Biomass Based Power

Introduction

Electricity has today become a basic necessity for not just the developed world, but also for the developing and underdeveloped countries. Diminishing supply and environmental concerns have been brought to light in recent years, exposing fossil fuels, currently the world's primary source of energy, as unsustainable and potentially harmful to the environment. Because of this, clean renewable energy sources are controlling more of the available market and biomass is one of the leading options on this front.

Biomass has been used as a source of energy right since mankind started its existence. In fact, one of the predominant energy sources today is biomass. Biomass has been used, in the place of coal, for steam generation at power plants, though in a limited way. Biomass based power generation holds immense potential and this white paper intends to unveil the basic strategies and technologies that are in need while commissioning a biomass based power plant.

Biomass based power scenario in India

The contribution of bioenergy to the total primary energy consumption in India is over 27%. This is indeed the case for many other countries, because biomass is used in a significant way in rural areas in many countries. However, the contribution of biomass to power production is much smaller than this percentage – currently, biomass comprises only about 2650 MW of installed capacity, out of a total of 172000 MW of total electricity installed capacity in the country.

Current Level of Biomass Power Production in India

No	Sources/Systems	Achievements during 2010-2011 (upto 20.06.2010)	Achievements (upto 30.06.2010) Cumulative
Grid Connected			
1	Biomass Power (Agro residues)	45.50 MW	901.10 MW
2	Cogeneration-baggase	67.50 MW	1411.53 MW
Off-Grid			
1	Biomass Power/Cogen (non- baggase)	6.00 MW	238.17 MW
2	Biomass Gasifier	4.00 MWeq	125.44 MWeq
Remote Village Electrification		208 villages and hamlets	6867 villages and hamlets
Family Type Biogas Plants		0.07 lakhs	42.60 lakhs

Source: EAI Biomass gasification report

Potential for Biomass Power in India

Provided here are data and projections for the potential for biomass based power production in India. We have provided two different estimates, each under a different set of assumptions.

The first estimate has been done by EAI team for a wider scope of biomass. It should be noted that in most cases, waste from municipal solid waste (MSW) and sewage waste (MLW) are not taken into account while estimating biomass power.

Biomass Type	Potential (MWe)	Percentage
Agro Potential	18728	54
Livestock	9332	27
Fruits	660	2
Vegetables	1220	3
Industrial Wastes	1470	4
Subtotal	31410	90

Estimate 1 - Current Biomass Potential in India, excluding MSW and MLW (2010)

The second estimate has been estimated based on the total amount of agro biomass surplus available in various states of India. The scope considered for this estimate is the more traditionally accepted one in the context of biomass power production.

This scope also includes dedicated energy crops, grown for power production. While there is a trend in India towards growing dedicated energy crops for biomass power, currently this segment contributes negligible amounts to power production.

State	Area (KHa)	Productivity (millionT/yr)	Biomass Generation (million T/yr)	Biomass Surplus (million T/yr)	Power (MW)
Rajasthan	12,537.50	93.65	204.89	35.33	
Punjab	6,693.50	27.81	46.34	21.27	
Uttar Pradesh	15,278.00	51.34	36.80	11.80	
Harayana	12,628.20	46.80	50.42	11.73	
Maharashtra					

Estimate 2 – *Estimate Based on Total Amount of Surplus Agro Biomass Available*

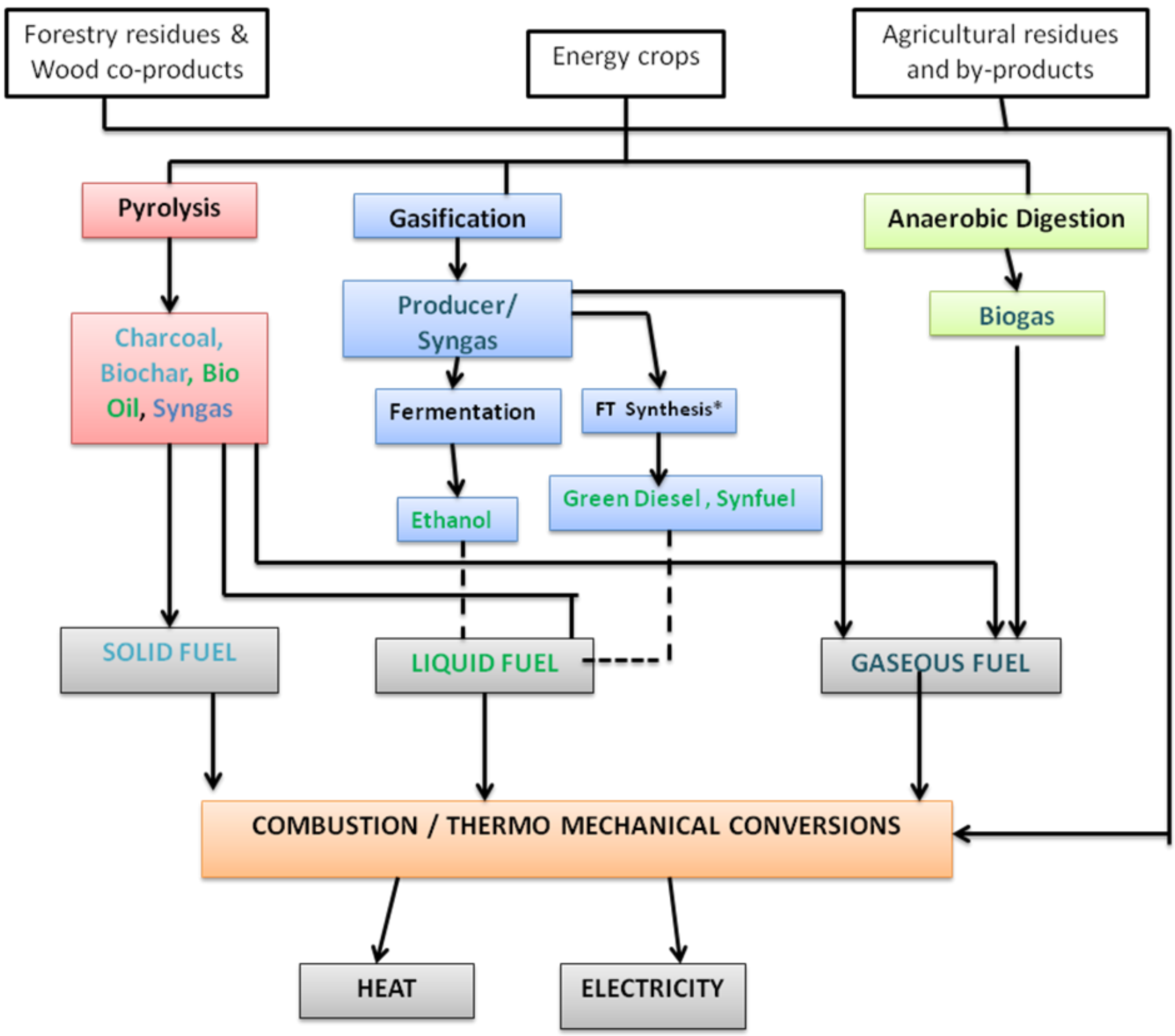
Rajasthan, Punjab, Maharashtra, Uttar Pradesh and Haryana are states with high biomass potential. Together, they comprise close to 50% of the total estimated potential for biomass in India.

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.

Biomass Power Production-Various Technologies and Pathways

Biomass is renewable energy derived from living organic material, or material that was recently alive. Wood pellets, corn husks, refuse, black liquor (a waste product of the paper making industry), and alcohol fuels are common examples of materials that classified as biomass.

There are multiple ways to produce power from biomass. This section provides detailed inputs on the various routes for power production from biomass.



*FT Synthesis: Fischer Tropch Synthesis

The Primary routes for biomass based power production are:

1. Combustion
2. Gasification
3. Anaerobic digestion
4. Pyrolysis

Combustion

Combustion is easy to understand – instead of using coal or other fossil fuel, use biomass to produce steam that runs a turbine. Combustion of biomass for power could either be in the form of co-firing (when it is burned along with coal) or pure play biomass based combustion.

Highlights of Combustion based power production

- ✓ Typically works well beyond 5 MW
- ✓ Well established technology works on the regular rankine cycle
- ✓ Comprises over 85% of installed capacity for biomass based power production in India (excluding biomass cogeneration)
- ✓ Works well for most types of biomass

Gasification

Biomass gasification refers to the incomplete combustion of biomass resulting in production of combustible gases consisting of Carbon monoxide (CO), Hydrogen (H_2) and traces of Methane (CH_4). This mixture is called producer gas. Producer gas can be used to run internal combustion engines (both compression and spark ignition) for power production, or can be used as substitute for furnace oil in direct heat applications.

Highlights of biomass gasification based power production

- ✓ Can work at low scales – as low as 20 kW, and works well up to 2 MW, with current technology.
- ✓ Technology uses a combination of gasifier and gas engines. The technology has been in vogue for decades, but is still evolving.
- ✓ Currently, less than 125 MW of cumulative installed capacity in India (less than 15% of total biomass power capacity, excluding biomass cogeneration).
- ✓ Works best for woody biomass, but latest gasifiers also work reasonably well with non-woody (including fine biomass)

Gasification vs. Combustion

The two major technologies used for agri/crop waste based power generation are combustion and gasification. In India, combustion technology is used predominantly for agri/crop waste based biomass power production (85%), with gasification accounting only for about 15% of biomass-based power. We hence provide a more specific comparison between these two technology routes.

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Comparative evaluation of Gasification and Combustion

Parameters	Combustion	Gasification
Chemical Process	Full Oxidation	Partial Oxidation
Chemical Environment	Excess oxygen (air) oxidizing	Oxygen-starved - reducing
Primary Product	Heat(e.g.Steam)	Producer gas(CO & H2)
Downstream Products	Electric power	Electric power, pure H2, liquid fuels, chemicals
Current application	Dominates coal-fired power generation worldwide	Mostly for power generation and thermal applications
Efficiency	35-37%(HHV)	39-42%(HHV)
Emissions	~NSPS	~1/10 NSPS
Capital cost	Rs 5 Crores / MW	Rs 5.5 Crores per MW
Maturity/Risk	High experience, low risk	Reliability needs improved

Anaerobic Digestion

Anaerobic digestion is usually applied to biomass that typically have a high amount of water in them (anaerobic digestion is most used for treating organic matter such as kitchen waste and sewage waste into energy). Under this route, microorganisms act upon the organic matter present in the biomass under anaerobic (absence of air) and convert it into biogas.

Highlights of Anaerobic Digestion

- ✓ Anaerobic digestion is increasingly used in small-size, rural and off-grid applications at the domestic and farm-scale. It has significant potential in India as well as worldwide.
- ✓ While a significant number of the existing anaerobic digestion plants are processing residual sludge from wastewater treatment plants, many other industries have potential for this.
- ✓ Most small-scale units such as tanneries, textile bleaching and dying, dairy, slaughterhouses cannot afford effluent treatment plants of their own because of economies of scale in pollution abatement. Generation of energy using anaerobic digestion process has proved to be economically attractive in many such cases.

Pyrolysis

An emerging route for biomass based power is **pyrolysis**. In this, the biomass is heated to 450 - 600 °C in absence of air, and depending on the speed at which the process is undertaken, results in a bio-oil called the pyrolysis oil that can in turn be used for firing the boilers (fast pyrolysis), or results in a mixture of char and organic gases (slow pyrolysis)

Highlights of Pyrolysis

- ✓ Pyrolysis as a method for power production is not well established currently in India or elsewhere in the world.
- ✓ Typically pyrolysis plants work well beyond 2 MW scale, while gasification plants work well until 2 MW scale, at the current technological progress. Thus, it can be said that pyrolysis takes off where gasification ends.
- ✓ Fast pyrolysis yields 60% bio-oil, 20% biochar, and 20% syngas, and can be done in seconds, whereas slow pyrolysis can be optimized to produce substantially more char (~50%) along

with organic gases, but takes on the order of hours to complete. In either case, the gas or oil can be used as a fuel for firing the boiler for steam production and subsequent power production

Examples of Feedstocks that can be used in Biomass based power production

Anaerobic Digestion	Biomass Combustion	Gasification	Pyrolysis
***Agricultural Origin*-** **Livestock manure, Agricultural residues, Animal mortalities, Energy crops** ***Municipal Origin*-Sewage sludge, Municipal solid waste, Food residuals** ***Industrial Origin*-** **Wastewater, Industrial sludges, Industrial by-products, Slaughterhouse waste, spent beverages**	**Rice husk (rice mills), Bagasse (sugar plants), Groundnut shells (oil mills), Jute waste (jute mills), Jute sticks, Wood from casuarinas trees, Cotton and red gram stalks, Woody biomass**	**Rice husk, Rice straw, Coconut shells, Cotton husk, Bamboo and Casuarina. All types of coal and petroleum coke (a low value byproduct of refining) and biomass, such as wood waste, agricultural waste, and household waste, Liquid refinery residuals (including asphalts, bitumen, and other oil sands residues) and liquid wastes from chemical plants and refineries.**	**Lignocellulosic biomass, any biomass or organic material such as alfalfa, corn stover, crop residues, debarking waste, forage grasses, forest residues, hulls , municipal solid waste, pomace, scrap and spoilage (fruit & vegetable processing), sawdust, spent grains, spent hops, spent yeast, switchgrass, waste wood chips**

Comparative Analysis of Biomass Power Generating Technologies

Parameter	Combustion	AD	Gasification	Pyrolysis
Resource	Mainly solid biomass	Wet biomass	Mainly solid biomass	Mainly solid Biomass
Example of Raw materials	Wood logs, chips, agricultural residues, energy crops	Manure, sewage sludge	Wood chips and pellets, agricultural residues	Wood chips and pellets, agricultural residues
Technology status	Commercial	Commercial	Commercial	Demonstration
Temperature (°C)	700–1400	Not applicable	500–1300	380–530
Pressure (MPa)	> 0.1		> 0.1	0.1–0.5
Drying	Not essential, but may help	Not essential	Necessary	Necessary
Advantages		Anaerobic digestion is a very effective method of treating high moisture content organic wastes, and many implementations of anaerobic digestion are driven by waste management needs, with biogas as a valuable by-product	• Advantages compared to combustion in terms of economies of scale, higher electrical efficiencies of up to 50% are possible. • Up to 25% efficiency in small scale applications (between few tens of KW up to 5 MW) This makes gasification especially for small scale application interesting, because there is no efficient technology for solid biomass for power production available	The main advantages compared to combustion or gasification is the fact that the main product is a liquid (especially for fast pyrolysis) with high energy content, easy to store and transport, and can be used for different uses

Bottlenecks and Barriers in Biomass based power production

One of the most critical bottlenecks for biomass power 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. There are other concerns and bottlenecks as well. These are presented in this table.

- ✓ *Absence of effective institutional and financing mechanisms*
- ✓ *Lack of adequate policy framework*
- ✓ *Non-uniform policies*
- ✓ *Lack of effective regulatory framework*
- ✓ *Lack of technical capacity*
- ✓ *Absence of effective information dissemination*
- ✓ *Limited successful commercial demonstration model experience*
- ✓ *High transactions cost –*
- ✓ *Limited interest in power projects*
- ✓ *High investment risks -*
- ✓ *Lack of working capital*

Summary

As fossil fuel supplies are depleted and in the wake of recent environment tragedies, the world's energy suppliers will continue to search for safe, renewable and inexpensive sources in order to meet demand. This has provided an opportunity for nontraditional resources, such as biomass materials, to grab the increasingly available market shares.

If biomass is to be used to support renewable electricity policies, several questions should be addressed. Different conversion technologies have different strengths and weaknesses and may support processes in different ways. It is thus important to understand which service within the electricity markets is bio-based electricity most suitable for, and what technology pathways are most appropriate to provide these services.