Biomass & its processing techniques in India

Dipanshu Chinwan[#1], Anandini Arora[#2], Rohit Singh[#3], Vaibhav Garg[#4]

[#]*Student, Dept. of Agricultural Engineering, G.B.Pant University of Agri. & Tech.*
42 Vijay colony, New cantt. road Dehradun. India

***Abstract*—** This review is intended, to largely concentrate on and give an overview of the biomass that is available in the various regions of India and the appropriate techniques that are associated with the processing of the biomass collected.

Biomass is highly diverse in nature and classified on the basis of site of origin, the different types of biomass are Field and plantation biomass (Cobs, stalks, Straw, Cane trashes, etc), Industrial biomass (Agro-industrial processed biomass and their wastes, Husk, Oilcake),Forest biomass (Timber, Log residues, Forest floor debris, Animal carcass),Urban waste biomass (Municipal solid wastes, Sewage sludge, Kitchen and canteen wastes), Aquatic biomass (Microalgae blooms, Sea weeds (E.g. Kelp), Fresh water weeds (E.g. Water Hyacinth), Dead fishes).

Biomass is a complex class of feed stocks with significant energy potential to apply different technologies for energy recovery. Typically technologies for biomass energy are broadly classified on the basis of principles of thermo chemistry as combustion, gasification, pyrolysis and biochemistry as anaerobic digestion, fermentation and trans-esterification. Each technology has its uniqueness to produce a major calorific end product and a mixture of by-products.

Since conventional form of energy is limited, the only alternative lie in the potential of renewable energy to supplant it as a major energy provider and India has a vast scope in this area to develop and prosper.

***Keywords*—** Biofuel, Biomass, biomass energy

I. INTRODUCTION

With serious concern globally and in India on the use of fossil fuels, it is important for India to start using renewable energy sources. India is the 7th largest country in the world spanning 328 million hectares and amply bestowed with renewable sources of energy. Among the renewable energy sources, biomass plays a vital role especially in rural areas, as it constitutes the major energy source to majority of households in India. Biomass energy is the utilization of organic matter present and can be utilized for various applications.

- Biomass can be used to produce heat and electricity, or used in combined heat and power (CHP) plants.
- Biomass can also be used in combination with fossil fuels (co-firing) to improve efficiency and reduce the build up of combustion residues.
- Biomass can also replace petroleum as a source for transportation fuels.

While petroleum products currently supply much of this demand, the increasing difficulty of sustained supply and the associated problems of pollution and global warming are acting as a major impetus for research into alternative renewable energy technologies. Fuel cells offer a possible (and partial) solution to this problem, with the fuel needed for conventional cells usually being either hydrogen or methanol, although some cells have been developed which run on other fuels such as hydrocarbons (de Bruijn, 2005; Bagotzky et al., 2003).

II. BIOMASS ENERGY

A. *Introduction*

Biomass generally refers to the renewable organic matter generated by plants through photosynthesis, wherein solar energy combines with CO2 and moisture to form carbohydrates and oxygen. Materials having combustible organic matter are referred to as biomass. Biomass contains C, H and O which are oxygenated hydrocarbons. It generally contains a high level of moisture and volatile matter but has a low bulk density and calorific value. Coal is the end product of a sequence of biological and geological processes that biomass undergoes.

B. *Biomass energy*

Biomass energy is the utilization of energy stored in organic matter. It is humanity's oldest external source of energy, dating back to prehistoric man's first use of fire. And biomass is still an important part of the world's energy system; the use of traditional biomass—charcoal, firewood, and animal dung—in developing countries accounts for almost 10% of the world's primary energy supply.

Bio energy can be utilized in varied applications:

Biomass can be combusted to produce heat (large plants or localized biomass boilers), electricity, or used in combined heat and power (CHP) plants.

- Biomass can also be used in combination with fossil fuels (co-firing) to improve efficiency and reduce the build up of combustion residues.
- Biomass has potential to replace petroleum as a source for transportation fuels.

Biomass is also used in conjunction with fossil fuels for electricity generation in "waste-to-energy" projects. These are niche applications, which depend on the biomass having no other commercial value and being in close proximity to the application.

C. *Waste to Energy*

Most wastes that are generated find their way into land and water bodies without proper treatment, causing severe water and air pollution. The problems caused by solid and liquid wastes can be significantly mitigated through the adoption of environment-friendly waste to energy technologies that will allow treatment and processing of wastes before their disposal. The environmental benefits of waste to energy, as an alternative to disposing of waste in landfills, are clear and compelling. Waste to energy generates clean, reliable energy from a renewable fuel source, thus reducing dependence on fossil fuels, the combustion of which is a major contributor to GHG emissions. These measures would reduce the quantity of wastes, generate a substantial quantity of energy from them, and greatly reduce pollution of water and air, thereby offering a number of social and economic benefits that cannot easily be quantified. In addition to energy generation, waste-to-energy can fetch significant monetary benefits. Some of the strategic and financial benefits from waste-to-energy business are:

1) Profitability - If the right technology is employed with optimal processes and all components of waste are used to derive value, waste to energy could be a profitable business. When government incentives are factored in, the attractiveness of the business increases further.

2) Government Incentives - The government of India already provides significant incentives for waste to energy projects, in the form of capital subsidies and feed in tariffs. With concerns on climate change, waste management and sanitation on the increase (a result of this increasing concern is the newly formed ministry exclusively for Drinking Water and Sanitation), the government incentives for this sector is only set to increase in future.

3). Related Opportunities - Success in municipal solid waste management could lead to opportunities in other waste such as sewage waste, industrial waste and hazardous waste. Depending on the technology/route used for energy recovery, eco-friendly and “green” co-products such as charcoal, compost, nutrient rich digestate (a fertilizer) or bio-oil can be obtained. These co-product opportunities will enable the enterprise to expand into these related products, demand for which are increasing all the time.

4) Emerging Opportunities - With distributed waste management and waste to energy becoming important priorities, opportunities exist for companies to provide support services like turnkey solutions. In addition, waste to energy opportunities exist not just in India but all over the world. Thus, there could be significant international expansion possibilities for Indian companies, especially expansion into other Asian countries

According to MNRE estimates, there exists a potential of about 1460 MW from MSW and 226 MW from sewage

TABLE I.
INDIA-POTENTIAL OF ENERGY RECOVERY FROM URBAN AND INDUSTRIAL WASTES

.State/Union Territory	From Liquid Wastes* (MW)	From Solid Wastes (MW)	Total (MW)
Andhra Pradesh	16.0	107.0	123.0
Assam	2.0	6.0	8.0
Bihar	6.0	67.0	73.0
Chandigarh	1.0	5.0	6.0
Chhattisgarh	2.0	22.0	24.0
Delhi	20.0	111.0	131.0
Gujarat	14.0	98.0	112.0
Haryana	6.0	18.0	24.0
Himachal Pradesh	0.5	1.0	1.5
Jharkhand	2.0	8.0	10.0
Karnataka	26.0	125.0	151.0
Kerala	4.0	32.0	36.0
Madhya Pradesh	10.0	68.0	78.0
Maharashtra	37.0	250.0	287.0
Manipur	0.5	1.5	2.0
Meghalaya	0.5	1.5	2.0
Mizoram	0.5	1.0	1.5
Orissa	3.0	19.0	22.0
Pondicherry	0.5	2.0	2.5
Punjab	6.0	39.0	45.0
Rajasthan	9.0	53.0	62.0
Tamil Nadu	14.0	137.0	151.0
Tripura	0.5	1.0	1.5
Uttar Pradesh	22.0	154.0	176.0
Uttarakhand	1.0	4.0	5.0
West Bengal	22.0	126.0	148.0
Total	226.0	1457.0	1683.0

*Liquid wastes in this case refers to total sewage sludge viz., sewage sludge generated at STPs and untreated sewage.

According to the Ministry of New and Renewable Energy, there is a potential to recover 1,300 MW of power from industrial wastes, which is projected to increase to 2,000 megawatt by 2017. Projects of over 135 megawatt have been installed so far in distilleries, pulp and paper mills, and food processing and starch industries. (2011). From the above section one can infer that there exists an estimated potential of about 225 MW from all sewage (taking the conservative estimate from MNRE) and about 1460 MW of power from the MSW generated in India, thus a total of close to 1700 MW of power. Of this, only about 24 MW have been exploited, according to MNRE. Thus, less than 1.5% of the total potential has been achieved

TABLE II.
CURRENT WASTE-TO-ENERGY INSTALLED CAPACITY

GRID-INTERACTIVE POWER		(CAPACITIES IN MW)	Contribution (%)
Waste to Power			
	Urban	20.20	27.4
	Industrial	53.46	72.6
	Total	73.66	
OFF-GRID/ CAPTIVE POWER		(CAPACITIES IN MWEq*)	Contribution (%)
Waste to Energy			
	Urban	3.50	4.6
	Industrial	72.30	95.4
	Total	75.8	

*MWEq: Megawatt Equivalent;
Source: MNRE, 2011

C. *Types of Biomass*

Biomass is highly diverse in nature and classified on the basis of site of origin, as follows:

TABLE III.
SOURCES OF BIOMASS

Field and plantation biomass	**Industrial biomass**	**Forest biomass**	**Urban waste biomass**	**Aquatic biomass**
Agricultural crop residues- Cobs, stalks, Straw, Cane thrashes and etc **Edible matters from crops-** Environmentally spoiled grains, pulses, fruits, nuts, spices, seeds and lint etc **Dedicated energy crops-** Bamboo, Prosopis, Casuarinas, Willow and poplar etc **Plantation debris-** Leaves, stubbles, barks and trunks etc	Agro-industrial processed biomass and their wastes – Husk Oil cake Sugar bagasses Sugar molasses Whey Hides and skin wastes Fruit and pulp debris Saw dust Wood pulp and paper shavings Fermented microbial mass etc	Timber Log residues Forest floor debris Animal carcass	Municipal solid wastes Sewage sludge Kitchen and canteen wastes	Microalgae blooms Sea weeds (E.g. Kelp) Fresh water weeds (E.g Water Hyacinth) Dead fishes
Livestock wastes from fields, slaughter houses and animal husbandries etc				

TABLE IV.
RENEWABLE BIO-FEEDSTOCK IN INDIA AND THEIR AVAILIBILITY FOR HEAT AND POWER GENERATION[a]

Crop	Residue	Biomass Produced (kT/Yr)	Power potential (MW)	Calorific potential (Mcal/sec)
Arecanut	Fronds	788.5	94	22.4
Arecanut	Husk	212.3	25	5.9
Arhar	Stalks	5120.2	609	145.4
Arhar	Husk	614.4	73	17.4
Bajra	Stalks	12039.4	1433	342.2
Bajra	Cobs	1986.5	236	56.3
Bajra	Husk	1805.9	215	51.3
Banana	Residue	11936.5	1421	339.4
Barley	Stalks	563.2	67	16
Barseem	Stalks	71.6	8	1.9
Black pepper	Stalks	29.1	3.5	0.8
Cardamom	Stalks	43.6	5	1.1
Cashew nut	Stalks	148.2	18	4.2
Cashew nut	Shell	41.2	4.5	1.0
Castor seed	Stalks	1657.2	197	47
Castor seed	Husk	41.4	5	1.1
Casuarina	Wood	211.8	25	5.9
Coconut	Fronds	7278.9	866	206.8
Coconut	Husk & pith	3184.7	379	90.5
Coconut	Shell	1321.9	157	374.9
Coffee	Pruning & wastes	1457.6	173	41.3
Coffee	Husk	133.4	16	3.8
Coriander	Stalks	188.3	22	5.2
Cotton	Stalk	31358.3	3733	891.6
Cotton	Husk	10789.1	1284	306.6
Cotton	Bollshell	10789.1	1284	30.6.6
Cow gram	Stalks	48.5	5.7	1.3
Cumin seed	Stalks	182.6	21.7	5.182
Dry chilly	Stalks	268.6	32	7.6
Castor seed	Husk	41.4	5	1.1
Groundnut	Shell	13148.2	1565	373.8
Groundnut	Stalks	1972.2	235	56.1
Guar	Stalks	233.3	28	6.7
Horse gram	Stalks	191.3	23	5.5
Jowar	Cobs	5043.5	600	143.3
Jowar	Stalks	17147.8	2041	487.4
Jowar	Husk	2017.4	240	57.3
Kesar	Stalks	9.4	1	0.23
Kodo millets	Stalks	3.13	0.4	0.95
Linseed	Stalks	86.3	10	2.3
Maize	Stalks	23421.3	2788	665.9
Maize	Cobs	3536.4	421	100.5
Masoor	Stalks	600.3	71.4	17.053
Meshta	Stalks	1605.4	191	456.1
Meshta	Leaves	40.1	5	1.1
Moong	Stalks	671	80	19.1
Moong	Husk	91.5	11	2.6
Moth	Stalks	17.8	2	0.47
Mustard	Stalks	6999	833	198.9
Mustard	Husk	1658.1	197	47.0
Niger seed	Stalks	94	11	2.6
Others	Others	0.34	0.04	0.009
Paddy	Straw	149646.9	17815	4255

Paddy	Husk	19995.9	2380	568.4
Paddy	Stalks	322.3	38	9.0
Peas & beans	Stalks	27.4	3.2	0.764
Potato	Leaves	832.5	99	23.6
Potato	Stalks	54.8	6.5	1.5
Pulses	Stalks	1390.4	165	39.4
Ragi	Straw	2630.2	313	74.7
Rubber	Primary wood	1495.3	178	42.5
Rubber	Secondary wood	996.9	118	28.1
Safflower	Stalks	539.3	64	15.2
Sunnhemp	Stalks	14.1	1.6	0.382
Sawan	Stalks	0.22	0.02	0.004
Small millets	Stalks	600.1	71.4	17
Soyabean	Stalks	9940.2	1183	282.5
Sugarcane	Tops & leaves	12143.9	1445	345.1
Sunflower	Stalks	1407.6	167	39.8
Sweet potato	Stalks	12.8	1.5	0.358
Tapioca	Stalks	3959	471	112.4
Tea	Sticks	909.8	108	25.7
Til	Stalks	1207.7	144	34.3
Tobacco	Stalks	204.8	24.3	5.8
Turmeric	Stalks	32.3	4	0.955
Urad	Stalks	782.6	93	22.2
Total -511041.39				

[a] Estimations are approximated for a unit megawatt (MW) power plant

TABLE V.
POTENTIAL OF VARIOUS CELLULOSIC FEED STOCKS IN INDIA FOR ETHANOL PRODUCTION

S.No	Agro-feedstock	Ethanol yield (L/Kg)	Biomass surplus availability (kT/Yr)	Projected yield of ethanol (Million litres)
1	Barley stalk	0.31	563	174.5
2	Corn stalk	0.29	23421	6792
3	Rice straw	0.28	149646	41900.8
4	Sorghum stalk	0.27	17147	4629.6
5	Wheat straw	0.29	105000	30450
6	Sugarcane bagasse	0.28	162000	45360

TABLE VI
POTENTIAL OF DIFFERENT OILSEEDS AND TRESS OF INDIA FOR BIODIESEL PRODUCTION[b]

S.No	Oilseed crop	Average oil yield (kg/ha)	Biodiesel potential (kg)
1	Castor	1045	940.5
2	Groundnut	921	829.3
3	Mustard	409.5	368
4	Sunflower	530	477
5	Safflower	408	367.2
6	Rapeseed	394.5	355
7	Soybean	307	276.3
8	Linseed	725	652.5
9	Niger	122	109.8
10	Sesame	566	509.4
11	Cotton	190	171
12	Jatropha	1200	1080
Potential of Tree Borne Oil seeds in India			
	Tree	Total oil potential (tonnes)	Projected biodiesel volume (tonnes)
13	Sal (*Shorea robusta*)	744000	669600
14	Mahua (*Madhuca indica*)	182000	163800
15	Neem (*Azadirachta indica*)	100000	90000
16	Rubber (*Hevea braziliensis*)	35000	31500
1	Karanja (*Pongamia pinnata*)	30,000	27000
18	Kusum (*Schleichera oleosa*)	15000	13500
19	Khakan (*Salvadora oleoides*)	14000	12600
20	Undi (*Calophyllum inophyllum*)	7000	6300
21	Dhupa (*Vateria indica*)	2000	1800

[b] Estimations are made on theoretical conversion of vegetable oils to methyl fatty esters (Biodiesel) at 90% efficiency. In case of oilseeds from trees, oil is assumed to be used only for biodiesel production.

III. BIOMASS TO ENERGY PATHWAYS

Biomass is a complex class of feed stocks with significant energy potential to apply different technologies for energy recovery. Typically technologies for biomass energy are broadly classified

on the basis of principles of thermo chemistry as combustion, gasification, pyrolysis and biochemistry as anaerobic digestion, fermentation and trans-esterification. Each technology has its uniqueness to produce a major calorific end product and a mixture of by-products. Choice of a processing method often depends on nature and origin of feed stocks, their physio-chemical state and application spectrum of fuel products derived from it.
The flow chart below comprehensively highlights the major biomass conversion technologies, their range of compatible feed stocks and major fuel products for power, heat and transport utilizations.

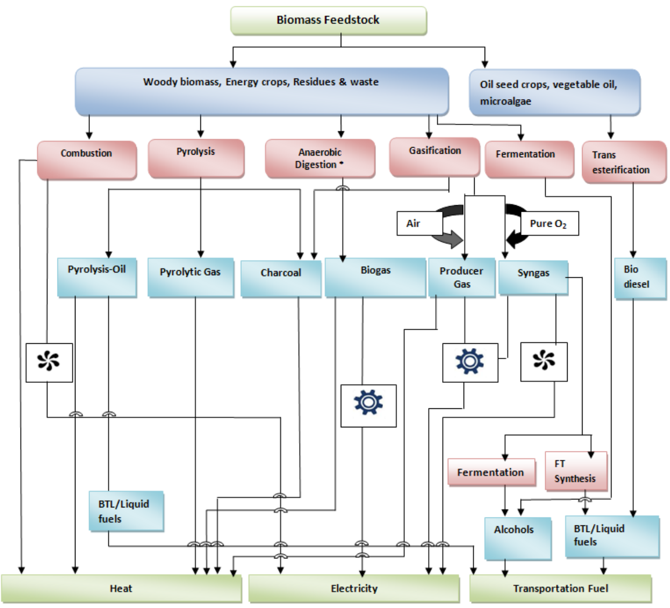

Fig. 1 Major biomass conversion technologies

* Anaerobic digestion (AD) also results in a nutrient-rich digestate as a co-product. This, however, cannot be used as an energy source, and hence is not included here.  Turbine,  Gas Engine

A. Process Description

A brief description of the technologies for energy generation from biomass is as follows:

1) Combustion: In this process, biomass is directly burned in presence of excess air (oxygen) at high temperatures (about 800°C), liberating heat energy, inert gases, and ash. Combustion results in transfer of 65%–80% of heat content of the organic matter to hot air, steam, and hot water. The steam generated, in turn, can be used in steam turbines to generate power.

2) Transesterification: The traditional method to produce biodiesel from biomass is through a chemical reaction called transesterification. Under this method, oil is extracted from the biomass and it is processed using the transesterification reaction to give biodiesel as the end-product.

3) Alcoholic Fermentation: The process of conversion of biomass to biofuels involves three basic steps. Converting biomass to sugar or other fermentation feedstock. Fermenting these biomass-derived feed stocks using microorganisms for fermentation. Processing the fermentation product to produce fuel-grade ethanol and other fuels.

4) Anaerobic Digestion: In the absence of air, organic matter such as animal manures, organic wastes and green energy crops (e.g. grass) can be converted by bacteria-induced fermentation into biogas (a 40%-75% methane-rich gas with CO2 and a small amount of hydrogen sulphide and ammonia). The biogas can be used either for cooking/heating applications, or for generating motive power or electricity through dual-fuel or gas engines, low-pressure gas turbines, or steam turbines.

5) Pyrolysis: Pyrolysis is a process of chemical decomposition of organic matter brought about by heat. In this process, the organic material is heated in absence of air until the molecules thermally break down to become a gas comprising smaller molecules (known collectively as syngas). The two main methods of pyrolysis are “fast” pyrolysis and “slow” pyrolysis. Fast pyrolysis yields 60% bio-oil, 20% biochar, and 20% syngas, and can be done in seconds. Slow pyrolysis can be optimized to produce substantially more char (~50%) along with organic gases, but takes on the order of hours to complete.

6) Gasification: In this process, biomass reacts with air under extreme temperatures and results in production of producer gas, to produce power (or) react with pure oxygen to produce synthesis gas for fuel production. The combustible gas, known as producer gas, has a calorific value of 4.5 - 5.0 MJ/cubic meter. A wide range of biomass in the form of wood or agro residue can be used for gasification.

TABLE VII
SUMMARY OF BIOENERGY PROCESSES, FEEDSTOCKS AND PRODUCTS

Process	Biomass feedstock	Products	Features/ Highlights
Thermal Conversion			
Combustion	*Diverse biomass*	*Heat and power*	• Combustion can be applied for biomass feedstocks with moisture contents up to atleast 60 percent • Combustion is ideally suited for power segments which works well beyond 5 MW • Combustion is a established technology working on the regular rankine cycle • Combustion comprises over 85% of installed capacity for biomass based power production in India (excluding biomass cogeneration) • The process works well for most types of biomass
Thermo-chemical Conversion			
Gasification	Diverse biomass	Low or medium-Btu producer gas	• Gasification systems are well-suited for small-scale applications. The process can work at low scales – as low as 20 kW, and works well up to 2 MW. • Currently, less than 125 MW of cumulative installed capacity in India (less than 15% of total biomass power capacity, excluding biomass cogeneration). • Gasification can produce a high purity syngas for catalytic conversion processes for the production of liquid biofuels. This process is currently in pilot phase.
Pyrolysis	Wood, Agricultural Waste Municipal Solid Waste	Synthetic Fuel Oil (Biocrude), Charcoal	• Pyrolysis is not well established currently in India or elsewhere in the world. • Pyrolysis is a simple, low-cost technology capable of processing a wide variety of feedstocks • Typically pyrolysis plants work well beyond 2 MW scale.
Biochemical Conversion			
Anaerobic Digestion	Agricultural Waste, Municipal Solid and Liquid Wastes, Landfills and Animal Manure	Biogas	• Anaerobic digestion is a commercially proven technology and is widely used for recycling and treating wet organic waste and waste waters • Anaerobic digesters of various types were widely distributed throughout India and China. • Anaerobic digestion is increasingly used in small size, rural and off-grid applications at the domestic and farm-scale. • Small scale biogas for household use is a simple, low-cost, low-maintenance technology, which has been used for decades.
Alcohol fermentation	Agricultural Waste, Sugar Or Starch Crops, Wood Waste, Pulp Sludge and Grass Straw etc	Ethanol	• Sugar molasses is extensively used as a feedstock for alcoholic fermentation • Recent advances in the use of lignocellulosic biomass as a feedstock may allow bioethanol to be made competitively from woody agricultural residues and trees.
Chemical Conversion			
Pressing /extraction Transesterification	Oils from plant seeds and nuts etc, Fats from animal tissues	Biodiesel	• Transesterification is a fairly simple and well-understood route to produce biodiesel from biomass. • Glycerol, a by-product obtained from the process is difficult to be removed. Meanwhile it can be used as fuel in stationary applications, or can be converted into other high-value products • Jatropha is used as a source for biodiesel production in India. Food crops such as soybean are also used as sources in some countries.

IV. CONCLUSIONS

Drawbacks:

A. *Biomass to Power/Heat*

One of the most critical bottlenecks for biomass plants (based on any technology) is the supply chain bottlenecks that could result in non-availability of feedstock. A related problem is the volatility, or more precisely increase, in the feedstock price. Both these could render the project unviable.

B. *Biomass to Transportation fuels*

Biodiesel: One of the main problems in getting the biodiesel programme rolling is the difficulty linked to initiating large-scale cultivation of Jatropha.

Bio ethanol: The overwhelmingly dominant factor in the production of ethanol in India is the price and availability of molasses. The Central government sets the policy regarding ethanol blending, but the State governments control the movement of molasses and often restrict molasses transport over State boundaries. State governments also impose excise taxes on potable alcohol sales, a lucrative source of revenue.

Potential

India produces about 450-500 million tonnes of biomass per year. Biomass provides 32% of all the primary energy use in the country at present. EAI estimates that the potential in the short term for power from biomass in India varies from about 18,000 MW, when the scope of biomass is as traditionally defined, to a high of about 50,000 MW if one were to expand the scope of definition of biomass. The current share of biofuels in total fuel consumption is extremely low and is confined mainly to 5% blending of ethanol in gasoline, which the government has made mandatory in 10 states. Currently, biodiesel is not sold on the Indian fuel market, but the government plans to meet 20% of the country's diesel requirements by 2020 using biodiesel.

Plants like Jatropha curcas, Neem, Mahua and other wild plants are identified as the potential sources for biodiesel production in India. There are about 63 million ha waste land in the country, out of which about 40 million ha area can be developed by undertaking plantations of Jatropha. India uses several incentive schemes to induce villagers to rehabilitate waste lands through the cultivation of Jatropha. The Indian government is targeting a Jatropha plantation area of 11.2 million ha by 2012.

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