Bioenergy Resource Status in India

WORKING PAPER

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Purpose of the Paper

The issue of energy security is central to the sustainable development aspirations of developing countries such as India. Bioenergy occupies a significant share of the rural energy mix. Fuel wood is the dominant source of household energy in rural areas of the country and even acquires a sizeable share in peri-urban and urban areas. Besides fuel wood, agricultural biomass, agro-residues and dung cake are also being used. So it is essential to understand the biomass availability situation and the level of biomass resource dependency in the country.

This report attempts to analyze the trends of biomass production and consumption in the country. The recent developments in the liquid biofuel sector find a place in the paper. Though the share of liquid biofuels such as biodiesel and bioethanol in household energy consumption is marginal, the report makes an attempt to outline what liquid biofuel could mean to the rural energy sector.

1. Introduction:

Energy is a basic requirement for economic development. India's staggering 8 per cent average economic growth rate makes a huge demand on energy inputs. The growing consumption of energy has resulted in increasing dependency on fossil fuels. The consumption of crude oil was about 185 MT for the year 2007-08 but 80 per cent of this demand was met by imports (TERI 2007). Energy consumption is increasing at 6.5 per cent per annum, while reserves of petroleum are decreasing day by day. India's share of crude oil production is about 1 per cent of global crude oil production, whereas consumption amounts to 3.1 per cent of global consumption (Energy Statistics 2003-04). The energy deficit can be decreased significantly if biomass-based renewable energy is pressed into service. In India, biomass fuels dominate rural energy consumption patterns, accounting for over 80 per cent of total energy consumed. Fuel wood is the preferred and dominant biomass source, accounting for 54 per cent of biomass fuels used in India. Crop residues, agricultural biomass, and livestock dung are also being used. In quantitative terms, India consumed 470 million ton oil equivalent (mtoe) in total of primary energy in 2003-04, of which the amount of commercial energy was 327 mtoe (70 per cent). The remaining 143 mtoe (30 per cent) was met through non-commercial sources such as fuel wood, agro residue, dung cake and biogas. In 2005, as is shown in the last column of Table 1, although the total amount of primary energy consumption had increased to 537.3 mtoe, the share of traditional energy from biomass had remained almost unchanged at 29 per cent.

Table 1: Shares of different fuel-mix[1]				
Energy Type	**1960-61**	**1990-91**	**2001-02**	**2005****
Coal	74.1	39	34.65	38.7
Oil & Gas	20.9	43.4	30.65	29.3
Non–Fossil Fuel	5	17.6	34.70*	32.0#

Source: Planning and Commission, Government of India. Eighth Five Year Plan, Vol.2: MNES New and Renewable Energy Policy – Draft II. 2005

In a situation of high dependency on biomass for energy services, this report attempts to take stock of the biomass production and use trend in the country. This report also delves into the liquid biofuel sector and reports on the existing production and consumption trends.

2. Biomass Resources and their status:

Wood fuels: One of the important features of rural energy use is the dependence on locally available biomass resources. Over 77 per cent of rural households in the country were estimated to depend on firewood and chips for cooking (NSSO 2007–08). It has been estimated that about 2–3 million people are engaged in fuel wood 'head loading' in India, making it the largest source of employment in the energy sector in the country (CIFOR news online). It is reported that most of the fuel wood is derived from forests, with some portion also being obtained from trees growing on homesteads, farmlands, and common lands.

Forest as a wood fuel source: Forestry is the second-largest land use in India after agriculture, covering about 641,130 square kilometers, or 22 per cent of the total land base. Roughly 275 million poor rural people in India—27 per cent of the total population—depend on forests for at least part of their subsistence and cash livelihoods, which they earn from fuel wood, fodder, poles, and a range of Non-Timber Forest Products (NTFP) such as fruits, flowers and medicinal plants (World Bank .2005).

Trends in production and consumption of fuel wood and charcoal: Total wood production (round wood) in Indian forests has increased from 199.17 m. cum in 1970–80 to 248.52 m.cu m in 1981–2000, registering a compound growth rate of 2.03 per cent for the time period 1970–2000 (Table 2). The production of fuel wood and charcoal increased at the rate of 1.98 per cent per annum (Malik and Dhanda 2003).

Table 2: Fuel wood and charcoal production						
Forest products	Production			Growth rate (Per cent per annum)		
	1970– 80	1981–2000	1970–2000	1970–80	1981–2000	1970–2000
Round wood (Million m^3)	199.17	248.52	241.65	2.68	1.81	2.03
Fuel wood and charcoal	182.85	240.36	224.16	2.52	1.87	1.98

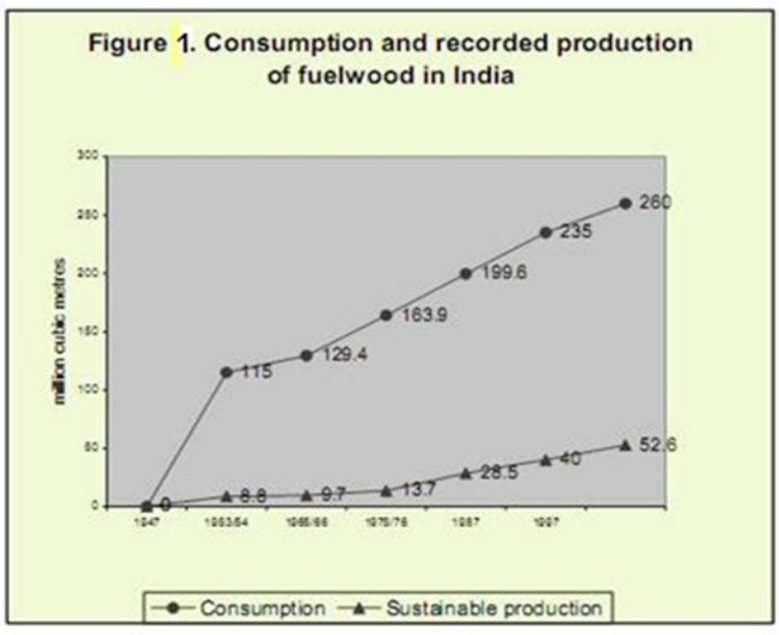
Source: Malik and Dhanda 2003.

Forest products consumption in India experienced a considerable growth in the same period. Round wood consumption increased from 199.14 m. cum in 1970–80 to 248.58 m. cum in 1981–2000 (Table 3). The fuel wood and charcoal consumption grew at compound growth rate of 2.18 per cent for the period 1970-2000.

Table 3: Fuel wood and charcoal consumption						
Forest products	**Consumption**			**Growth rate (Per cent per annum)**		
	1970–1980	**1981–2000**	**1970–2000**	**1970–80**	**1981–2000**	**1970–2000**
Round wood (Million m^3)	199.14	248.58	240.31	2.68	1.89	2.17
Fuel wood and charcoal	182.84	229.62	222.99	2.52	2.01	2.18

But the gap between consumption and recorded sustainable production of fuel wood has been increasing, indicating the seriousness of the fuel wood problem in India (Figure 1).

Figure 1. Consumption and recorded production of fuelwood in India



Source: Malhotra Preeti (TERI 2002)

Total growing stock of wood[2] follows a decreasing trend (Table 4) in forest and trees outside forests[3] (TOF). Moreover, average growing stock per hectare of forest area has declined to 58.46 cubic meters (cu. m) in 2009 from 61.72 cu. m in 2003. However, India is the only country in South Asia to record an increase in forest cover over the period 1987–2000 (50,080 sq. km).

Table 4: Growing stock in India

Growing Stock (Million. cu.m)	2003	2005	2009
Trees Outside Forest	1,632	1,616	1599.57
Inside Forest	4,782	4,602	4498.66
Total	**6,414**	**6,218**	**6098.23**

Source: State of Forest Report, Forest Survey of India

In addition, the average forest mean annual increment of 0.7 cu. m per hectare per year is significantly below the global average of 2.1 cu. m (World Bank 2005[4]. Understandably, the reasons for low productivity include human removal of forest biomass, grazing pressure, forest fire, and over cutting (Bahuguna *et al* 2004). About 41 per cent of the country's forest cover has been degraded to some degree in the past several decades as a result of intense anthropogenic and biophysical pressure.

Demand for timber (logs) and fuel wood is projected to increase in future while supply is to remain flat, leading to significant and growing fiber and wood supply deficits. By 2020, the total supply of fuel wood from forests and other source is estimated to be 44.4 million metric tonnes (Ministry of Environment and Forest, Government of India). An estimated 139 million metric tonnes of fuel wood was harvested above the sustainable supply in 2006 (Bahuguna *et al* 2004). Other estimates indicate fuel wood over-cutting of 13.1 million cubic meters. (Saigal, Arora, and Rizvi 2002). Subsistence collection of deadfall, and nondestructive wood sources from natural forests (collecting branches and litter) is widely practiced in rural areas. But unregulated removal of fuel wood from natural and plantation forests has a long standing impact on forest ecosystems.

1. **Bioresidues**: Biomass generated from agriculture is a measured component of the energy mix used in rural India. In 2005–06, 316.8 million tonnes of agriculture-based biomass had been generated in the country in comparison to 169.8 million tonnes in 1980-81 (Figure 2). Despite the importance of residual biomass generated from agriculture, waste land and forest, national level assessment studies are lacking. Recently the Indian Institute of Science, Banglore has prepared a "Biomass Resource Atlas", estimating total biomass generated from forests, agriculture and wasteland. The Biomass Resource Atlas has also estimated the power generation potential using the surplus biomass which amounts to nearly 176 million tones, which on efficient utilization would produce 23,250 MW of electricity. Annexure 1 shows the quantity of surplus biomass produced in each state and the corresponding power that could be generated potentially by using the biomass.

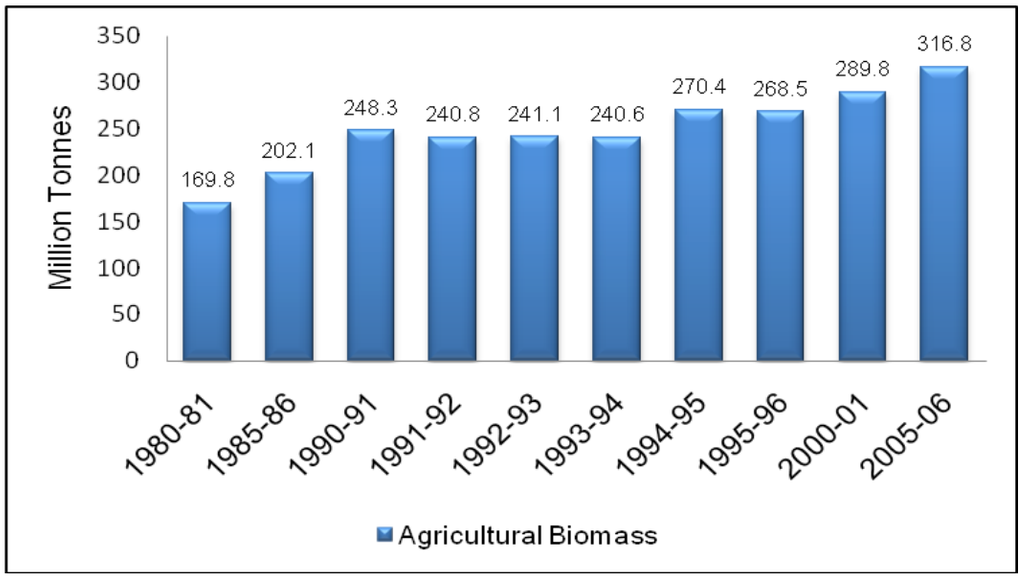


Figure 2: Potential availability of agricultural biomass

Table 5: Bioresidue Source and potential power generation for 2000–04

Bioresidue Source	Area (kHa)	Biomass Generation (MT/ Yr)	Biomass Surplus (MT/Yr)	Power Potential (MWe)
Forest	400,993	27.1	18,.2	2549
Agriculture	319,999	444.6	133.7	17354
Wasteland	425,276	35.6	23.9	3348
Total		507.4	175.9	23251

Source: Biomass Atlas of India prepared by Indian Institute of Science, Bangalore. (http://lab.cgpl.iisc.ernet.in/Atlas)

However, India's total installed capacity for electricity generation from biomass is 1,325 MW (MNRE and 2007). 605 MW of electricity is being produced from biomass firing and 720 MW from cogeneration activities. An additional 1178MW power is being commissioned, which will take the total power generation from biomass to 3,100MW.

Biomass as energy is gaining importance as a renewable source to strengthen the country's agriculture.

3. Biofuel: Renewed interest in oil yielding plants has surfaced on account of depletion of fossil fuel reserves, global warming concerns, and to spur rural development. India has emerged a front runner in promoting the production of bioethanol and biodiesel from domestically-grown crops.

3.1 Bioethanol: Bioethanol can be produced from three classes of vegetative sources.

- starch from grain, corn and tubers like cassava
- sugar plants (sugar beet or sugar cane)
- cellulose plants (trees and biomass).

In India molasses, a byproduct of the sugar industry, is the main feedstock for ethanol. During 2002–03, the total area under sugarcane production was 4,361,000 ha (Singh 2004). During 2001–02, the total production of ethanol from molasses was 1.77 billion litres - out of which about 70 per cent was used for potable or industrial purposes, leaving a balance of 0.53 billion litres for use as fuel (Planning Commission 2003). By 2007 the country was already the world's seventh largest ethanol producer, with an annual production of 200 million litres of ethanol (Worldwatch Institute 2007, 6).

Potential bioethanol-producing substrates:

Sugarcane: India is the second largest producer of sugarcane in the world, after Brazil. Total production of sugarcane in 2017 is projected at about 358 million metric tonnes (mmt) from 5.9 million ha, compared to approximately 233 mmt from 3.9 million ha in 2003. Despite the growth and substantial levels of production, India's sugarcane will probably be dedicated primarily to human consumption, and liquid biofuel production will remain limited to offsetting a relatively small percentage of domestic demand for imported fuels. The area under sugarcane has increased by a factor of 2.5 since 1950–51. In recent years, however, the area and the yield have stagnated, as shown in Table 3. At present, India has the capacity to produce about 1.3 billion liters of biofuel from molasses. However, only about one-tenth of that capacity was dedicated to fuel ethanol in 2005 and the government's soft targets for a 5 per cent blend (if commercially viable) in selected states have not been met.

Ethanol-producing firms purchase molasses from sugar industries. There has been steady progress in molasses production in India. During the year 2007–08, 11.313 million tonnes of molasses were produced. During the same year, 1,106 million liters of ethanol (95 per cent v/v, that is, rectified spirit) were produced.

Table 6: Sugarcane production in India

Year	Area under Sugarcane (Million ha)	Yield of Cane (Million Tonnes per ha)
2002–03	4,520	63.6
2003–04	3,938	59.4
2004–05	3,661	64.8
2005–06	4,202	66.9
2006–07	5,151	69
2007–08	5,055	68.9
2008–09	4,395	61.7

Source: Indian Sugar Mills Association and Ministry of Agriculture, Government of India

Bioethanol blending with petrol was made mandatory in 2003 in nine states and four union territories, and later extended to other parts of the country based on the availability of ethanol; but this is not implemented due to shortage of ethanol. The lack of progress was initially attributed to short supply (resulting from droughts and pest attacks), and more recently, with surplus sugarcane, to taxes, mill prices and state regulations. Among other

alternatives, efforts are underway to diversify the feedstock base so as to ensure improved availability. Efforts are being made to find alternative crops, such as sweet sorghum, for enhancing bioethanol production.

3.2 Sweet Sorghum: Sorghum is a potential alternative substrate to meet the growing demand of bioethanol. The stalks yield 15 to 20 per cent fermentable sugar which can be fermented and distilled to blend with petrol (gasoline). The crop can be grown in dry areas and needs less water as compared to sugarcane. Though commercial and large-scale production of sorghum has not been realized yet to its full potential, a few sugar-producing mills and corporates such as Tata Chemicals have started production. Organizations such as ICRISAT and the National Research Centre for Sorghum have developed open pollinated varieties and photo-period sensitive hybrids, enabling year-round production. Ethanol production in the country is constrained because of its dependence on a single source. Promotion of alternative crops as feedstock is a potential solution to increasing bioethanol production.

Bioethanol consumption: Currently bioethanol consumption is restricted to the transportation sector only. Rural India may benefit from the massive investment in developing the bioethanol value chain. Estimated potential of bioethanol production in the year 2008-09 was 1.7 billion liters. The Indian biofuel consumption market had a total revenue of $277 million in 2010, representing a compound annual growth rate (CAGR) of 18.6 per cent for the period 2006-2010. Market consumption volumes increased with a CAGR of 9.7 per cent between 2006 and 2010, to reach a total of 2.4 million barrels in 2010 (Market research, 2011). During the period March 2003 to September 2004, 0.37 billion liters of fuel ethanol was purchased by the oil industry [Ethanol India, 2005] as a part of the 5 per cent ethanol blending program. Ministry of Petroleum & Natural Gas vide its notification dated 20th September, 2006 has directed the OMCs to sell 5 per cent Ethanol-Blended Petrol (EBP) subject to commercial viability as per Bureau of Indian Standards specifications. The EBP programme was affected adversely due to shortfall in supply of ethanol by the sugar industry. Due to shortfall in sugarcane production and resultant crushing during the year 2009, the supply of alcohol was mere 15 per cent of the requirement. Efforts are being made to ensure availability of ethanol on consistent basis for the EBP programme and OMC's are in discussion with the sugar industry to firm up the status of availability at various locations. (Ministry of Petroleum and Natural Gas, GoI 2009-10).

4. Biodiesel: India has more than 300 different species of trees that produce oil-bearing seeds (Subramanian *et al* 2005). In India's agricultural economy, oilseeds are next to food grains in acreage, production, and value. While the country is already the world's seventh-largest ethanol producer, with an annual production of 200 million liters of ethanol (World Watch Institute 2007, 6), biodiesel production is very recent.

The country has an estimated potential of more than 5 million tonnes of tree borne oilseed (TBO). However, only 0.8 to 1 million tonnes are being collected. At present 15,000–20,000 tonnes of oil are being extracted, from the exploitable potential of more than 1 million tonnes from tree-origin resources (First R&D Report, NOVOD Board). The species identified as potential oil yielders are *Shorea robusta, Madhuca indica, Azadirachta indica, Simarouba*

glauca, Pongamia piñata, Jatropha curcus, Simmondsia chinensis (Jojoba), Diploknema botryceae (Cheura), *Garcinia indica*, *Prunus armeniaca* (wild apricot), among hundreds.

4.1 Biodiesel production potential: There is a huge scope for biodiesel production using the TBO resources of India by tapping the existing wild resources and conducting new plantation activities. The farming community is not willing to allocate productive agricultural land for fuel crop plantations because of the lower yield and price. Under the Joint / Community Forest Management programme, the Forest department has undertaken plantation of *Pongamia*, an oil-yielding crop of much potential, in forest tracts.

Besides mainstream plantations on agricultural and forest land, plantations along roads, railway lines, canals, farm bunds, and community land are also now being cultivated. Centrally sponsored programs such as the National Rural Employment Guarantee Scheme (NREGS) and Watershed Development Program provide subsidies to encourage *Pongamia* plantation.

Table 7: Type of land for plantation and cultivation

Type of Plantation	**Type of Land**		
Boundary Plantation	Land along roads, railway lines, canals, around agricultural fields etc.		
Monoculture block Plantation	Regular Agricultural Lands	Regular Forest Lands	Unutilized or under-utilized land
Intercropping on Plantation			

Source: (Tilman Altenburg 2009) Land for cultivation of oil-bearing trees.

The Wastelands Atlas of India, a satellite-based land survey by the Indian Ministry of Rural Development, identifies 553,000 km² of the 3.3 million km² of total land area in India as wasteland (MoRD 2005, 12). Yet, designating the entire area for biofuel crop plantation may lead to denial of the people heavily dependent on this type of land for livestock rearing, fuel wood collection etc. The term 'wasteland' is misleading; these lands have been degraded due to unsustainable usage. More recently, the Government of India reduced its estimate of land reserves that are suitable for biofuel crop cultivation to 72,000 km² (Shankar 2006, 94). The Planning Commission has estimated that 10 per cent of the total fallow land (24 million ha) can be brought under *Jatropha* plantation. An estimated 3.0 m ha can be brought under cultivation of biofuel plants by planting them as protective hedges around agriculture fields (Planning Commission 2003).

Jatropha and *Pongamia,* the crop species most widely used for biofuel crop cultivation, have a wide range of adaptability and regional suitability. Based on the ecological region approach evolved by the National Bureau of Soil Survey and Land Use Planning (NBSS&LUP), by taking into account soil, climate and other physiographic factors, suitability zones for *Pongamia* and *Jatropha* have been delineated (GTZ 2006). The suitability maps have been reproduced in Figure 5 (a) and 5 (b). Coastal areas were classified as "moderately suitable" for both species. They could be grouped in "high" since they grow well, but there are other tree species which are more profitable such as the "3 Cs" (Coconut, Cashew and Casuarina).

It is highly unlikely that *Jatropha* and *Pongamia* will compete with these species. Arid and humid areas were classified as "poor" because both *Jatropha* and *Pongamia* will grow, but seed setting and yield will be poor. In arid areas there are limited options; but humid areas have other options such as bamboo, which performs well in these areas. Therefore, it is the semi-arid and sub-humid tropical areas which are considered as "highly suitable" for plantations of *Jatropha* and *Pongamia.* Within the semi-arid tropics, *Jatropha* is preferable in semi-arid (dry) while *P*ongamia in semi-arid (wet).

Biodiesel consumption: During 2003-04, the diesel consumption in the country was around 38 MT, of which about 60 per cent was used for transportation and the rest in industries and the agricultural sector. Due to the rapid increase in the demand for diesel and other petroleum products, India's dependence on oil imports is expected to rise to 92 per cent by 2030 (World Energy Outlook, 2000). To reduce India's dependence on oil imports and at the same time cut down on the import bill, it is important to develop renewable options to substitute fossil diesel, such as biodiesel Table 3.3 below estimates of future demand of diesel in the country and calculates the amount of biodiesel, seed and area required at various percentages of blends. Table shows by the year 2020, against a total requirement of diesel of 162.67 MT, 32.53MT biodiesel (B20) will be required. To achieve this target, a land area of about 54Mha would be required for the cultivation of Jatropha and other oil seed crops. However, the land being cultivated for *Jatropha* in various states is given in Table 9, which shows that the maximum *Jatropha* cultivation is being done in the state of Maharashtra, followed by Gujarat, Tamil Nadu and Rajasthan.

Table 8. Diesel demand and future biodiesel requirements

Year	Diesel Demand	Biodiesel Requirement (MT)			Seed requirement (MT)			Area requirement (Mha)		
		BD_5	BD_{10}	BD_{20}	BD_5	BD_{10}	BD_{20}	BD_5	BD_{10}	BD_{20}
2007-08	60.1	3.0	6.0	12.0	10.0	20.0	40.1	5.0	10.0	21.0
2008-09	90.2	4.5	9.0	18.0	15.0	30.1	60.1	7.5	15.0	30.0
2009-10	95.2	4.7 76	9.5	19.0	15.8	31.7	63.5	7.9	15.8	31.7
2010-11	100.5	5.0	10.0	20.1	16.7	33.5	66.9	8.4	16.7	33.5
2011-12	106.0	5.3	10.6	21.2	17.6	35.3	70.6	8.8	17.6	35.3
2012-13	111.8	5.6	11.1	22.3	18.6	37.2	74.5	9.3	18.6	37.2
2013-14	118	5.9	11.8	23.6	19.6	39.3	78.6	9.9	19.6	39.3
2014-15	124. 5	6.2	12.4	24.9	20.7	41.5	82.9	10.3	20.7	41.5
2015-16	131.3	6.6	13.3	26.2	21.9	43.7	87.5	10.9	21.9	43.7
2016-17	138.5	7.0	13.8	27.7	23.1	46.1	92.6	11.5	23.1	46.1
2017-18	146.216	7.3	14.6	29.2	24.3	48.7	97.4	12.1	24.3	48.7
2018-19	154.2 19	7.3	15.4	30.8	25.7	51.4	102	12.8	25.7	51.4
2019-20	162.7	8.1	16.2	32.5	27.1	54.2	108	13.5	21.1	54.2

Source: Planning Commission, 2008

Table 9. Land Area under cultivation of *Jatropha* in various states of India **Source:** Puhan et.al 2008.		
State	**Area (Ha)**	**% of land**
Andhra Pradesh	260	2.63
Bihar	110	1.11
Chattisgarh	650	6.58
Delhi	665	6.63
Gujarat	1140	11.54
Goa	10	0.10
Haryana	520	5.26
Jharkhand	200	2.02
Karnataka	120	1.21
Kerala	50	0.5
Madhya Pradesh	84	0.85
Maharashtra	1310	13.26
Manipur	200	2.03
Meghalaya	200	2.03
Mizoram	300	0.30
Nagaland	240	2.43
Rajasthan	715	7.24
Tamilnadu	960	9.72
Uttar Pradesh	633	6.41
Uttarakhand	650	6.58
West Bengal	100	1.01
Total	9878	100

Figure 5a: Suitability map for *Pongamia*

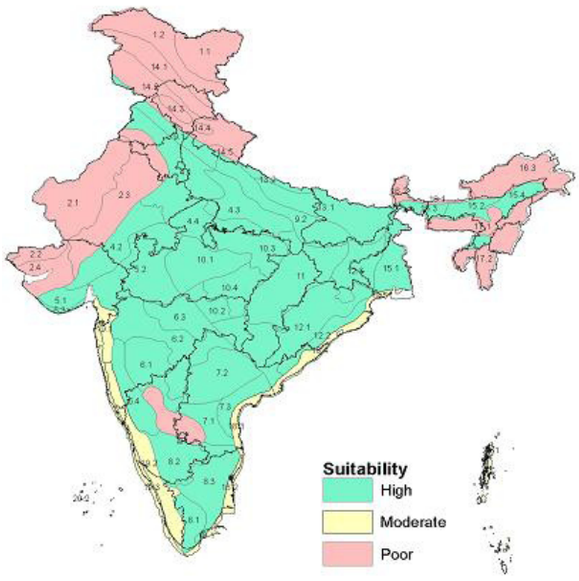
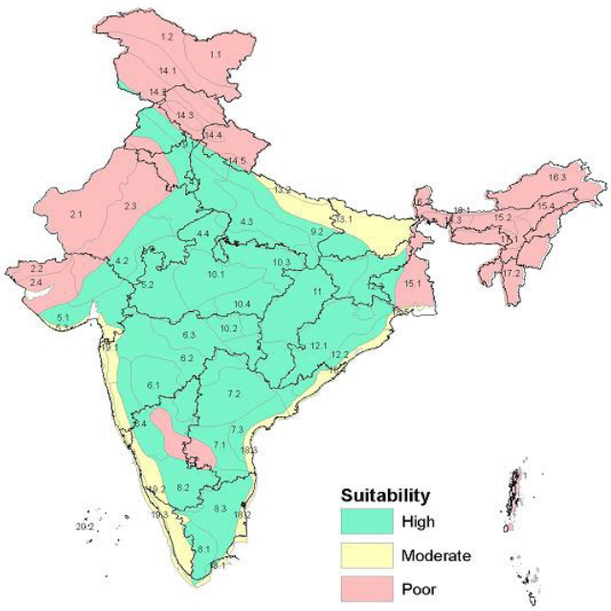


Figure 5.b: Suitability map for *Jatropha*



Source: Liquid Biofuels for Transportation: India country study on potential and implications fors for sustainable agriculture and energy (GTZ 2006). Area delineated using AESR map of NBSS&LUP, Nagpur (Sehgal et al 1996).

Table 10: Total area that can be brought under *Jatropha* plantation

Type of Land	Total Area (Million Ha)	Area estimated for *Jatropha* plantation (Million ha)	Assumptions
Forest cover	69	3	14 million ha of forests are under the scheme of Joint forest management out of which 20 per cent per cent would be able to available for *Jatropha* plantation
Agriculture Land	142	3	It is assumed that farmers will like to put a hedge (occupying 10% of the area) around 30 million hectares for protection of their crops
Agroforestry	NA	2	Considerable land is held by absentee landlords who will be attracted to *Jatropha* plantation since it does not require maintenance
Cultivable fallow lands	24	2.4	10 per cent per cent of the total area is expected to come under *Jatropha* plantation
Wastelands under Integrated Watershed Development and other poverty-alleviation programs of Ministry of Rural Development	NA	2	NA
Public lands along Railway tracks, roads and canals	NA	1	NA

Source: (Planning Commission 2003)

Biodiesel purchase Policy: To encourage production of bio-diesel in the country, the Ministry of Petroleum and Natural Gas has announced a biodiesel Purchase Policy in October, 2005, which became effective from 1.1.2006. Under this scheme Oil Marketing Companies (OMC) will purchase bio-diesel for blending with High Speed Diesel to the

extent of 5 per cent at identified purchase centers across the country. OMCs would buy bio-diesel at a uniform landed price, which is to be reviewed every six months. At present, the purchase price of bio-diesel is at Rs. 24.50 (USD 0.54) per liter. The policy has identified 20 purchase centers of the OMCs all over the country. The OMCs would purchase bio-diesel meeting the standards prescribed by the Bureau of Indian Standards (BIS), from those bio-diesel manufacturers who register with them after satisfying the technical specifications, at a specified delivered price. The bio-diesel industry is still at nascent stage of growth. OMCs have not been able to purchase bio-diesel at the identified purchase centers so far, as the parties who have expressed interest are not willing to supply at the declared price.

Implications on rural energy: India has a large biomass resource base which is currently being utilized inefficiently. It can therefore can be argued that efficient handling and management of biomass, with all its complexities, can substantially meet the demand through decentralized energy systems; leading to greater energy security for villages and small industries. Modern biomass conversion technologies can play an important role in providing sustainable solutions for energy demands in villages and small industries. In addition, biomass-based industries need to be promoted since they are a significant source of enterprise development, job creation and income generation in rural areas.

With a rural development agenda, a push to liquid biofuel production could diversify the livelihood base of rural people. Biofuel cropping can provide gainful employment in rural areas. Large scale investment in the liquid biofuel sector could open up new opportunities; but a concerted effort is needed to ensure that biofuel cropping also contributes to rural livelihoods.

Conclusion:

The requirement for forest products is growing and will continue to increase due to population and economic growth. Demand and supply projections reveal that there will be a deficit in supply of most forest products if the area under forest cover is not increased as identified by forest policy. Although the requirement for forest products is likely to rise from present levels, the rate of increase is expected to be lower than in the past. The demand–supply balance situation is disturbing and can only be improved through the implementation of conducive policies. Efforts should be made to increase the area under forest cover by afforesting wastelands through social and agro-forestry involving people's participation.

In the residential sector, energy use and specific end-uses show that wood fuels, which have traditionally been the main source of primary energy used in households, will stabilize in absolute terms. Demand for electricity will increase in the forthcoming years biomass would remain as principal source of energy particularly in the rural areas. It would be appropriate to utilize the huge agro-biomass resources that are surplus to farm needs to produce electricity, and by this means to reduce inefficient biomass utilization.

Constraints in the supply of molasses have severely impacted bio-ethanol production; and even reaching a target of 5 per cent blending in a few select states is proving to be a challenge. Dependence on molasses is a constraint for ethanol production in India. Unless

feedstock diversification is carried out, there are limited opportunities to achieve a quantum leap in ethanol production.

The long-term production potential of biodiesel is constrained by the limited availability of cultivable wasteland that could be brought under biodiesel plantations. In the near future, the overall contribution of biofuels to fuel demand is expected to remain small. Even if the *Jatropha* plantations on 400,000 ha of wasteland are taken up by 2007, at the current yield levels, the biodiesel contribution is expected to reach only a meager 0.5 per cent of the total diesel requirement in 2012. The projections of biodiesel plantations are mere indicative of government's preference. Several plantation ventures have been stalled midway. NOVOD Board has undertaken plantation in 8000Ha area by 2009-10 but discontinued thereafter to focus more on research and development of biodiesel crops, mainly *Jatropha* and *Pongamia.* Farm advocacy group of Reliance Industries overseeing *Jatropha* plantation has terminated the plantation operation citing poor performance. Obtaining quality planting material and standardized nursery raising technique is still a looming gap that is yet to be filled in.

The chance of significant improvement in bioethanol and biodiesel production is remote. Despite diverse options for promotion of tree species producing oil, the availability of land for large-scale plantation is still uncertain. The slim margin of financial gain in biofuel crop plantation restrains farmers from taking initiatives. The low productivity (1–2 tonnes/ha) of biofuel crops contributes to this concern. A synergy between technological innovation (to produce quality planting material) and biotechnological innovations (to increase the seed yield) is essential.

In the Indian context, biofuels cannot be considered only in the context of transport fuels. Perhaps a far more important application of biofuels could be in electricity generation and providing motive power for rural communities not having access to, or facing severe shortages of, modern forms of energy. Biofuels need to be considered as potential tools to bring about rural development.

India possesses ideal natural and cultural resources upon which a thriving bioenergy sector can be built. India has abundant capacity to produce reliable, price competitive and ecologically sustainable bioenergy to meet the energy demand of domestic and commercial sector. Developing a fraction of India's natural resource potential would ensure energy independence to millions of energy poor across the country.

Endnotes

1 The major components of the non-fossil fuel are: nuclear (1.18 per cent) and renewable total (33.52 per cent). The later consists of hydro- (1.73 per cent); biomass- (31.76 per cent); wind- (0.03 per cent); solar- and bio-fuel (negligible).** HDI 2007, # renewable source (1.7) + biomass and waste (29.4)+ nuclear (0.8).

2. Growing stock is the sum total (by number or volume) of all the trees growing in a forest or a stand. It is a useful measure of productive capacity.

3. TOF includes all the trees excluded from forest. Trees in agroforestry systems, orchards and small wood lots belong to TOF. They may grow in meadows, pastoral areas, on farms, along rivers, canals and roadsides, or in towns, gardens and parks.

4. The mean annual increment is the total growth of trees in a stand up to a given age divided by that age. It is often expressed in annual cubic meters of growth per hectare. The mean annual increment changes with different phases in a tree's life. It is highest during the middle years and slowly decreases with age. The point at which the mean annual increment peaks is commonly used to identify the biological maturity of the stand and its readiness for harvesting.

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Annexure-1

Crop	Area (MHa)	Biomass Surplus (MT/year)	Power Potential (MWe)
Paddy	122.6	37.1	4352.0
Cotton	24.1	25.1	3515.8
Wheat	43.8	23.9	3190.5
Coconut	5.4	6.0	833.2
Maize	12.5	6.0	800.6
Banana	0.11	4.1	541.8
Sorghum	27.8	4.0	529.5
Soyabean	6.0	3.2	423.4
Pearl Millet	244.9	3.1	402.0
Mustard	3.9	2.9 ,	388.2
Ground nut	13.0	2.7,	345.5
Tapioca	0.2	2.3	309.1
Rubber	1.0	1.8	251
Sugarcane	2.7	1.5	212.5
Black pepper	0.2	1.4	182.2
Coffee	0.7	1.1	156.2
Pigeon Pea	5.5	1.0	127.8
Gram	5.9	0.9	119.7
Castor seed	1.0	0.7	96.5
Sesame	1.2	0.64	83.6
Tea	0.6	0.6	81.5
Safflower	0.3	0.4	48.9
Green gram	2.6	0.3	42.3
Arecanut	0.5	0.3	46.3
Black Gram	2.9	0.3	35.2
Finger Millet	1.4	0.2	23.6
Casuarina	0.02	0.1 8	24.9
Potato	0.23	0.17	23.0
Cluster Bean	0.26	0.16	22.7
Eucalyptus	0.016	0.13	19.1
Sun flower	1.3	0.12	16.2
Pulses	1.87	0.11	14.9
Oilseeds	0.34	0.096	11.5

Countrywide biomass generation from crop residues and corresponding power potential for the year 2004.

Source: Indian Institute of Science, Bangalore. 2005

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MSSRF

The Mission of the foundation is use of Science for Fostering Sustainable Human Livelihood and the Conservation of Nature. The foundation works with rural and tribal communities and is in close collaboration with Government Departments, NGOs, Academic and Research Institutions and Civil Societies. The underlying focus of the Foundation's activities is to promote pro-nature, pro-poor, pro-women and pro-livelihood enhancement opportunities for the farming communities. The Foundation is known for its emphasis on bottom-up participatory approach, which places people before technology. Expertise includes:

- Coastal Systems Research Biotechnology and Biodiversity Ecotechnology Promotion and Biovillages - Biogas, biofuel and solar energy at community-level Reaching the Unreached, Information, Education and communication ICT-based knowledge dissemination through village knowledge centre Vulnerability. Assessment and Enhancing Adaptive Capacity to Climate Change in Semi-Arid regions of India (Swiss-funded).
- Identification and evaluation of suitable Jatropha germplasm and development of transgenic varieties for biofuel plantations.
- Policy Research and Advocacy.

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