lands which would, over time, replace 20% of total national diesel consumption with biodiesel.[5]

Widespread use of biodiesel would in turn dramatically improve air quality. Replacing 20% of the nation's diesel consumption with biodiesel would reduce total sulfur emissions by 20%, carbon dioxide emissions by 16% and particulate matter emissions by 22%.[6]

In addition, the Commission argued that the added supply of locally produced and potentially lower cost fuel could increase the delivery of commercial forms of energy to the poor, particularly those in rural areas. In fact, the Commission believed that the rural poor stood to benefit the most from their initiative. Not only would the poor enjoy improved access to energy, but developing millions of hectares of jatropha would also generate massive employment opportunities and new revenue streams for smallholder farmers. The Commission estimated that each new hectare of jatropha would create 263 person days of employment in the first year and an additional 48 person days each year thereafter. Moreover, it was estimated that farmers could earn as much as RS 25,000 in income per year from each hectare of jatropha they cultivated. [7]

Since the publication of the Planning Commission's report, both public and private sector players have begun to act on the Commission's roadmap. Well in excess of a hundred thousand hectares of jatropha have been planted, private firms have begun to build biodiesel processing plants and

[4] Francis, Edinger and Becker, "A concept for simultaneous wasteland reclamation, fuel production, and socio-economic development in degraded areas in India: Need, potential and perspectives of Jatropha plantations," *Natural Resources Forum29 (2005).*Published by Blackwell Publishing, Oxford, UK.
[5] National Planning Commission Report, pg. 118
[6] Ibid., page 68
[7] Kashyap, Diva and Glueck, Michael. GTZ, "Liquid Biofuels for Transportation.," submitted by The Energy and Resources Institutepg. 52. At a later point in the report, I provide an updated estimate of the long-run impact which suggests that peak profits are likely to be ~ RS 5,000 – 10,000.

state-owned petroleum product marketing firms have in principle committed to distributing biodiesel through at least some of its existing distribution channels. Producers and consumers have also begun to consider other products that can be made from the jatropha feedstock. In addition to biodiesel, which is chemically refined to become a perfect substitute for fossil diesel, the straight jatropha vegetable oil (or SVO) is also being blended with regular diesel to lower costs for diesel consumers.[8]

Not surprisingly, however, overall progress has fallen well short of the Planning Commission's original projections. This shortfall is due in part to national government policy, which over the last three years has often been unclear and at times misguided. Many investors in the sector complain that the government has not offered a firm ruling on the taxation of vegetable oil based biofuels. In addition, a recently issued national "biodiesel purchase policy," requiring state-owned distribution firms to purchase biodiesel at a *fixed price* of RS 26.5 has choked off potential supply. State-owned distribution firms are responsible for marketing in excess of 90%[9] of the petroleum products (diesel, gasoline, kerosene, etc) purchased by end-users throughout the country. Yet the fixed price set by the government was set well below the level which is economically viable for biodiesel producers, thus discouraging any measurable production.[10]

Yet the relatively slow progress is also simply a function of the best laid plans bumping up against reality. Developing a brand new value chain for liquid fuels clearly cannot happen overnight.

In the following chapter, I will provide a brief overview of the vegetable-oil based biofuels industry in the EU and United States. I will then provide an overview of the industry's economics and detail the requirements at each stage of the value chain for the industry to reach its potential. I will highlight the progress industry players have made towards achieving these requirements and the issues that they still must resolve.

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[8] For a more complete description of the differences between biodiesel and straight jatropha oil see the box on page 21.
[9] This is a rough estimate based on interviews with CleanStar. The remaining 10% is distributed by two private firms, Reliance and BP.
[10] Interview with CleanStar

The Global Context in the Vegetable Oil Biofuels Sector:

In 2005 over 3.5 billion liters of biodiesel were produced worldwide.[11] The EU is by far the largest market, with over 90% of production and consumption. Trailing a distant second, the US market represents approximately 8% of total production and consumption with the remainder accounted for by a variety of emerging markets (including Brazil, Argentina and Malaysia). The industry has grown at a compound annual rate of 29% since 1991, and experienced a substantial step-up in growth since 2000, when total production was roughly 1.6 billion liters.[12]

Demand in these markets has been supported by three factors. First, sub-markets within the US and Europe have mandated the blending of biodiesel in relatively small quantities (of 2-5%) in all conventional diesel sold.[13] These mandates have created a base market for the fuel regardless of price. In addition, both the EU and the US have developed generous subsidies, tax credits or fuel tax exemptions on biodiesel to ensure its cost competitiveness with regular diesel. (For example in the United States, distributors of biodiesel receive one dollar for every gallon of biodiesel they blend with conventional diesel.)[14] Finally, biodiesel demand has also been driven by environmental guidelines encouraging the use of renewable transportation fuels.

With global crude oil prices surging since 2005, awareness of biodiesel as an economic alternative in the developing world has risen sharply. From Indonesian palm-oil plantations to Argentinean and Brazilian soybean fields, there has been massive government and private sector interest in fostering full-fledged biodiesel industries. These countries plan to take advantage of their lower cost of raw materials - a key limiting factor in both the US and Europe. While some of this developing world biodiesel capacity is designed for domestic consumption, much of it is planned for export to the well-established American and European markets.

Vegetable Oil Biofuels in India – The Beginning of a New Approach?

In this context of large state-subsidized programs and centralized industrial production emphasizing edible oils, the nascent Indian vegetable oil biofuel industry is a relative anomaly.

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[11] *Biodiesel 2020: A Global Market Survey*. Emerging Markets Online. October 2006.
[12] Ibid.
[13] For example, all diesel sold in Minnesota must contain at least 2% biodiesel.
[14] If a distributor blends 5 gallons of biodiesel with 95 gallons of regular diesel to make a 5% biodiesel blend, this distributor can receive $5 directly from the IRS, even without incurring a taxable event. It is important to note that in today's market, the overwhelming majority of this $1 tax credit is passed on to the buyer in lower prices.

As discussed further below, the Indian industry has focused on inedible oils for feedstocks to avoid upsetting the delicate supply and demand balance for edible oils, an essential component of Indian food security. The program has emphasized the large-scale cultivation of jatropha on so-called "wastelands" currently not under cultivation. Moreover, unlike the centralized approach of most other emerging biodiesel markets involving large biodiesel manufacturing facilities, the Indian approach contemplates much more distributed production that could effectively address domestic (and particularly rural) energy needs.

ECONOMIC ANALYSIS OF THE INDIAN BIOFUELS INDUSTRY

Notwithstanding its potential benefits, vegetable oil biofuels' near-term success or failure will largely hinge on the products' underlying economics. The social impacts of biofuels will only be realized if the product is cost competitive with conventional diesel oil and price conscious consumers (of all income levels) elect to purchase it.

The cost-build up analyses in Tables 1 and 2 below highlight that jatropha based biofuels can be 12-32% less expensive than conventional diesel at current market prices. Table 1 reviews the costs of producing *biodiesel* while Table 2 outlines the costs of *straight vegetable oil* (SVO). The major cost categories for biodiesel and SVO are similar, except that producing biodiesel requires approximately RS 6.5 in extra costs associated with transesterification. Unlike biodiesel, SVO is not a perfect substitute for conventional diesel and SVO's lower cost of production corresponds to a lower quality of fuel. (For a complete treatment of the difference between SVO and biodiesel see Box on page 27).

Both Tables 1 and 2 highlight the fixed and variable costs in years one through ten for the planting of a 5,000 acre jatropha plantation and SVO/biodiesel refining operation. In both tables I have outlined all of the major costs for producing biodiesel and SVO. The costs are stated in absolute terms and per liter terms. To allow time for the jatropha trees to mature, the model assumes that fruits are only harvested beginning in year 4. Therefore, no jatropha oil or biodiesel is produced until the fourth year of operations. Importantly, the model also assumes a ramp up in the yield per jatropha tree. In the first year of harvest (year 4) yields are assumed to be 1 kg per tree ramping up to 3kgs per tree by year 8. As a result, biodiesel and SVO are actually more expensive (on a variable cost basis) in the first several harvests. Finally it should also be noted that the model assumes 100% equity financing and therefore there are no interest expenses or debt amortization costs.

More detailed versions of the tables that follow can be found in Appendices I(a) and I(b). Readers can also find the assumptions used to develop the model and an overview of the required fixed capital investment in Appendices II and III.

TABLE 1: On-going cost analysis: *Biodiesel* production costs vs current diesel price (April 2007)

			Year4	Year5	Year6	Year7	Year8	Year9	Year10
1	**Annual variable plantation costs**								
	Lease	Rs / lit	6.13	1.53	0.94	0.82	0.77	0.68	0.68
	Harvesting	Rs / lit	3.41	3.41	3.41	3.41	3.41	3.41	3.41
	Maintenance	Rs / lit	15.33	3.83	2.36	2.04	1.92	1.70	1.70
	Retainership (including irrigation costs)	Rs / lit	16.87	4.22	2.59	2.25	2.11	1.87	1.87
	Sub-total	Rs / lit	**41.74**	**12.99**	**9.31**	**8.52**	**8.20**	**7.67**	**7.67**
2	**Annual variable logistics costs**								
	Seed collection center	Rs / lit	0.15	0.07	0.07	0.06	0.06	0.07	0.07
	Wharehousing	Rs / lit	1.59	0.40	0.49	0.43	0.40	0.35	0.35
	Transport	Rs / lit	1.02	1.02	1.02	1.02	1.02	1.02	1.02
	Sub-total	Rs / lit	**2.76**	**1.49**	**1.58**	**1.51**	**1.48**	**1.44**	**1.44**
3	**Annual extraction operating costs**								
	Seed preparation	Rs / lit	0.34	0.34	0.34	0.34	0.34	0.34	0.34
	Decorticator and oil extraction unit operations	Rs / lit	3.07	3.07	3.07	3.07	3.07	3.07	3.07
	Sub-total	Rs / lit	**3.41**	**3.41**	**3.41**	**3.41**	**3.41**	**3.41**	**3.41**
4	**Oil distribution (to biodiesel production plant)**	Rs / lit	**0.45**	**0.45**	**0.45**	**0.45**	**0.45**	**0.45**	**0.45**
5	**Biodiesel production (total refining costs)**								
	Methanol	Rs / lit	4.52	4.52	4.52	4.52	4.52	4.52	4.52
	KOH	Rs / lit	0.18	0.18	0.18	0.18	0.18	0.18	0.18
	Electricity, water and other	Rs / lit	1.19	1.19	1.19	1.19	1.19	1.19	1.19
	Yield loss (10%)	Rs / lit	0.59	0.59	0.59	0.59	0.59	0.59	0.59
	Sub-total	Rs / lit	**6.49**	**6.49**	**6.49**	**6.49**	**6.49**	**6.49**	**6.49**
6	**Depreciation of fixed costs**	Rs / lit	**4.62**	**1.16**	**0.71**	**0.62**	**0.58**	**0.51**	**0.51**
	Sub-total costs for BIODIESEL before distribution to end-u	RS / lit	59.48	25.99	21.95	20.99	20.60	19.97	19.97
	Distribution to end-users	RS / lit	3.00	3.00	3.00	3.00	3.00	3.00	3.00
	Producer's margin	RS / lit	3.00	3.00	3.00	3.00	3.00	3.00	3.00
	Assumed tax (excise and sales)	RS / lit	4.00	4.00	4.00	4.00	4.00	4.00	4.00
	Total cost of biodiesel (delivered)	**RS / lit**	**69.48**	**35.99**	**31.95**	**30.99**	**30.60**	**29.97**	**29.97**
	Current average cost of diesel fuel	RS / lit	34.00	34.00	34.00	34.00	34.00	34.00	34.00
	Difference (current diesel price - production costs)	RS / lit	**(35.48)**	**(1.99)**	**2.05**	**3.01**	**3.40**	**4.03**	**4.03**
	% difference with current diesel price	RS / lit	**NM**	**NM**	**6.0%**	**8.8%**	**10.0%**	**11.8%**	**11.8%**

Source: CleanStar and author estimates

* Estimates begin in Year 4, the first year in which jatropha trees actually begin to provide seeds.

NOTE: Model does not include any costs for executive management overhead

TABLE 2: On-going cost analysis: *Straight vegetable oil* production costs vs current diesel price (April 2007)

			Year4	Year5	Year6	Year7	Year8	Year9	Year10
1	**Annual variable plantation costs**								
	Lease	Rs / lit	6.13	1.53	0.94	0.82	0.77	0.68	0.68
	Harvesting	Rs / lit	3.41	3.41	3.41	3.41	3.41	3.41	3.41
	Maintenance	Rs / lit	15.33	3.83	2.36	2.04	1.92	1.70	1.70
	Retainership (including irrigation costs)	Rs / lit	16.87	4.22	2.59	2.25	2.11	1.87	1.87
	Sub-total	Rs / lit	**41.74**	**12.99**	**9.31**	**8.52**	**8.20**	**7.67**	**7.67**
2	**Annual variable logistics costs**								
	Seed collection center	Rs / lit	0.15	0.07	0.07	0.06	0.06	0.07	0.07
	Wharehousing	Rs / lit	1.59	0.40	0.49	0.43	0.40	0.35	0.35
	Transport	Rs / lit	1.02	1.02	1.02	1.02	1.02	1.02	1.02
	Sub-total	Rs / lit	**2.76**	**1.49**	**1.58**	**1.51**	**1.48**	**1.44**	**1.44**
3	**Annual extraction operating costs**								
	Seed preparation	Rs / lit	0.34	0.34	0.34	0.34	0.34	0.34	0.34
	Decorticator and oil extraction unit operations	Rs / lit	3.07	3.07	3.07	3.07	3.07	3.07	3.07
	Sub-total	Rs / lit	**3.41**	**3.41**	**3.41**	**3.41**	**3.41**	**3.41**	**3.41**
4	**Depreciation of fixed costs**	Rs / lit	**4.62**	**1.16**	**0.71**	**0.62**	**0.58**	**0.51**	**0.51**
	Sub-total costs for SVO before distribution to end-users	RS / lit	52.54	19.05	15.01	14.05	13.66	13.03	13.03
	Distribution to end-users	RS / lit	3.00	3.00	3.00	3.00	3.00	3.00	3.00
	Producer's margin	RS / lit	3.00	3.00	3.00	3.00	3.00	3.00	3.00
	Assumed tax (excise and sales)	RS / lit	4.00	4.00	4.00	4.00	4.00	4.00	4.00
	Total cost of SVO (delivered)	**RS / lit**	**62.54**	**29.05**	**25.01**	**24.05**	**23.66**	**23.03**	**23.03**
	Current average cost of diesel fuel	RS / lit	34.00	34.00	34.00	34.00	34.00	34.00	34.00
	Difference (current diesel price - production costs)	RS / lit	**(28.54)**	**4.95**	**8.99**	**9.95**	**10.34**	**10.97**	**10.97**
	% difference with current diesel price	RS / lit	**NM**	**15%**	**26%**	**29%**	**30%**	**32%**	**32%**

Source: CleanStar and author estimates
* Estimates begin in Year 4, the first year in which jatropha trees actually begin to provide seeds.
NOTE: Model does not include any costs for executive management overhead

As can be seen at the bottom of Table 1, given certain assumptions, the cost of producing a liter of biodiesel is roughly RS 20 in the tenth year after the initial planting of feedstocks. If one then adds another RS 3 for distribution costs, RS 4 for excise and sales taxes, the full cost of the biodiesel could be as little as RS 27.[15] The analysis assumes a multi-level strategy of a plant that crushes its own oil (sources within a 25 mile radius) and then distributes it within the same 25 mile radius. Distribution beyond 25 miles would result in still higher distribution costs, making it likely that producers would either sell their product to one of the government owned petroleum firms or within local market. If one then assumes a gross margin of RS 3 for the producer, final delivered cost, of RS 30.0, would still be RS 4 (or roughly 12%) less expensive than the current price of conventional diesel, but RS 5 higher than the price offered in 2006 by the state owned petroleum companies.

The analysis in table 2 highlights the costs of producing straight vegetable oil, i.e. without the transesterification step. Using the same assumptions for distribution costs, excise tax and the producer's absolute margin, SVO can be up to 32% less expensive than conventional diesel.

There are several critical assumptions required to develop these estimates. Among these, the yield per plant is by far the most important. If peak plant yields ultimately prove to be 2 kgs per plant (as opposed to the 3 kgs per plant projected in the model above) the estimated variable costs of biodiesel would rise by RS 3, practically eroding biodiesel's entire cost advantage. (See Appendix for more detailed description of key assumptions.)

Importantly, this model assumes relatively small scale production of approximately 3.0 million liters per annum. Such levels of production could be conducted in a distributed fashion with the biodiesel output being delivered to villages and towns within a fairly tight radius.

[15] Such high levels of final product distribution costs may be appropriate if one hopes to deliver products to the rural poor, as opposed to delivering the product in the specific village in which it is produced.

THE INDIAN BIOFUELS INDUSTRY VALUE CHAIN

The evolution of the Indian vegetable oil biofuels value chain will ultimately determine whether the assumptions outlined above are achievable. The value chain for vegetable oil biofuel production has four main steps:

1. **Feedstock production:** the growing and harvest of oilseed crops used for biofuels
2. **Oil extraction:** extracting and crudely refining the oil from harvested seeds
3. **Transesterification:** the chemical process of turning the raw vegetable oil into biodiesel[16]
4. **Final distribution and demand**: bringing the final product to end-users

The sections that follow will outline the current state of key steps in the value chain and provide a perspective on the potential challenges to its development.

FEEDSTOCK PRODUCTION

Key requirements:

Vegetable oil typically represents 80% of the total costs of biofuels making feedstock development by far the most critical segment of the overall value chain. Given the great importance of edible oils to food preparation and the fact that India is a net importer of such oils[17], the fledgling Indian biofuels industry has focused on the development of inedible oilseeds.

Two such oil sources, jatropha and pongamia are widely recognized as the most economically viable and environmentally neutral feedstock options. Both of these tree-borne oilseeds are adaptable to reasonably harsh climatic and growing conditions, enabling them to be cultivated on so-called "wastelands" that are not currently employed in agricultural production.

As can be seen in the table below, based on still relatively limited field evidence, both jatropha and pongamia require considerably less water than other common oil crops. Yet at the same

[16] The process for producing straight vegetable oil does not require the transesterification step.
[17] India currently imports approximately 50% of its edible oil consumption, Source: Srinivasan, P.V. Impact of Trade Liberalization on India's Oilseed and Edible Oils Sector, Feb 2, 2005.

time, these crops also have relatively high yields per hectare, enhancing their attractiveness as a feedstock source.

Of the two, jatropha is considered the feedstock of choice due to its shorter maturation period and its superior adaptability to arid conditions. The growing characteristics and yields of jatropha and pongamia are summarized below and compared to palm and soybean oil, two edible oil crops which are also cultivated in India.

Table 3: Comparison of growth characteristics and yield for Jatropha, Pongamia, Palm & Soybean[18]

Characteristics	Jatropha	Pongamia	Palm	Soybean
Climate	Arid to semi-arid	Semi-arid to sub-humid	Tropical/forest life	Sub-tropical
Rainfall required	200-1000mm	500-2500mm	640-4260mm	500-4100
Fixes nitrogen	No	Yes	No	Yes
Land type	Waste-land	Waste-lands	Agricultural land	Agricultural land
Plant size	Bush / small tree	Tree	Tree	Vine-like bush
Gestation period	First yields in year 3. Maturity in 5^{th}.	Starts yielding in yr. 5. Yield growths w/ canopy	Starts yielding in year 3-4	Annual crop
Oil content	18-38%	20-39%	45-55%	20%
Toxicity of oil	Toxic	Non-toxic	Non-toxic	Non-toxic
Yields (tons/ha)	1 – 5	0.9 – 9	5.5	0.5

Source: Based on (but revised in part from) GTZ: "Liquid Biofuels for Transportation" and James A. Duke. Handbook of Energy Crops, 1983.

Jatropha seed yields are estimated to be 1 to 5 tons per hectare. Empirical studies suggest typical peak yields of 1.0-1.2 tons of seed / ha in poor, non-irrigated soil and 3-5 tons per ha in irrigated or rain-fed conditions, using germplasm that is available today. These yields assume approximately 1,300 plants per hectare, with each plant typically taking three years to begin bearing fruit and maturity being reached in year five or six.[19]

[18] Table adapted from GTZ: "Liquid Biofuels for Transportation: India country study on potential and implications for sustainable agriculture and energy." Information on Palm and Soybean sourced from James A. Duke. Handbook of Energy Crops, 1983.
[19] Francis, Edinger and Becker, page 18.

There is considerably less field trial data available on pongamia cultivation leading to a very wide range of estimated productivity. Pongamia yields are estimated to be 9-90 kgs of seeds per tree at maturity of 4-7 years (for a total seed yield of 900-9000 kg assuming 100 trees per hectare).[20]

In order to achieve significant scale and stay cost competitive with conventional diesel (at current prices) the biofuels industry must:

1. Secure significant quantities of wasteland on which to grow jatropha and
2. Achieve peak yields of at least five tons per hectare (equating to roughly 3 kgs per plant).

Current state of development:

While progress towards these two requirements is underway, it is still too early to assess whether and when these results will be achieved. Both public and private sector actors (highlighted in the following section) have already begun to plant significant quantities of jatropha country-wide, but credible yield data may not be available for another two years.

Examples of private sector initiatives to develop feedstocks:

Several private sector players are attempting to cultivate a superior breed of jatropha that can "live up" to its billing as an exceptionally hearty crop. Notable examples include Jain Irrigation, Labland Biotech, and Nandan Biomatrix.

Jain Irrigation: initiated a program known as "Jatropha Yadnya," which they assert is "an alternative farming system for jatropha." In fact, much like other firms in the sector, Jain has embarked on a vertically integrated initiative from R&D in jatropha seedlings to biodiesel production and marketing. The company is currently testing 150,000 seedlings in a variety of soil conditions, preparing contract farmers who will cultivate their seeds, and developing plans for a large scale biodiesel production plant in Maharashtra.[21]

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[20] Francis, Edinger and Becker, page 18. The pongamia tree is much larger than jatropha accounting for the relatively small number of plantings per hectare.
[21] See Jain website available at: http://www.jains.com/jatropha/Jatropha%20cultivation.htm

Labland Biotech: Based on press releases by the company, Labland has entered into a $50 million dollar supplier agreement with UK based biodiesel manufacturer D1 Oils to provide approximately 10,000 tons (roughly 11.4 million liters) of Jatropha oil each year for the next 15 years.[22] At present, Labland has not shipped any oil to D1 and is unlikely to do so until 2008 at the earliest. Labland claims to have established a vertically integrated set of services from developing "seedlings of selected high-yielding clones" to oil extraction. Labland has not provided any specific information on expected yields from its germplasm. The company plans to have 130,000 acres under cultivation by 2010.[23]

Nandan Biomatrix: With over 10 years experience in crop science focused on medicinal plants, Nandan has begun an extensive R&D effort in jatropha that is part of a broader vertically integrated effort to manufacture biodiesel. The company claims to have identified varieties that can comfortably provide 3 tons of seeds per hectare and yield more than 35% of oil by seed weight (roughly 40% more than current varieties). In a recent interview the company stated that it has already planted 20,000 hectares of seedlings, managed on a contract farming basis, and is targeting another 80,000 over the next 12 months. It plans to work with UK based Green Fuel to roll out biodiesel production capacity as its jatropha plantings mature.[24]

Importantly, none of these players report that they have reached yields of five tons per hectare with existing germplasm. However, both Nandan Biomatrix and Labland/D1 assert that they will be able to reach such levels within the next 18 months.

Examples of public sector initiatives to develop feedstocks

Over the last four years, there has been significant government interest at the national, state and district level in fostering the growth of tree-born oilseeds for biofuels. The National Oilseeds and Vegetable Oils Development Board (NOVOD) of the Ministry of Agriculture, estimates that there is approximately 8,300 hectares of "model plantations" that are currently being grown in collaboration with 20 provincial governments. Most of these initiatives involve 200-300 hectare

[22] See Labland website available at: http://www.lablandbiodiesel.com/
[23] Labland press release available at: http://www.lablandbiodiesel.com/news1.html
[24] Interview March 5, 2007 with Director, Mr. B Jaya Kumar

plots with the intention of identifying superior germplasm for certain sets of agro-climatic conditions. [25]

In addition, two states in particular claimed to have made substantial progress in supporting the growth in feedstock development. The government of Chhattisgarh reports that it has fostered 80 million saplings in 350 nurseries operated by local NGO's. The government hopes to plant up to 20,000 hectares of jatropha by the end of this fiscal year with a long-term target of 1 million hectares state-wide.[26] The government of Andra Pradesh, meanwhile, has offered generous subsidies covering 100% of the initial cost of planting jatropha on plots of up to 5 acres. It has set-up a separate department to encourage planting of up to 728,000 hectares. Unfortunately, it is difficult to assess the actual progress governments have made towards realizing these goals. However, interviews with participants on the ground suggest that they are proceeding, albeit at a slower pace than originally expected. [27]

Key open issues:

Notwithstanding the reported interest in cultivating jatropha for biofuels, there are significant unanswered questions about the crop's long-term potential and viability. The following paragraphs outline the key issues that producers must address:

1. Is there sufficient wasteland to foster a scaleable biofuels industry?
2. Will the industry be able to achieve peak yields to ensure its economic viability?
3. What is the most sustainable approach to securing the land for feedstock production?

Issue 1: *Is there sufficient wasteland to foster a scaleable biofuels industry?*

Due to the limited experience in cultivating jatropha on a commercial basis, there is considerable anecdotal evidence that farmers are skeptical about potential returns.[28] Moreover, given the crop must mature for three years before any seeds can be harvested, the opportunity cost is too high for such a crop to be grown on cultivable land. As a result, at the *present* time, farmers are likely to only consider such a crop as viable if grown on wastelands.

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[25] NOVOD Board presentation. "Jatropha." Available at: www.**novod**board.com/**Jatropha**.pdf

[26] GTZ, pg 73

[27] Lele, Satish, "India's Biodiesel Scene," Ecoworld. Available at: http://www.ecoworld.com/home/articles2.cfm?tid=385

[28] Interview with IDE India January 23, 2007

Government sources estimate that there are approximately 64mm hectares of wastelands across India. The table below outlines the estimated breakdown of wasteland area by category:

Table 4: Breakdown of types of wasteland across India, 2000

Category	Wasteland by area (ha mm)	Percent of total
Land with or w/out scrub	19.4	30
Underutilized/degraded forest land	14.1	22
Barren rocky/stony area	6.5	10
Sands (inland and coastal)	5.0	8
Shifting cultivation	3.5	5
Degraded pasture grazing land	2.6	4
Gullied or ravined land	2.1	3
Steep slopes	0.8	1
Mining / industrial wasteland	0.1	0
Other	9.3	15
Total	63.9	100%

Source: Wastelands Atlas of India[29]

Of these categories, most jatropha plantations are currently planned in areas labeled as "land with or without scrub" or "under-utilized forest land." These lands account for nearly 52% of total wasteland. Still, experts suggest that *at most* 15% (or approximately 9.6mm ha) of the total wasteland can be brought under cultivation.[30] These estimates suggest that the government goal of cultivating 11.2mm hectares of jatropha is likely a "stretch target."

Issue 2: *Will the industry be able to achieve peak yields to ensure its economic viability?*
As with any crop, yields (of both seeds and their oil content) depend greatly on such factors as the quality of germplasm, overall soil conditions, water accessibility, fertilizer intensity, and spacing of the crop. Given that most jatropha cultivation is done on wastelands, it is also essential to consider other factors such as the slope of the land and plant life already growing on

[29] This table was adapted from: Francis, Edinger and Becker, pg 17.
[30] Interview with IDEI, January 23, 2007

the lands in question. Each of these factors in turn depends on the location of the plantations themselves, making it nearly impossible to generalize about yields across India.

Interestingly, some groups' initial optimistic estimates for extremely high yields have been scaled back, presumably after the reality of actual field trials has set in. For example, Labland's partner D1 Oils (mentioned above) has stated that existing crops yields will be approximately 1.8 tons / ha , but that "elite yielding" varieties could provide upwards of 3-5 tons / ha. Such estimates are a far cry from the 12 tons/ha D1 targeted initially.[31]

In addition to the challenge of cultivating higher-yielding germplasm, output will depend greatly on the level of water input. As with other inputs, it is difficult to generalize about the amount of water that is required to achieve higher yields. However, in conditions, such as those observed in Andra Pradesh (500-700 mm of rainfall at an altitude of 50-500 meters above sea level), one cultivator estimates that each plant would require 5-7 liters of water per week, or roughly 9,000 liters of water per hectare each week.[32]

The use of such inputs raises costs and could call into question the crops' sustainability. Water is an exceptionally scarce resource across rural areas in India. Jatropha plantations that displace water from food production for fuel may become as politically problematic as the use of edible oils for fuel itself. Moreover, providing sufficient water to wasteland based plantations may prove extremely challenging. As the CEO of a drip irrigation system manufacturer put it: "Wastelands are wastelands for a reason. They are not cultivable because they often do not have access to water."[33] Such caveats suggest that investors in jatropha based biofuels initiatives should carefully assess the assumptions underlying cultivators' yield estimates. Cultivators must be able to provide a credible plan for how they will achieve robust yields without abusing local water resources.

[31] GTZ, page 8 and D1 website. "Interview with D1 CEO" available at: d1plc.com
[32] Interview March 5, 2007 with Director, Mr. B Jaya Kumar
[33] Interview with IDE India, January 23, 2007

Issue 3: *What is the most sustainable approach to securing the supply of feedstocks?*

Assuming there is sufficient land to scale the industry, biofuels producers still must ensure a consistent supply of feedstocks from that land. There are three potential approaches to securing the supply of feedstocks:

1. **Contract farming:** Under contract farming, a biofuels producer typically gives jatropha seedlings to farmers at no cost with the explicit promise that they will purchase the entire harvest for a fixed price each year over a fixed period of time. Given that most farms are cultivated by small-holders, a contract farming approach would involve coordinating the collection of seeds from tens of thousands of farmers. Such arrangements obviously carry significant risk for both parties since they are unenforceable and either party can ultimately renege on their agreement. Yet the farmer arguably bares a disproportionate risk because they must invest time and inputs (water and fertilizer) before knowing if the seedlings will realize hoped-for yields.
2. **Leasing land:** Under such an arrangement, the biofuels producer contracts for a long-term lease with a larger land-owner such as a state government. The producer then must manage the land and is responsible for cultivating and harvesting the oilseeds. Typically, the producer will source labor from among landless peasants.
3. **Operating owned land:** At times a producer may have the opportunity to purchase larger tracts of land and then manage the feedstock development in the same way as leasing. Given the uncertainty surrounding land titles, this is a rare and often risky option.

Each of these approaches has their own pitfalls, yet the latter two arguably provide greater certainty for both the farmers and the biofuels producer. Farmers who are hired as laborers can obtain a relatively steady source of income while the biofuels producer can have greater control over the feedstock development. The producer would not have to manage relationships with thousands of smallholder farmers and can ensure that best practices in cultivation are spread across their entire production area.

OIL EXTRACTION AND PROCESSING

Key requirements:

The second step in the biofuel value chain is oil extraction and processing. The key inputs for the oil extraction segment of the value chain are fairly straightforward and, in India, may already be in place. The oil extraction step consists of:

1. Collecting and storage of jatropha seeds,
2. Hulling and crushing of the seeds to extract oil
3. Refining the oil to prepare it for use in biodiesel manufacturing or as a straight vegetable oil fuel.

In order for the biofuels sector to achieve its potential, there must be sufficient capacity for the warehousing and processing of jatropha oilseeds.

Current state of development:

Fortunately for the fledgling biofuels sector, there is currently significant *overcapacity* in the Indian vegetable oil processing sector. In a bid to achieve self-sufficiency in oilseed production during the late 80's and early 90's, the Indian government put in place a number of market distorting product market regulations which encouraged a boom in oilseed processing capacity. With the removal of import quotas in 1994, imports of edible oil increased dramatically, leaving much of this new capacity idle.[34]

As can be seen in the table below, overcapacity exists in each of the major types of oil crushing facilities. Based on the most recently available data (published in 2004), crushing facilities of varying sizes were operating at capacity utilization rates between 10-40%. While some consolidation has occurred in the sector since this time, interviews with companies in the biofuels sector indicate that considerable overcapacity persists in both oilseed processing and warehousing facilities.

[34] Persaud, Suresh and Landes, Maurice. "The Role of Policy and Structure in India's Oilseed Markets," USDA, ERS. ERR-17. Available at: http://www.ers.usda.gov/Publications/ERR17/

Table 5: Indian Vegetable Oil Processing sector (as of 2004)

Process	Units	Capacity[1] Total	Average	Use rate
	Number	Million tons	Tons/day	Percent
Mechanical crushing:				
"Ghanis"	130,000	2.0	0.05	10
Expellers	20,000	40.5	7	30-40
Solvent extraction[2]	766	36.0	157	30-40
Vanaspati	241	4.8	66	35
Oil refining	800	4.7	20	35

[1] Capacity and use based on raw material; 300 days/year, 24 hours/day basis.
[2] Includes expander units.
Source: Solvent Extractors' Association of India.

Chart taken from: "The Role of Policy and Structure in India's Oilseed Markets"[35]

The biofuels industry has the ability to take advantage of this existing capacity as the supply of jatropha oilseeds begins to come on line.

Key open issues:

Even with this existing capacity in the oil extraction industry, there are still several outstanding issues which biofuels players must resolve in order to ensure the long-term development of the sector:

1. **Logistics:** how should industry players collect/aggregate feedstocks across many dispersed smallholder farmers?
2. **Scale:** what is the optimal size for each oil extraction facility?
3. **Quality of oil:** how will oil extraction centers ensure quality of their output?

Issue 1: Logistics - *how should industry players collect/aggregate feedstocks across many dispersed smallholder farmers?*

The overwhelming majority of Indian farmers are smallholders who have plots of less than two acres and much of the wasteland on which jatropha will be planted is extremely fragmented.[36] As

[35] Persaud, pg. 13

a result, the challenge of aggregating jatropha seeds (once harvested) could be significant. For example a jatropha seed processing center with a capacity of 3,000 tons per annum would likely need to aggregate seeds from an area of at least 1,000 hectares (or 10 square kilometers). Assuming that on average, each smallholder farmer had one hectare of jatropha under cultivation, each processing center would therefore have to collect seeds from as many as 1000 different growers!

One potential solution to this problem is to leverage underutilized government and privately held warehousing facilities which are currently used for the intermediate collection of edible oilseeds and are fairly accessible to major growing areas.[37] As described above, there is substantial excess capacity in edible oilseed warehouses which could be used to collect jatropha seeds. Each smallholder farmer could bring their harvested jatropha to such warehouses, thus simplifying the logistics of collection across many producers.

Such a logistical arrangement could be institutionalized through the creation of jatropha oilseed cooperatives. These cooperatives could benefit the biofuels industry by maintaining the warehouse facilities and ensuring a consistent supply of jatropha feedstock. At the same time, the cooperative would also benefits farmers. By aggregating the jatropha production from many small players, farmers increase their market power and potentially negotiate long-term supplier agreements at favorable prices.

Issue 2: Scale - *what is the optimal size for each oil extraction facility?*
In addition to coordinating the consistent supply of feedstocks across many small players, the biofuels industry must also determine the appropriate scale of oil extraction and processing centers.

As can be seen in the chart below, a medium-sized extrusion mill offers a reasonable compromise in terms of both scale and logistical complexity.[38] Some participants in the industry

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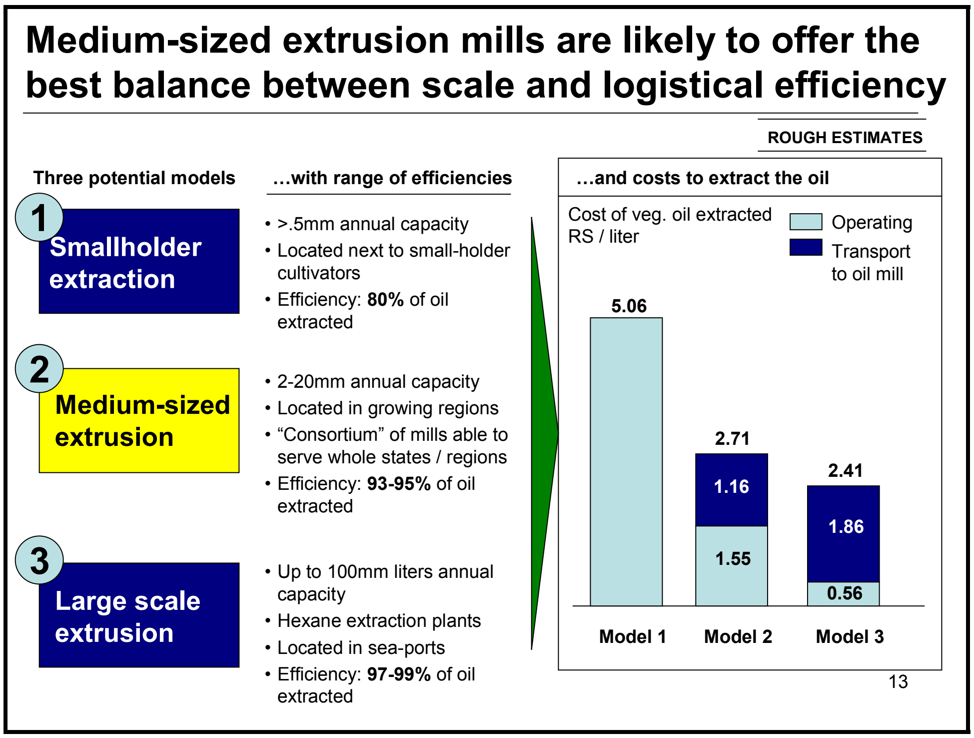
[36] There is no firm estimate of the average farm size for small-holders in rural India, but an oft-cited is estimate is approximately one hectare of cultivable land. Alongside this cultivable land, farmers typically also have several acres of non-cultivable land.
[37] Interview with CleanStar. In the region in which CleanStar operates, these warehousing facilities are scattered across the countryside at 15-30 km intervals
[38] Analysis based on transportation costs for jatropha quoted by CleanStar and author's own estimates.

have encouraged the use of smaller, manually operated extraction units with annual capacities of less than 0.5mm liters. While such an approach practically eliminates the transportation costs of delivering seeds to a processing center, the lack of scale and the inefficiency of the extraction equipment undercut the economics of this approach. On the other end of the spectrum, larger extrusion plants will likely have substantially greater transportation costs as they attempt to coordinate the supply of seeds across a larger area. For example a 100mm liter extraction plant would likely have to coordinate feedstock from an area of roughly 600 kilometers. Medium sized mills enable producers to realize scale economies without incurring extraordinary coordination costs.



Source: Author estimates, See Appendix IV for assumptions.

Issue 3: Quality - *how will oil extraction centers ensure quality of their output?*

Practically no oil extraction center that exists in India today has any expertise in processing jatropha oilseeds. As a result there is still uncertainty as to how processors will maintain the quality of their oil output. Different oil extraction processes can lead to varying levels of free fatty acids and gums (also known as phospholipids) which can in turn lower yields in the biodiesel refining process (discussed further below). Any producer that intends to market straight vegetable oil will need to add extra refining steps (for example to remove all gums) and generally ensure that the oil is fuel-ready.

BOX 1 Biodiesel vs. Straight Vegetable Oil: The basic differences of two viable biofuels

As described briefly above, there are two basic types of vegetable oil based biofuels, straight vegetable oil (SVO) and biodiesel. Both can be substitutes for diesel fuel but there are important differences in their production, use and regulation.

1. **Production:** Biodiesel is made in a chemical process known as transesterification (described in the following section) while SVO is – as the name suggests – pure vegetable oil that has not been chemically altered. While SVO has not undergone the extra transesterification steps, it still must be adequately refined (e.g. to remove excess gums) so that it can be used as a fuel.

2. **Consumption:** While biodiesel (manufactured properly) is a perfect substitute for diesel requiring no engine modifications, SVO generally must be blended with conventional diesel before being used in a standard (unmodified) diesel engine. Typically SVO is not blended at levels greater than 20%, but some producers are conducting trials with 50% and even 100% jatropha SVO.

3. **Quality concerns:** Both biodiesel and SVO can cause long-run and even short-run engine failure if not produced properly. Consumers must ensure that they are purchasing from a reliable producer regardless of whether they are buying SVO or biodiesel. In addition, producers providing **SVO** should also ensure that their customers are using the product within a relatively short period of time (within at least one month). Even if the oil is refined properly, it still may break down chemically in storage, leaving a product that can cause damage to diesel equipment.

4. **Cost:** As described in the economics section, SVO can be considerably less expensive (as much as 20%) than the true market price of biodiesel. The extra processing steps require additional feedstock input and processing costs. Consumers and producers must decide whether the improved quality and performance that biodiesel offers is worth the extra cost.

5. **Price regulation:** The price for biodiesel is in effect set by the national government and at the time of writing is RS 25. This is the price at which state-owned diesel distribution firms (who control 90% of distribution) must pay producers who bring their product to one of 20 biodiesel "collection centers." This price is not economically viable for producers and, as a result, very few have even attempted to sell their product at this price. SVO is not subject to this price regulation and there are currently no plans to control the pricing of SVO. Most producers believe that these price restrictions will be eliminated or at least reformed to reflect economic realities but uncertainty remains.

6. **Taxation:** SVO is currently not taxed whereas there is continued uncertainty about the level of excise taxes biodiesel is subject to. Having said this, if SVO's use as a fuel were to become more widespread it is very possible that it too would be subject to the same excise and sales tax regime applied to biodiesel.

As issues with respect to price and taxes are ultimately resolved and consumers become more aware of the trade-offs between the two fuels, it is highly likely that a market will develop for both of these products. Some consumers will be able to adapt to using SVO, while others will demand the further refined biodiesel.

TRANSESTERIFICATION / BIODIESEL PRODUCTION

The process of manufacturing biodiesel involves widely understood and well-documented basic chemistry. Biodiesel can be made from any vegetable oil or fat through a chemical reaction known as transesterification. In this reaction, the oil/fat is mixed with a chemical catalyst called methoxide (which itself is a mixture of a base catalyst[39] and methanol) in the presence of heat. The methoxide "breaks down" the oil into two final products, methyl-esters (or biodiesel) and glycerol (also referred to as glycerine). These two products are then separated and the biodiesel is washed (typically with water) to remove excess amounts of methanol, unreacted oils, and any remaining glycerol. After washing, the remaining water is removed from the biodiesel product and it is ready for use as a perfect substitute for conventional diesel.

There are three broad approaches producers could take to manufacture biodiesel in an Indian context[40]:

1. **Micro-processors:** are very small scale production plants (less than 500,000 liters of annual capacity) designed to serve a small group of consumers or a single large consumer (e.g. a trucking fleet). Micro-processors enable diesel consumers to have greater control over the availability and cost of their fuel supply. Upfront capital costs for a unit producing ~200,000 liters per annum is approximately RS 150,000 – 250,000.[41]
2. **Multi-local producers:** are groups that have built relatively de-centralized production plants located nearby jatropha growing areas and oil extraction mills. Each production plant would have an annual capacity of 500,000-10,000,000 liters and serve rural and smaller urban markets within a 50 km radius. Multi-local producers may elect to run several such plants enabling it to serve an entire state or region of the country. Up front capital costs for a unit producing 3-5 mm liters is approximately RS 15-30 million.[42]
3. **Centralized producers:** operate very large scale production plants (10mm-300mm liters of annual capacity). Plants at this scale could serve the market in an urban or rural area within a several hundred kilometer radius. Such producers must locate facilities on relatively good transportation routes because of their need to source significant quantities

[39] Typically sodium hydroxide (NaOH) or potassium hydroxide (KOH)
[40] These labels for different levels of production are the author's own and do not correspond to any industry standard classification.
[41] Based on Greenfuels Ltd. Model. Pricing available at: www.greenfuels.co.uk
[42] Based on interview with CleanStar and author's own estimates from developing a start-up biodiesel plant.

of jatropha oil (and other inputs) from great distances. Capital costs for building a 50 mm liter plant are likely to be a minimum of RS300mm.[43]

Key requirements:

Despite the simplicity of the production process, manufacturing quality biodiesel is nevertheless very challenging. Process problems can occur at practically every step, resulting in poor quality fuel that can cause long-run damage to equipment in which the fuel is used. In fact, biodiesel production is still more of a craft (akin to beer brewing) than a strictly controlled chemical manufacturing process. Producers must adapt their process to variations in feedstock inputs and must learn to strike a balance between efficiency (in terms of liters produced per day) and quality. This balance is often anything but self-evident.

No matter how "proven" a particular biodiesel production technology may be, manufacturers can be certain that production problems will inevitably arise. In order to deal with these on-going production problems, each manufacturer must have a sufficient scale (and therefore revenue base) to pay for the technical expertise and organizational capacity which will help solve those problems. In other words, problem-solving capability can be thought of as a fixed cost which producers must pay regardless of their facility's size.

Given this context, the **key requirement** of the biodiesel production step of the value chain is a minimum efficient scale which *at least* reaches the multi-local producer capacity level of 500,000 to 10,000,000 liters per annum.

Current state of development:

Given the relative complexity of developing sound production assets, aggressive plans to build billions of liters of capacity within a period of less than 4 years (as recommended by the National Mission on Biodiesel), should be treated with healthy skepticism. At present there are several small scale production plants run by R&D centers such as the Central Salt and Marine Chemicals

[43] Different technology providers offer different estimates for the cost per liter of capacity, however the current rule of thumb is roughly $0.50 to $1.00 per gallon of capacity of approximately $0.12 to $0.25 per liter of capacity.

Research Institute and the Indian Institute of Chemical Technology in Hyderabad, but no significant production capacity has been installed.

At present there are examples of local producers considering (or currently developing) manufacturing plants following the models described above:

Micro-processors: Green Fuels Ltd, a UK firm which has built such units across Africa has plans to roll out its small-scale production technology in partnership with Nandan Biomatrix (described above).[44]

Multi-local producers: CleanStar Private Ltd. (described in further detail in the case study below) is one example of a producer planning to create a network of production assets in the state of Maharashtra. While CleanStar currently plans on marketing straight vegetable oil, its operations would have the potential to produce biodiesel once the company installed the appropriate process equipment.

Centralized Processors: Southern Online Biotechnologies[45] has already begun construction of a 10 mm liter facility in Choutuppal, Andra Pradesh. There are several other firms planning even larger production plants, but (at the time of writing) none appear to have made the same progress as Southern Online. Southern Online is planning to spend RS 150 million to establish their initial facility.

Key open issues:

There are two key issues in the transesterification step of the value chain:

1. What is the optimum size for a production plant to reap scale economies without adding undue complexity to a plant's logistical operations.
2. How can producers ensure adequate quality of their input (feedstocks) and outputs

[44] Interview with Green Fuels CEO, Colin Hygate, February 27, 2007
[45] Southern Online is an internet service provider which is now attempting to enter the biodiesel business.

Issue 1: *Scale vs logistics*

While the above analysis suggests that biodiesel manufacturers must achieve a minimum efficient scale of at least 500,000 liters the question remains how much larger producers should make each facility. As in the oil extraction step, the greatest issue facing biodiesel producers is how to strike the appropriate balance between scale and logistical efficiency. As scale increases, at a certain point it is offset by the costs of logistical coordination required to bring tens of thousands of tons of jatropha oil feedstocks to a biodiesel refinery.

Without more detailed information on the specific transportation costs within certain sub-regions it is difficult to say precisely what the optimal scaled biodiesel plant would be. Yet a rough analysis, assuming different price levels for key inputs suggests that the multi-local approach is likely to provide the best compromise between reaping some scale economies without taking on overly burdensome logistical challenges.

When one looks just at the added cost of processing jatropha oil into biodiesel (which includes methanol, base catalyst, water, electricity and an estimate for yield loss) in the table below, one can see that the scale economies diminish substantially once producers reach the multi-local level. The micro-processor's biodiesel processing costs are likely to reach upwards of RS 10 / liter, while costs under the multi-local approach are expected to be roughly RS 6 – 7.5 / liter. Centralized processors, meanwhile, are expected to have costs of approximately RS 5 – 6 / liter.[46]

Table 6: Estimated costs to process jatropha oil into biodiesel at different scales (RS / Liter)

Input	**Micro-processor**	**Multi-local**	**Centralized processor**
Methanol	RS 7.14	RS 4.52	RS 4.29
Base catalyst	RS 0.37	RS 0.18	RS 0.10
Water, electricity, other	RS 1.19	RS 1.19	RS 0.60
Yield loss	RS 0.83	RS 0.59	RS 0.10
Total biodiesel processing cost	RS 9.57	RS 6.49	RS 5.08

Source: Author estimates based on experience producing biodiesel in 1mm gallon pr year facility over a 3 year period, interviews with local Indian producers. See Appendix V for assumptions.

[46] All costs are excluding labor. Biodiesel manufacturing is not particularly labor intensive and these costs are not likely to affect the analysis.

Issue 2: *Quality*

The second key issue biodiesel producers must confront is how they will maintain the quality of their end product. While the Indian government has created a biodiesel standard (resembling the one used by the US and EU), enforcing such standards is extremely difficult.

In fact, consistently producing high quality biodiesel is in and of itself relatively difficult. While the basic chemistry required to manufacture biodiesel is straightforward, immense variability in quality can arise as the process is scaled to commercial production levels. The most common cause of poor or inconsistent quality of biodiesel is variability in the quality of vegetable oil feedstocks. Even slightly elevated levels of impurities in the oil, such as gums (also known as phospholipids) or free fatty acids[47], can inhibit the transesterification reaction from going to completion. This in turn results in biodiesel that can clog fuel filters and even lead to engine failure.

To maintain the quality of their biodiesel, producers must regularly test their oil feedstocks to ensure they are of sufficient quality. In addition, producers should regularly test their biodiesel end product to ensure completeness of reaction. This generally requires testing the fuel in a gas chromatograph which is an expensive and relatively difficult instrument to master.

Those producers that establish rigorous quality controls are likely to be the industry winners in the long-run. However, it is practically inevitable that some manufacturers will create and market poor quality biodiesel, harming the reputation of the fuel generally and hampering the industry's development near-term.

[47] Higher levels of free fatty acids do not necessarily lead to poor quality biodiesel. However, producers must adjust the levels of other inputs (in particular their base catalyst) in order to counter the effect of higher free fatty acid levels.

DEMAND AND DISTRIBUTION OF VEGETABLE OIL BASED BIOFUELS

Total diesel consumption in India was estimated to be 52.3 mm tons (61.3 bn liters) in 2006. The majority of this fuel is consumed in the transportation sector (60%)[48] with the remainder going to industry, and agriculture (including fueling tractors, diesel powered generators, and pumps commonly used for irrigation).

Indian consumers have already begun experimenting with straight vegetable oil and biodiesel in both urban and rural areas in nearly every application where diesel is used. The following paragraphs will provide a rough sizing of key potential market segments and highlight the critical issues that must be overcome to achieve widespread penetration of vegetable oil biofuels.

Estimating total potential penetration:

As described above, the National Mission on Biodiesel optimistically targets the replacement of 20% of total diesel consumption with jatropha based biodiesel by 2010-11. The Mission develops this target by taking a view on the potential supply that could be achieved under an optimistic set of circumstances. Assuming growth rates of diesel consumption in line with current levels (between 5-6%), total diesel consumption will be 66 mm tons in 2010-2011, requiring 13 mm tons (14.4 bn liters) of biodiesel to fulfill the 20% target.

Table 7: Projected diesel demand and potential biodiesel demand (in mm metric tons) assuming 5-20% replacement

Year	Diesel demand (est.)	5% biodiesel	10% biodiesel	20% biodiesel
2006	49.6	2.5	5.0	9.9
2010	66.1	3.3	6.6	13.2
2020	111.9	5.6	11.2	22.4
2030	202.8	10.1	20.3	40.6

Source: TERI

Given the current development of feedstock sources, expeller and transesterification capacity, it is unrealistic to think that 13 mm metric tons *of supply* could be achieved in such a short period

[48] GTZ: "Liquid Biofuels for Transportation," pg. 40.

of time, even if the government were to mandate such levels of consumption. At best, therefore, these estimates provide an upper-bound estimate for the total market potential for biodiesel and SVO in 2010.

Notwithstanding these supply side limitations there is substantial potential demand for vegetable oil based biofuels. A demand side estimate can also be developed using a rough top-down analysis of diesel consumption within rural and urban market sub-segments. While there is limited data available on the split between rural and urban diesel consumption, interviews and secondary source material provide a picture of the largest sub-segments in each of these markets.

Table 8: Major sub-segments of diesel consumption split between rural and urban areas[49] (Thousands of metric tons)

Geography	Transportation	Agriculture	Industry	Residential
Rural	5,561	4,580	2,731	573
Urban	25,589	-	10,922	2,290
Total	31,239	4,580	13,653	2,863

Source: TERI and author estimates/analysis[50]

In rural areas there are two key sub-segments that could become large potential consumers of vegetable oil based biofuels: transportation and agriculture. In the transportation sector, a significant portion of diesel is consumed by informal taxis, which often provide essential mobility services to the poor. Fuel is typically the primary cost for such services, making lower cost biofuels an attractive alternative to conventional diesel.

An equally attractive sub-segment in rural areas is diesel powered pumps used in irrigation. Roughly eight million diesel engines currently power irrigation systems across the country, typically in areas with limited or inconsistent access to electrical power.[51] Operating such engines for one hour typically requires approximately one liter of diesel (or biofuel). Assuming

[49] Assuming that 80% of transport, industry and residential consumption are in urban areas, while 100% of agriculture consumption is in rural areas.
[50] Estimates based on TEDDY (TERI Energy Data Directory and Yearbook 2003/4), The Energy Resource Institute. 2004, and author's own analysis
[51] Kulkarni, SD. "Country Paper India, Agricultural Mechanization: Present Scenario and Perspective." Central Institute of Agricultual Engineering. Bhopal, India., pg. 6.

these engines are used for 150 hours per year (the amount typically required to irrigate 1 hectare of land using drip irrigation techniques)[52], would total 1.2 bn liters of diesel consumption for irrigation purposes alone.

A third potential sub-segment in rural markets is industry. Within this category are a variety of businesses, which looks to diesel power to supplement the inconsistent flow of electricity from the grid. For example, Idea Cellular hopes to power a number of its mobile base stations, which lack adequate grid access, with biodiesel.[53] Given the persistence of brown-outs across rural India, practically every business has a daily need for back-up electricity generation. Nearly all of this need is met through diesel powered generator sets which these businesses operate during periods when the grid is not operational.

Key demand drivers and requirements:

There are several key factors that are likely to determine the appetite for biodiesel and SVO in the domestic market:

1. **Cost:** By far the most important factor in driving demand will be biodiesel and SVO's cost competitiveness. In fact, cost is even likely to outweigh any concerns about performance of the fuel vis-à-vis conventional diesel. To illustrate this one can take note of the widespread use of kerosene in diesel powered engines. A significant number of rural consumers, elect to "spike" their conventional diesel with kerosene taking advantage of its lower subsidized price.[54] Given their experience with diesel engines and diesel fuel, these consumers are no doubt aware of the long-term deleterious effects of using kerosene in their engines, yet they continue to do so.

   Based on the analysis described in the first section, biodiesel and straight vegetable oil can be cost competitive with conventional diesel. Assuming yields of 3 kgs per plant can be achieved,

[52] Interview with IDE India
[53] "Ericsson, GSMA and IDEA to use Biofuels to Extend Mobile Coverage in rural India." Assodigitale. available at: http://www.assodigitale.it/content/view/4625/31/
[54] Based on interviews with CleanStar. Kerosene currently sells for RS 15 / lit at the subsidized price and RS 20-25 / lit, or about RS 10-20 less than regular diesel.

and that producers require a 10-13% gross margin[55], jatropha based biodiesel could be up to RS 4 less expensive than conventional diesel. SVO meanwhile could be as much as 30-40% less expensive depending on whether the product is taxed as a fuel.

Potential changes to fuel excise taxes will likely impact the final cost of biofuels in India. Currently, biodiesel is taxed like conventional diesel with a range of tax rates that depend on the state in which the product is sold to the end-user. Taxes on diesel are approximately RS 4[56] making up a substantial portion of the final cost to the consumer and representing $5.9 billion in total revenue to the national government.[57] The National Mission on Biodiesel recommended an excise tax holiday to encourage the use of biodiesel.[58] The recently released 2007-2008 budget appears to indicate that excise duties for biodiesel will be eliminated for the time being, but uncertainty about duties on the fuel persist.[59]

Straight vegetable oil's tax status, meanwhile, remains an open issue. Currently straight jatropha vegetable oil is treated like any other vegetable oil and is therefore not taxed. However, given that this oil can *only* be used as a fuel there is considerable speculation that the government will elect to levy the same taxes that are currently applied to diesel. This could ultimately result in significantly eroding SVO's overall cost advantage.

2. **Superior availability:** Vegetable oil based biofuels could also help alleviate regular shortages in the diesel supply chain. Kerosene is often unavailable at subsidized prices (of RS 15) and even difficult to find at black market rates (of up to RS 25), leaving unmet demand at these price levels. Rural consumers are likely to respond positively to a well-organized supply chain that can bring the fuel to rural areas on a consistent basis.

3. **Government mandates:** The National Mission on Biodiesel outlined an ambitious proposal to ensure that 5% biodiesel blends were required in 10% of the country's districts, by 2005. However, this recommendation was conditional upon availability, which has yet to materialize.

[55] As can be seen in Tables 1 and 2, producers are assumed to make RS 3 per liter, i.e. a 10% gross margin (RS 3 / RS 29.97) when marketing biodiesel or a 13% gross margin (RS 3 / RS 23.03) when marketing SVO
[56] Interview with CleanStar and Misra, Neha. Petroleum Pricing in India, pg 15.
[57] Francis, Edinger and Becker, pg 21
[58] National Mission on Biodiesel
[59] Interview March 5, 2007 with Director, Mr. B Jaya Kumar

As a result, progress on such mandates has been slow. Indeed, mandates are unlikely to be a driving force until significant supply can come on line. Given the pace of investment and growth in feedstocks (and biodiesel refining infrastructure) this is unlikely to take place until 2008 at the earliest.

Potential distribution mechanisms for vegetable oil based biofuels:

Two broad approaches are likely to emerge for distributing vegetable oil based biofuels to end users:

1. Upstream blending within the existing diesel distribution chain
2. "Direct" marketing of neat (i.e. 100%) biofuel

Upstream Blending:

In developed markets, the vast majority of biodiesel is mixed with conventional diesel to create a biodiesel blend before it reaches the end-user.[60]

In India, nearly 90% of all diesel is distributed by state-owned petroleum distribution firms, most notably Indian Oil.[61] These distributors could provide vegetable oil biofuels to the end-user by mixing the product into conventional diesel upstream in the distribution chain. The Indian government has attempted to support such an approach through its "biodiesel purchase policy," which mandates state-owned distribution firms purchase biodiesel (at a fixed price of RS 25) at twenty distributions centers across the country.[62] As discussed above, few biodiesel producers are selling into these distribution centers because the mandated purchase price is still too low. Yet the capacity for blending biofuels into the conventional diesel distribution chain exists and provides a relatively straightforward solution for bringing biofuels to the end-user.

This approach lends itself to large-scale (>50mm liters per production site), centralized biofuel producers. These large producers are likely to locate their operating plants near major metropolitan areas with ready access to the twenty distribution centers. Moreover, such

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[60] Biodiesel and regular diesel are completely miscible, meaning they can be perfectly blended by simply mixing the two products together.

[61] Interview with CleanStar

[62] "Government Announces Biodiesel Purchase Policy," Tribune India, October 10, 2005.

producers would not be able to market their entire product without an extensive distribution chain, making the existing state-owned network a logical partner to distribute their output. In most cases, it would not be economically profitable for a biofuel producer to distribute his or her product in competition with the state-owned petroleum distribution firms.

Direct Marketing of "Neat" Biofuels:

Producers of vegetable oil based biofuels could also market and supply their product independently of the existing diesel distribution chain. In this approach a producer could sell 100% neat biodiesel or SVO through private retailers or even directly to larger end-users (e.g. in industry). Producers could also market and distribute the product in more rural areas through village Panchyats or the existing network for agricultural supplies, providing access to poorer consumers who only require smaller quantities of fuel. Since blending can be done at any point in the supply chain (even by the end-user) the retailer or end-user could blend in the desired amount of biofuel or choose to use the biodiesel or SVO in its pure form. Such an approach would be best suited for more decentralized, small-medium sized producers (10mm-50mm per production site) which are located in close proximity to their target end-users.

Key open issues:

While both biodiesel and straight vegetable oil ultimately have the potential to penetrate a considerable portion of the current diesel market, policy makers and businesses must address a number of issues before use of vegetable oil biofuels will become commonplace. There are three key issues that producers and policy makers will need to confront as the industry grows:

1. How will the industry educate consumers on the benefits of biofuels?
2. Will demand from developed markets (EU and US) hinder the growth of the domestic Indian market?
3. Which product will become most prevalent over time - biodiesel or SVO?

Issue 1: *Educating the consumer*

Despite the fanfare surrounding the government's National Mission on Biodiesel, the vast majority of Indian consumers are still likely unaware of the potential to substitute vegetable oil biofuels for diesel fuel. Even as supply comes on line and awareness increases, biofuel producers will confront the challenge of convincing consumers, who have only used petro-diesel, to switch to biofuels.

Producers and marketers will not only need to educate the market about the potential benefits of biofuels (e.g. lower cost, and reduced emissions), but also address consumer concerns about the technical compatibility of biofuels with their diesel engine. Many consumers understandably assume that their diesel-powered engine must be modified to use biofuels. (While such modifications may be necessary for SVO they are not typically required to use biodiesel.) Still others fear that this "new fuel" may cause severe or even irreparable damage to equipment that would be extremely expensive to repair or replace. These concerns may be compounded by poor quality biofuels as supply begins to come on line.

Issue 2: *The double-edged sword of export demand*
The models described above assume there is sufficient feedstock and finished product (SVO or biodiesel) to serve the local market. Yet, given the demand from developed country markets (particularly within the EU), export demand could in fact make domestic marketing efforts far less viable. The EU is already on pace to become a net importer of rapeseed[63] (the region's primary feedstock for biodiesel) and multiple large plants are under construction which expect to receive their feedstocks from imported oilseeds. With EU biodiesel production expected to grow from 3.5 mm tons to 8.5 mm tons from 2005 to 2010, the thirst for feedstocks to supply this production will be extreme.[64]

Given the dramatic growth in developed markets, biodiesel producers in the EU could begin to import jatropha oil from India. Under a relatively conservative set of assumptions, jatropha oil can be produced for less than RS 15 (~$0.33) per liter which is less than half the cost of feedstocks European producers purchase today. While freight and logistics will erode some of this cost advantage, jatropha oil may nevertheless be very attractive for European biodiesel producers. If significant export demand does materialize then the domestic price for jatropha oil will rise in turn. Assuming the Indian government does not cut off the export market though export controls, this development could severely dampen growth of the domestic biofuels sector.

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[63] USDA Foreign Agricultural Service, "Crop Intelligence Report," June 21, 2006.
[64] Rabobank: "Biodiesel Global Trends: EU Focus," August 24, 2006.

Issue 3: *Which product – SVO or Biodiesel?*

Finally, it remains uncertain which vegetable oil based biofuel will gain acceptance in the marketplace. Since the publication of the Planning Commission's work in 2003, most of the initiatives in the industry have focused on the development of biodiesel. However with the introduction of the government's economically unattractive "biodiesel purchase policy," some firms have begun to focus on the potential of marketing straight jatropha oil as a fuel.

As described in the box above, straight jatropha oil has a number of benefits over biodiesel, including its lower cost and simple manufacturing process. Yet there is also considerable uncertainty surrounding straight jatropha oil as a fuel. First, and foremost, SVO is not a perfect substitute for diesel and therefore is more prone to causing equipment failures. Second, some of its cost advantage depends on its tax exempt status. If SVO becomes widely accepted as a fuel source, the government may elect to apply the same taxes which are applied to diesel and biodiesel today.

There are also several critical uncertainties surrounding biodiesel. It is impossible to say when, if ever, the government will dismantle the "biodiesel purchase policy," which has stunted the industry's growth. Moreover, there are currently no producers (beyond relatively small pilot plants) which have demonstrated that they can produce and market a quality product that the market will purchase.

PRO-POOR POTENTIAL OF VEGETABLE OIL BASED BIOFUELS

The National Mission on Biodiesel laid out an impressive vision for how vegetable oil based biofuels can positively impact the lives of the poor. The vision argued that biodiesel from jatropha not only would reduce India's dependence on the volatile global petroleum market, it would also create substantial economic opportunities for oilseed producers and processors as well as increase access to basic energy services.

As described above in the value chain review, the industry has made considerable progress since the Mission's initial findings. Yet it remains uncertain whether vegetable oil based biofuels can in fact have their intended pro-poor impact. In this section, I will outline the expected positive impact that the sector can have on the poor and assess the risks to this impact being realized.

The energy challenge for the rural poor in India:

Access to basic energy services in India remains extremely uneven. While close to 88% of urban households have access to electricity services, approximately 57% of rural households are still not connected to the grid. More generally, as much as 15% of all villages across the country are not connected, and those that are suffer regular brown-outs.[65]

In place of affordable and reliable electricity through the grid system, many Indians resort to "traditional" sources of energy for heating, cooking and lighting. The International Energy Agency estimates that roughly 585 million Indians rely on biomass (e.g. wood, grasses and crop residues) as their primary source of energy. Of the 139 million households (72% of the total) that rely on traditional forms of energy for cooking, nearly 90% (or 124 million households) live in rural areas.[66]

While these traditional sources of energy are often less expensive in a monetary sense, they are extremely costly to human development. Time spent collecting firewood or dung to provide basic energy severely hampers household productivity. Moreover these energy sources - often

[65] Rajogopal, Khan and Yoo. Presentation on "India's Unique Sources of Fuel for Electricity and Transportation," UC Berkeley, 2005.

[66] Data adapted from 2001 Census and sourced from Ailawadia, VS and Bhattacharyya, S., "Access to energy services by the poor in India. Current situation and need for alternative strategies," Natural Resources Forum 30, 2006 2-14.

burned indoors - are linked to as much as half a million premature deaths and 500 million illnesses annually.[67]

More efficient, and generally cleaner, commercial forms of energy have taken some share of total energy consumption. In urban areas, 44% of households are able to use LPG, and 22% kerosene, for cooking purposes. Yet penetration of commercial energy remains considerably lower in rural areas, with fewer than 10% of households using LPG or kerosene for cooking. And while 60 million rural households (43.5%) have access to electricity for lighting, another 78 million rely mostly on kerosene. In addition to these commercial energy sources, an increasing percentage of the rural population relies on electricity generated through diesel powered engines. [68]

Yet while commercial energy sources are in principal available, uptake, especially in rural areas, remains limited for several reasons. First, many of these energy sources remain too expensive. In rural areas, there does not appear to be significant switching away from traditional sources towards greater use of LPG and kerosene until annual household incomes surpass RS 40,000 to $60,000.[69] Second, while both kerosene and LPG are heavily subsidized, supplies often do not reach the rural poor for whom the subsidies are intended. Government studies indicate that as little as 20% of subsidized LPG and 62% of subsidized kerosene actually are sold to families below the poverty line in rural areas. The remainder is diverted to wealthier (often urban) households through active black markets. [70] Finally, the upfront equipment cost for commercial energy systems can also prevent access. The average price in 2005-2006 of a standard 14.2 kg cylinder of LPG (one month's supply for a typical household) was RS 250 or the entire energy budget for a family with total expenditures of RS 3,125 per month. [71] And even fewer households in rural areas can afford the RS 10,000-15,000 it costs to purchase even the lowest cost diesel generator or pump.

[67] World Bank, "Access of the Poor to Clean Household Fuels in India," pg. 1 available online at: http://lnweb18.worldbank.org/SAR/sa.nsf/Attachments/InHHFuel-full/$File/Access+of+the+Poor+to+Clean+Household+Fuels+in+India.pdf.
[68] Ibid. Pages 29-51
[69] Ibid. Pages 29-51
[70] Petroleum Product Pricing in India: Where have all the subsidies gone? IEA, October 2006.
[71] World Bank, "Access of the Poor to Clean Household Fuels in India," pg 46.

Jatropha based biofuels have the potential to positively impact the lives of the rural poor in India through:

1. Improved access to energy services
2. Reduced emissions relative to traditional fuels
3. New employment opportunities and income streams

Energy Access:

Jatropha based SVO and biodiesel have the potential to improve access to energy services under certain conditions.

The lower cost of biofuels could lead to substantial annual savings for those consumers who are currently purchasing diesel (e.g. for electricity generation or irrigation pumps). Take for example a farmer with one acre of land, irrigated by a drip irrigation system powered by a diesel pump. To irrigate each acre the pump must operate for approximately 150 hours per year and use roughly one liter of diesel per hour of operation. At a cost of RS 35 / liter of diesel, total fuel costs are RS 5,250 per year. However, if the farmer switched to biodiesel or SVO, he could realize an annual savings of RS 473 – RS 1,575 ($10.5 – 35) per year. This example should be viewed as a lower bound estimate of potential savings (given current prices) because it assumes the use of a relatively energy efficient drip irrigation systems. (Sprinkler or flood systems can require 30-100% more diesel fuel per annum).[72]

Such cost reductions can have significant spill-over effects. An annual savings of RS 1,575 would amount to an additional 63 liters of SVO, enough fuel to bring another 0.4 acres under irrigation, which in turn can substantially improve crop yields and overall livelihoods. Even without “re-investing” savings, RS 1,575 is a substantial increase in annual disposable net income in rural areas, where most live off less than RS 45 per day.

In addition to providing measurable cost savings, growth in SVO and biodiesel distribution could also increase the general *availability* of critical fuels for farming, cooking and lighting. A

[72] Interview with IDE India

regular supply of vegetable oil based biofuels can assure that rural Indians have the energy they need, when they need it.

Public Health Benefits:

Beyond cost-savings, both SVO and biodiesel are substantially cleaner burning. These products reduce particulate emissions (the primary cause of respiratory illness) by 50% in comparison to conventional diesel or kerosene. If used in the home for cooking and lighting, or even in the field for irrigation, SVO and biodiesel should lead to a reduction in emissions translating into fewer cases of respiratory illness.

Wealth Creation Potential:

Finally, development of a vegetable-oil based biofuels industry has the potential to create significant income generating opportunities for farmers and under-employed laborers in rural areas.

The National Mission on Biodiesel estimates that the labor requirements for each hectare of jatropha cultivated will be 263 person-days in the first year and 48 person-days for the following 29 years.[73] Based on discussions with a start-up biofuels producer, the requirement for on-going labor is likely closer to 65 person days.[74] Based on these estimates, a 5,000 hectare operation could require over 1.3 mm person days to set-up and 325,000 person days to maintain each year.

In addition to offering income generating opportunities for laborers who work for larger scale operators, independent farmers will likely have the opportunity to develop income streams by growing jatropha on marginal lands of their own. Assuming peak yields of 3.0 tons per hectare (~ 1.2 tons per acre), a farmer growing an acre of jatropha and marketing his product for RS 6 per kg could make peak cash profits (before interest payments) of approximately RS 5,000 per year[75] (for 20 years) on an initial investment of RS 13,100. Assuming a discount rate of 15%, such an investment has a positive NPV of RS 8,340.

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[73] National Planning Commission, Annexure VII
[74] Interview with CleanStar
[75] Includes all costs for harvesting, maintenance and irrigation.

Admittedly, many farmers may not have access to the resources to divert even marginal lands and wait up to five years for the returns. Yet even in such cases, they may be able to generate small side income streams from planting jatropha trees as hedges around their cultivable farm land. A farmer that plants 20 trees in such a fashion could reap as much a 3 kgs per tree for a total of RS 360 per year of additional income.

Key open issues:

In spite of these noteworthy benefits, there are legitimate concerns about the long-term pro-poor potential of jatropha based biofuels.

First, while less expensive, it is doubtful that vegetable oil based biofuels are cheap enough to dramatically increase the number of rural poor who can afford commercial forms of energy. A savings of RS 5-10 is substantial for those who already use diesel (and are able to pay RS 35), but it is still considerably more expensive than traditional biomass, which can in practice be collected for free. Jatropha based SVO is likely to be priced in-line or perhaps even more expensive than higher priced black market kerosene.   Thus, these fuels are not likely to have a great impact (in terms of energy access) on the poorest, but will most likely benefit those with $3-5 per day in total spending who have already switched over to commercial forms of energy.

Moreover, it is uncertain that these biofuels will be available to the poor in substantial quantities. Much of the feedstock supply may be exported to developed country markets (as mentioned above). Even that supply which remains in the domestic market will likely first go to larger diesel consumers. Given the relatively high costs to transport these fuels into more rural areas, producers will understandably prefer to make deliveries to larger customers that can purchase hundreds if not thousands of liters at a time. While distribution systems can be arranged (for example through village *Panchyats*) to sell the fuel one liter at a time, it remains uncertain whether these distributors will be the most profitable partner for a biofuel producer.

Third, vegetable oil based biofuels do not directly tackle the challenge of providing the poor their own energy generation equipment. It is perhaps an obvious, but nevertheless important point, that access to cheap biofuels is useless unless one has the generator to consume them. While diesel generators and diesel powered irrigation pumps are increasingly present across rural areas of India, they remain beyond the reach of many families.

Finally, legitimate concerns remain about the long-run sustainability of a jatropha based biofuels program. The government and even many private actors have been careful to pursue the program in a way that disrupts food-based agriculture as little as possible. Yet some disruption is almost inevitable and under certain conditions could become quite profound.

The re-allocation of water resources is of immediate concern. Water for food crops is an already scarce resource in many parts of rural India. While the efficiency and affordability of irrigation systems is improving, farmers still struggle to find the groundwater necessary for their crops. Diverting the limited water resources towards a fuel crop has at least *the potential* of upsetting the delicate balance in food production. Admittedly the same concern can be made of any cash crop that is not ultimately edible for its producers. Moreover, cash crops, such as sugarcane, require far more water than jatropha. But, while markets for cash crops are volatile, they nevertheless have been proven over decades of cultivation. By comparison, jatropha remains a relative unknown.

A second and perhaps more distant concern is the re-allocation of land. The Indian government in principal forbids the growth of jatropha (or any biofuel crop) on cultivable land currently in use for food production. Yet in practice, such a law is impossible to enforce. Thus, if jatropha cultivation proves to be economically fruitful to small farmers (in the near term), it is quite probable that they will in turn divert some of their cultivable land towards additional jatropha cultivation. While on its face, such a diversion may seem like a rational economic decision, the farmers will likely be making this decision without full information on the risks associated with the crop. It is impossible to forecast the real long-term demand of these crops, given the volatility of energy prices and the potential for another alternative feedstock that would be even less expensive than jatropha is today.

CONCLUSIONS AND RECOMMENDATIONS

As evidenced by the analyses above, the vegetable oil biofuels sector can provide substantial benefits to the rural poor in India by:

- **Delivering energy to the poor:**
  - Assuming a 10-13% margin for producers, biodiesel can be approximately 12% less expensive, while SVO can be as much as 32% less expensive than conventional diesel
  - Given these costs savings, rural farmers who already have access to rudimentary power generation equipment (e.g. diesel-powered irrigation pumps and generators), could save as much as RS 1,500 in fuel costs per year for each acre of irrigated land.
  - These benefits could be extended to greater numbers of the poor through marketing programs in which the cost of generators or pumps is financed through the on-going fuel cost.

- **Generating earnings for smallholder farmers and wage laborers:**
  - Assuming farmers can realize projected yields of 3-5 tons per hectare, they could earn as much as RS 5,000-10,000 in peak cash profits for every acre of jatropha planted
  - In addition, the biofuels sector will likely create substantial opportunities for wage laborers. As much as 325,000 annual person days of work could be created for every 5,000 hectares of jatropha planted.

- **Improving the rural environment and public health:**
  - Use of biofuels could substantially reduce diesel / kerosene emissions in rural areas
  - In addition, using biofuels in place of traditional biomass could help reduce life threatening respiratory illnesses among the rural poor

There are significant risks inherent to the industry's development. These risks exist at three levels:

- **Industry-wide risks:**
    - The government mandated biodiesel purchase policy, which fixes the price at RS 25, has virtually stalled all sales of biodiesel. Such price regulation could be applied to SVO, further distorting the market for biofuels as a whole.
    - Demand for jatropha feedstocks from export markets could limit the availability of feedstocks to producers serving the domestic fuel market

- **Company specific / execution risks:**
    - Companies must ensure that they have an adequate supply of land (contracted, leased or owned) to produce the feedstocks for their operations
    - Companies must still prove that they can achieve the necessary crop yields of 3 kgs per plant to ensure biofuels' economic viability
    - Companies must also prove that they can produce quality end-products (either SVO or biodiesel)
    - Companies cannot take demand for granted and must create marketing approaches that educate consumers on the benefits of switching to biofuels.

- **Threats to the long-term sustainable development of the sector:**
    - While jatropha and pongamia typically use far less water than many other crops, concerns may arise about the impact widespread cultivation has on scarce water resources.
    - Smallholder farmers contracted to grow biofuels crops may ultimately be left with considerable losses if yields fail to materialize

Appendix I (a): Detailed version of production costs of biodiesel

Table 1: Biodiesel production costs vs current diesel price (April 2007)

		Year1	Year2	Year3	Year4	Year5	Year6	Year7	Year8	Year9	Year10
Jatropha produced											
Seeds (i.e. unprocessed jatropha)	Tons	NA	NA	NA	1,112	4,446	7,225	8,337	8,893	10,004	10,004
Jatropha oil	Tons	NA	NA	NA	293	1,174	1,908	2,201	2,348	2,641	2,641
Jatropha oil	Liters	NA	NA	NA	326,089	1,304,290	2,119,447	2,445,504	2,608,548	2,934,604	2,934,604
Plantation costs											
Lease	RS	666,667	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000
Retainership (including irrigation costs)	RS	1,833,333	5,499,633	5,499,633	5,499,633	5,499,633	5,499,633	5,499,633	5,499,633	5,499,633	5,499,633
Plantation maintenance	RS	1,666,667	4,999,667	4,999,667	4,999,667	4,999,667	4,999,667	4,999,667	4,999,667	4,999,667	4,999,667
Harvesting	RS	-	-	-	1,111,667	4,446,444	7,225,389	8,336,944	8,892,778	10,004,333	10,004,333
Sub-total	RS	4,166,667	12,499,300	12,499,300	13,610,967	16,945,744	19,724,689	20,836,244	21,392,078	22,503,633	22,503,633
Sub-total	**RS / liter**	**NA**	**NA**	**NA**	**41.74**	**12.99**	**9.31**	**8.52**	**8.20**	**7.67**	**7.67**
Logistics costs											
Seed collection center variable costs	RS	NA	NA	NA	48,000	96,000	144,000	144,000	144,000	192,000	192,000
Wharehousing center variable costs	RS	NA	NA	NA	520,000	520,000	1,040,000	1,040,000	1,040,000	1,040,000	1,040,000
Transport	RS	NA	NA	NA	333,500	1,333,933	2,167,617	2,501,083	2,667,833	3,001,300	3,001,300
Sub-total	RS	NA	NA	NA	901,500	1,949,933	3,351,617	3,685,083	3,851,833	4,233,300	4,233,300
Sub-total	**RS / liter**	**NA**	**NA**	**NA**	**2.76**	**1.50**	**1.58**	**1.51**	**1.48**	**1.44**	**1.44**
Extraction operating costs											
Seed preparation	RS	NA	NA	NA	111,167	444,644	722,539	833,694	889,278	1,000,433	1,000,433
Decorticator operations	RS	NA	NA	NA	1,000,500	4,001,800	6,502,850	7,503,250	8,003,500	9,003,900	9,003,900
Sub-total	RS	NA	NA	NA	1,111,667	4,446,444	7,225,389	8,336,944	8,892,778	10,004,333	10,004,333
Sub-total	**RS / liter**	**NA**	**NA**	**NA**	**3.41**	**3.41**	**3.41**	**3.41**	**3.41**	**3.41**	**3.41**
Oil distribution to biodiesel production plant											
Sub-total	RS	NA	NA	NA	146,740	586,931	953,751	1,100,477	1,173,847	1,320,572	1,320,572
Sub-total	**RS /liter**	**NA**	**NA**	**NA**	**0.45**	**0.45**	**0.45**	**0.45**	**0.45**	**0.45**	**0.45**
Biodiesel production (total refining costs)											
Methanol	RS	NA	NA	NA	1,475,164	5,900,361	9,587,976	11,062,993	11,800,575	13,275,591	13,275,591
KOH	RS	NA	NA	NA	60,149	240,584	390,945	451,088	481,163	541,306	541,306
Electricity, water and other	RS	NA	NA	NA	388,162	1,552,571	2,522,899	2,911,023	3,105,104	3,493,227	3,493,227
Yield loss (10%)	RS	NA	NA	NA	192,348	769,352	1,250,182	1,442,510	1,538,684	1,731,012	1,731,012
Sub-total	RS	NA	NA	NA	2,115,823	8,462,868	13,752,003	15,867,614	16,925,525	19,041,137	19,041,137
Sub-total	**RS / liter**	**NA**	**NA**	**NA**	**6.49**	**6.49**	**6.49**	**6.49**	**6.49**	**6.49**	**6.49**
Depreciation of fixed capital investment											
Plantation set-up costs	RS	164,897	494,659	494,659	494,659	494,659	494,659	494,659	494,659	494,659	494,659
Irrigation set-up costs	RS	75,000	224,985	224,985	224,985	224,985	224,985	224,985	224,985	224,985	224,985
Seed collection centers	RS	-	-	-	18,000	18,000	18,000	18,000	18,000	18,000	18,000
Transport vehicles	RS	320,000	320,000	320,000	320,000	320,000	320,000	320,000	320,000	320,000	320,000
Exatraction machinery	RS	-	-	-	450,000	450,000	450,000	450,000	450,000	450,000	450,000
Sub-total of depreciation	RS	559,897	1,039,644	1,039,644	1,507,644	1,507,644	1,507,644	1,507,644	1,507,644	1,507,644	1,507,644
Sub-total of depreciation	**RS/ liter**	**NA**	**NA**	**NA**	**4.62**	**1.16**	**0.71**	**0.62**	**0.58**	**0.51**	**0.51**
Sub-total costs for BIODIESEL before distribution to end-users					59.48	25.99	21.95	20.99	20.60	19.97	19.97
Distribution to end-users					3.00	3.00	3.00	3.00	3.00	3.00	3.00
Producer's margin					3.00	3.00	3.00	3.00	3.00	3.00	3.00
Assumed tax[see footnote below]					4.00	4.00	4.00	4.00	4.00	4.00	4.00
Total cost of biodiesel (delivered)					69.48	35.99	31.95	30.99	30.60	29.97	29.97
Current average cost of diesel fuel					34.00	34.00	34.00	34.00	34.00	34.00	34.00
Difference (current diesel price - production costs)					(35.48)	(1.99)	2.05	3.01	3.40	4.03	4.03
% difference with current diesel price					NM	NM	6.0%	8.8%	10.0%	11.8%	11.8%

Source: Author estimates based on interviews

* Estimates begin in Year 4, the first year in which jatropha trees actually begin to provide seeds.

Taxes vary by province. RS 4 was taken to be tha average at the time of writing.

NOTE: Model does not include any costs for executive management overhead

Appendix I (b): Detailed version of production costs of straight vegetable oil

Table 1: *Straight vegetable oil* production costs vs current diesel price (April 2007)

		Year1	Year2	Year3	Year4	Year5	Year6	Year7	Year8	Year9	Year10
Jatropha produced											
Seeds (i.e. unprocessed jatropha)	Tons	NA	NA	NA	1,112	4,446	7,225	8,337	8,893	10,004	10,004
Jatropha oil	Tons	NA	NA	NA	293	1,174	1,908	2,201	2,348	2,641	2,641
Jatropha oil	Liters	NA	NA	NA	326,089	1,304,290	2,119,447	2,445,504	2,608,548	2,934,604	2,934,604
Plantation costs											
Lease	RS	666,667	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000	2,000,000
Retainership (including irrigation costs)	RS	1,833,333	5,499,633	5,499,633	5,499,633	5,499,633	5,499,633	5,499,633	5,499,633	5,499,633	5,499,633
Plantation maintenance	RS	1,666,667	4,999,667	4,999,667	4,999,667	4,999,667	4,999,667	4,999,667	4,999,667	4,999,667	4,999,667
Harvesting	RS	-	-	-	1,111,667	4,446,444	7,225,389	8,336,944	8,892,778	10,004,333	10,004,333
Sub-total	RS	4,166,667	12,499,300	12,499,300	13,610,967	16,945,744	19,724,689	20,836,244	21,392,078	22,503,633	22,503,633
Sub-total	**RS / liter**	**NA**	**NA**	**NA**	**41.74**	**12.99**	**9.31**	**8.52**	**8.20**	**7.67**	**7.67**
Logistics costs											
Seed collection center variable costs	RS	NA	NA	NA	48,000	96,000	144,000	144,000	144,000	192,000	192,000
Wharehousing center variable costs	RS	NA	NA	NA	520,000	520,000	1,040,000	1,040,000	1,040,000	1,040,000	1,040,000
Transport	RS	NA	NA	NA	333,500	1,333,933	2,167,617	2,501,083	2,667,833	3,001,300	3,001,300
Sub-total	RS	NA	NA	NA	901,500	1,949,933	3,351,617	3,685,083	3,851,833	4,233,300	4,233,300
Sub-total	**RS / liter**	**NA**	**NA**	**NA**	**2.76**	**1.50**	**1.58**	**1.51**	**1.48**	**1.44**	**1.44**
Extraction operating costs											
Seed preparation	RS	NA	NA	NA	111,167	444,644	722,539	833,694	889,278	1,000,433	1,000,433
Decorticator operations	RS	NA	NA	NA	1,000,500	4,001,800	6,502,850	7,503,250	8,003,500	9,003,900	9,003,900
Sub-total	RS	NA	NA	NA	1,111,667	4,446,444	7,225,389	8,336,944	8,892,778	10,004,333	10,004,333
Sub-total	**RS / liter**	**NA**	**NA**	**NA**	**3.41**	**3.41**	**3.41**	**3.41**	**3.41**	**3.41**	**3.41**
Depreciation of fixed capital investment											
Plantation set-up costs	RS	164,897	494,659	494,659	494,659	494,659	494,659	494,659	494,659	494,659	494,659
Irrigation set-up costs	RS	75,000	224,985	224,985	224,985	224,985	224,985	224,985	224,985	224,985	224,985
Seed collection centers	RS	-	-	-	18,000	18,000	18,000	18,000	18,000	18,000	18,000
Transport vehicles	RS	320,000	320,000	320,000	320,000	320,000	320,000	320,000	320,000	320,000	320,000
Exatraction machinery	RS	-	-	-	450,000	450,000	450,000	450,000	450,000	450,000	450,000
Sub-total of depreciation	RS	559,897	1,039,644	1,039,644	1,507,644	1,507,644	1,507,644	1,507,644	1,507,644	1,507,644	1,507,644
Sub-total of depreciation	**RS/ liter**	**NA**	**NA**	**NA**	**4.62**	**1.16**	**0.71**	**0.62**	**0.58**	**0.51**	**0.51**
Sub-total costs for BIODIESEL before distribution to end-users					52.54	19.05	15.01	14.05	13.66	13.03	13.03
Distribution to end-users					3.00	3.00	3.00	3.00	3.00	3.00	3.00
Producer's margin					3.00	3.00	3.00	3.00	3.00	3.00	3.00
Assumed tax[see footnote below]					4.00	4.00	4.00	4.00	4.00	4.00	4.00
Total cost of biodiesel (delivered)					62.54	29.05	25.01	24.05	23.66	23.03	23.03
Current average cost of diesel fuel					34.00	34.00	34.00	34.00	34.00	34.00	34.00
Difference (current diesel price - production costs)					(28.54)	4.95	8.99	9.95	10.34	10.97	10.97
% difference with current diesel price					NM	15%	26%	29%	30%	32%	32%

Source: Author estimates based on interviews

* Estimates begin in Year 4, the first year in which jatropha trees actually begin to provide seeds.

Taxes vary by province. RS 4 was taken to be tha average at the time of writing.

NOTE: Model does not include any costs for executive management overhead

Appendix II: Key assumptions for cost analysis in tables 1 & 2

Category of assumption	Units	Assumption	Comments / source:
Overall assumptions			
Liters per ton of jatropha oil	lit / ton	1111	Based on specific gravity of jatropha oil
Plantation costs / outputs			
Number of acres planted	acres	5,000	Planted over two years
Lease rate	RS / acre	400	Based on estimates from state Government of Maharshtra
Seed yield	kgs / plant	1 to 3	Starts as 1 kg in year 4 increasing to 3 kgs by year 8 after planting
Number of plants	plants / acre	667	Assumes roughly 2.5 x 2.5 spacing
Harvesting	RS / acre	1000	Labor cost for each acre
Retainership	RS / acre	1100	Industry interviews
Maintenance	RS / acre	1000	Industry interviews
Annual variable logistics costs			
Seed collection center labor	RS / year	48,000	Industry interviews
Collection center capacity	tons / year	3000	Need up to 4 centers for 5000 acres
Warehouse labor and leases	RS / year	520,000	Industry interviews
Warehouse capacity	tons / year	5,000	Need up to 2 warehouses for 5000 acres
Transportation costs of seeds	RS / ton	300	Fuel, and driver costs
Annual extraction operating costs			
Seed preparation	RS / ton	100	Industry interviews
Decorticator and oil extraction unit operations	RS / ton	900	Industry interviews
Oil distribution (to biodiesel production plant)	RS / ton	500	Industry interviews
Biodiesel production (total refining costs)			
Methanol	RS / lit	4.52	Assumes 20% consumption per liter of veg oil & $0.5 / lit methanol price
KOH	RS / lit	0.18	Assumes .012 kg of KOH per liter and price of .34 per kg
Electricity, water and other	RS / lit	1.19	Author experience, Industry interviews
Yield loss (10%)	RS / lit	0.59	Author experience
Depreciation of fixed costs			
Plantation set-up costs	**RS**	15,000,000	Using plants per acre estimate above
Irrigation set-up costs	**RS**	2,250,000	Assumes a total of 50 pumps to cover 5000 acres
Seed collection centers	**RS**	2,400,000	Assumes 4 centers at 60,000 a piece
Transport vehicles	**RS**	3,200,000	4 vehicles at 800,000 a piece
Extraction operations	**RS**	12,000,000	4 at 3,000,000 a piece (each with 3000 tons per year capacity)

Appendix III: Fixed capital investment required

	Usable life (yrs)	Year1	Year2	Year3	Year4	Year5	Year6	Year7	Year8	Year9	Year10
Plantaton set up costs	30	4,946,917	9,892,844								
Irrigation set-up costs	10	750,000	1,499,850								
Seed collection centers	10	-	-	-	60,000	60,000	60,000	-	-	60,000	-
Transport vehicles	10	3,200,000									
Extraction operations set-up	20	-	-	-	3,000,000.00	3,000,000.00	3,000,000.00	-	-	3,000,000.00	-
Total		8,896,917	11,392,694	-	3,060,000	3,060,000	3,060,000	-	-	3,060,000	-

APPENDIX IV: Comparative costs of different jatropha oil extraction methods (rough estimates)

Comparative costs of different extraction methods (rough estimates)

	Hexane	**Extrusion**	**Manual**
Processing capacity (tons per day)	350	15	0.6
Days operation (per year)	350	350	350
Capacity per year	122,500	5,250	210
Yield	25%	25%	25%
Extraction efficiency	97%	93%	80%
Tons of oil (per year)	29,706	1,221	42
Liters per ton	1,111	1,111	1,111
Liters of oil	33,003,644	1,356,114	46,662
Plant operating costs			
Operating costs per ton of seed (RS / ton of seed)	150	400	1,125
Total seed operating costs (RS)	18,375,000	2,100,000	236,250
Operating cost per ton of oil (RS / ton of oil)	619	1,720	5,625
Plant operating costs (RS / liter of oil)	**0.56**	**1.55**	**5.06**
Area coverage			
Tons of seed (per hectare)	4.0	4.0	NA
Total area at 100% capacity (hectares)	30,625.0	1,312.5	NA
Sq Km	306.25	13.13	NA
Transportation costs			
Transport per ton of seeds	500	300	0
Total transport costs	61,250,000	1,575,000	-
Transport cost per ton of oil	2,062	1,290	0
RS / Liter	**1.86**	**1.16**	**0.00**
Total costs / ton (RS)	2,680	3,011	5,625
Total costs / liter (RS)	**2.41**	**2.71**	**5.1**

APPENDIX V: Assumptions used to develop Table 6 "Estimated costs to process jatropha oil into biodiesel at different scales"

	Micro-processor	Multi-local	Centralized processor	Source
Methanol price ($ per liter of methanol)	$0.79	0.50	0.48	Current world market price adjusted for distribution costs
Methanol use (% per liter of oil)	20%	20%	20%	Production experience (assumes no methanol recovery)
KOH price ($ per Kg of KOH)	$0.68	0.34	0.18	Current world market price adjusted for distribution costs
KOH use (Kg per liter of oil)	0.012	0.012	0.012	Production experience
Other costs	$0.03	0.03	0.01	Production experience
Ex Rate (INR/US$)	45	45	45	

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