Biomass energy and its potential in India associated with its cost, production and utilization

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Dear Sirs:

Declaration by the Guide

This is to certify that the Mr. Avneesh Sharma a student of Power Management, Roll No: 500025130 of UPES have successfully completed this dissertation report on “Biomass energy and its potential in India associated with its cost, production, and utilization” under my supervision.

Further, I certify that the work is based on the investigation made, data collected, and analyzed by him and it has not been submitted in any other University or Institution for award of any degree. In my opinion it is fully adequate, in scope and utility, as a synopsis towards partial fulfilment for the award of degree of MBA.

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Table of Contents

List of Tables and illustrations

List of figures

Executive summary / Abstract

Renewable power generation can help countries meet their sustainable development goals through provision of access to clean, secure, reliable and affordable energy.

Renewable energy has gone mainstream, accounting for the majority of capacity additions in power generation today. Tens of gigawatts of wind, hydropower and solar photovoltaic capacity are installed worldwide every year in a renewable energy market that is worth more than a hundred billion USD annually. Other renewable power technology markets are also emerging.

Recent years have seen dramatic reductions in renewable energy technologies' costs as a result of R&D and accelerated deployment. Yet policy-makers are often not aware of the latest cost data.

This study has been carried out to provide valuable insights into the current state of deployment, types of technologies available and their costs and performance. The analysis is based on a range of data sources with the objective of developing a uniform dataset that supports comparison across technologies of different cost indicators – equipment, project and levelised cost of electricity – and allows for technology and cost trends, as well as their variability to be assessed.

This report is not a detailed financial analysis of project economics. However, they do provide simple, clear metrics based on up-to-date and reliable information which can be used to evaluate the costs and performance of different biomass power generation technologies.

This report helps to inform the current debate about renewable power generation and assist governments and key decision makers to make informed decisions on policy and investment, especially when the environment norms are becoming stringent day by day in India.

Therefore, I welcome your feedback on the data and analysis presented in this report.

1. INTRODUCTION

1.1. Overview

Electricity has today become a basic necessity for not just the developed world, but also for the developing and underdeveloped countries. At the same time, the feedstocks used for power generation have been primarily fossil fuel based and non-renewable in nature. Not only will these fuels be exhausted, but they also give rise to harmful pollution, especially in the form of greenhouse gases that lead to climate change and global warming.

With serious concern globally and in India on the use of fossil fuels, it is important for India to start using renewable energy sources. It is equally important for India to explore sources that can bring power in a distributed manner and on small scales so that over 60,000 villages that have no access to power can benefit from electricity. This is where biomass power, and especially biomass gasification based power, will come useful.

The average electricity consumption in India is still among the lowest in the world at just 630 kWh per person per year, but this is expected to grow to 1000 kWh in the near future. According to **Central Electricity Authority (CEA),** the peak electricity demand in 2008 was 120 GW of power, while only 98 GW could be supplied. According to an analysis by the Indian PV project developer Astonfield, this deficit is likely to grow to 25 GW by 2020. The Ministry of Power has set an agenda of providing “Power to All” by 2020.

1.2. Background

If solar energy is the ‘mother’ of all other forms of renewable energy, the primary source of food energy for all multi-cellular organisms is biomass.

Biomass is the general term which includes phytomass or plant biomass and zoomass or animal biomass. Sun's energy when intercepted by plants and converted by the process of photosynthesis into chemical energy, is ‘fixed’ or stored in the form of terrestrial and aquatic vegetation. The vegetation when grazed (used as food) by animals gets converted into zoomass (animal biomass) and excreta. In countries (for example China and India) where per capita energy consumption is low and the number of dairy animals large, even the excreta of dairy animals has the potential to provide a sizeable fraction of the total energy requirement. But, in general, animal biomass contributes very little to the overall biomass potential of the world. Therefore, subsequent discussion shall focus on phytomass and, as is popular convention, the term biomass shall be used to denote only the phytomass.

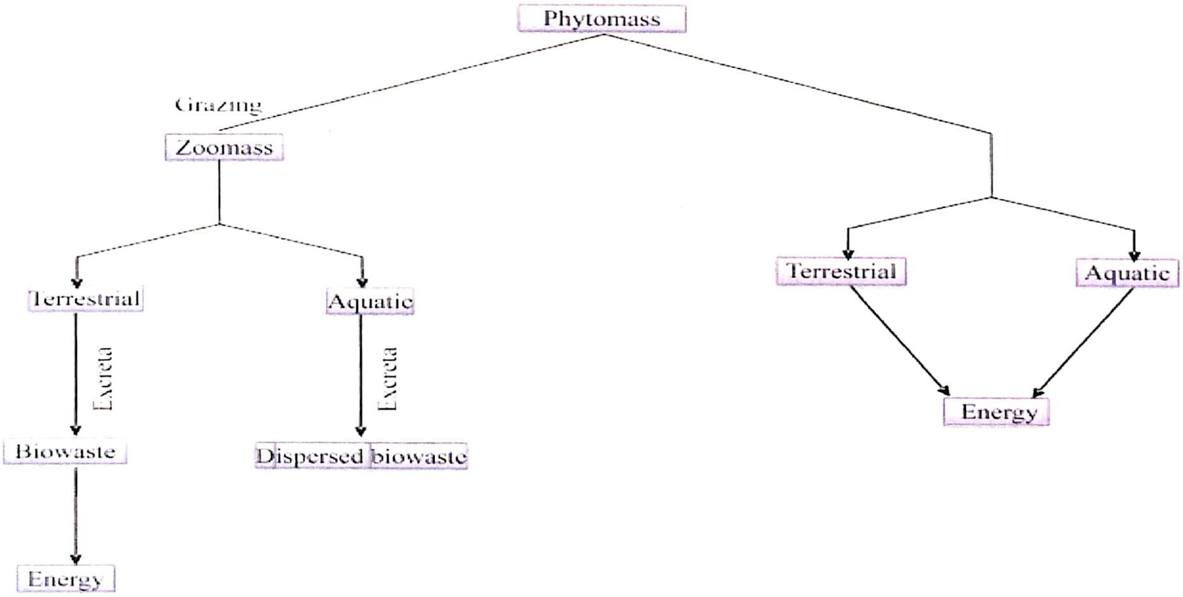

Figure 1.1: Phytomass distribution

The total volume of biomass that is created is very large—10 times our present energy demand. About 100 billion tonnes of carbon is converted to biomass every year.

Biomass has always been an important energy source for the country considering the benefits it offers. It is renewable, widely available, carbon-neutral and has the potential to provide significant employment in the rural areas. Biomass is also capable of providing firm energy. Ministry of New and Renewable Energy has realised the potential and role of biomass energy in the Indian context and hence has initiated a number of programmes for promotion of efficient technologies for its use in various sectors of the economy to ensure derivation of maximum benefits Biomass power generation in India is an industry that attracts investments of over Rs.600 crores every year, generating more than 5000 million units of electricity and yearly employment of more than 10 million man-days in the rural areas. For efficient utilization of biomass, bagasse based cogeneration in sugar mills and biomass power generation have been taken up under biomass power and cogeneration programme.

Biomass power & cogeneration programme is implemented with the main objective of promoting technologies for optimum use of country's biomass resources for grid power generation. Biomass materials used for power generation include bagasse, rice husk, straw, cotton stalk, coconut shells, soya husk, de-oiled cakes, coffee waste, jute wastes, groundnut shells, saw dust etc.

1.3. Purpose of the study

The study takes stock of the various sources of biomass and the possible ways in which it can be utilized for generating energy. The main objective of the present study is to investigate potential and use of biomass energy in India and its contribution to the sustainable energy development by presenting its historical development.

Due to environment changes, the Government norms are becoming tougher day by day for energy production, therefore this report shall discuss the use of biomass energy available in India and how it can be utilized economically.

The report shall also discuss the benefits, challenges faced in biomass power plant in terms of cost, production, etc.

1.4. Biomass potential

1.4.1. Global Scenario

- Biomass is an important energy source contributing to more than 14% of the global energy supply. About 38% of such energy is consumed in developing countries, primarily in the rural and traditional sectors of the economy.
- In 2009, biomass production contributed 3.9 quadrillion Btu of energy to the 73.1 quadrillion Btu of energy produced in the United States or about 5.3% of total energy production.
- The U.S. and Brazil produced about 89 percent of the world's fuel ethanol in 2008 out of total world production of 17335MW.
- In terms of energy content the total annual production of biomass is estimated at 2,740 Quads (1 Quad = 10,000,000,000,000,000 Btus). Biomass production is about eight times the total annual world consumption of energy from all sources (about 340 Quads). Therefore, biomass represents a very large energy resource. At present the world population uses only about 7% of the annual production of biomass. Therefore, we are only partially exploiting nature's abundant renewable resource.

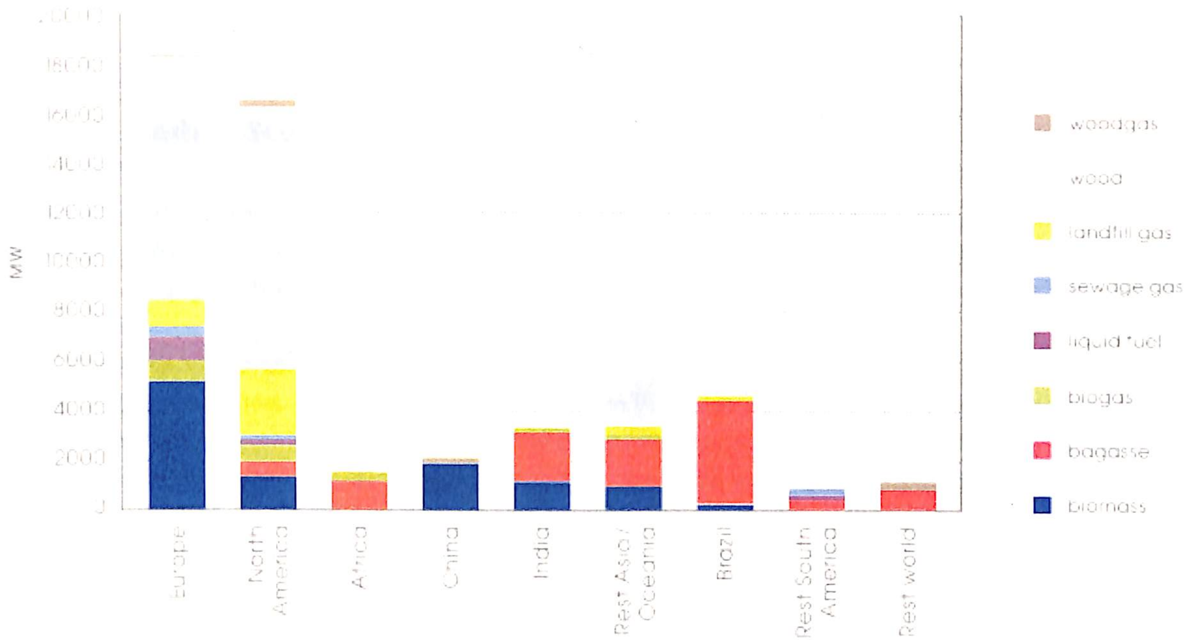

Figure 1.2: Global grid-connected biomass capacity by feedstock and country / region (MW)

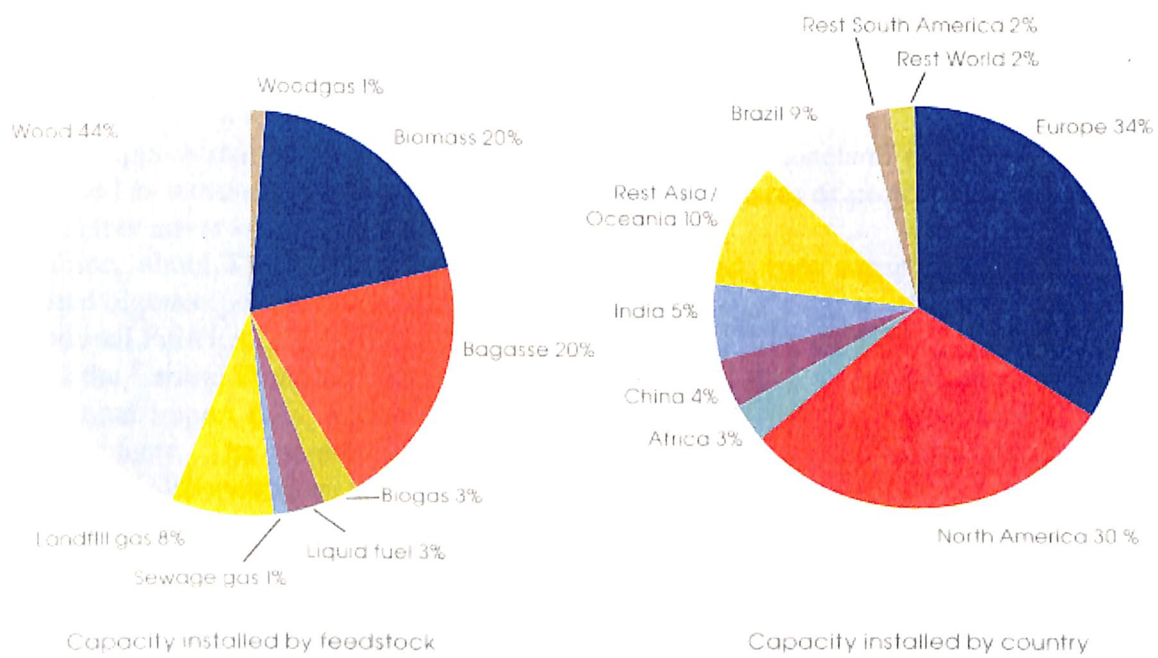

Figure 1.3: % Capacity installed by feedstock and country / region

1.4.2. Indian Scenario

- Indian climatic conditions offer an ideal environment for biomass production. Bio-energy has remained critical to India's energy mix. The current potential of surplus agro and forest residues to energy is estimated at 16,881 MW along with an additional "waste-to-energy" potential of 2,700 MW.
- With the setting up of new sugar mills and the modernization of existing ones, the potential of Bagasse cogeneration is estimated at 5,000 MW. The cumulative installed capacity, of grid-interactive biomass and Bagasse cogeneration power was 2313.33 MW only, as on 30.10.2010.
- In India, biomass-based power generation has attracted investments worth USD 120 million and generated more than 5,000 million units of electricity, besides providing an employment to more than 10 million man-days in rural areas. India ranks second in the world in biogas utilisation.
- Under the 11th Plan period (2007-12) the Government of India plans to add as much as 1700 MW through biomass and Bagasse cogeneration in various states
- India encourages ethanol as a fuel for automobiles and Regulations provide for the mandatory blending of 5% of ethanol with petrol (to be increased to 10%). The Government also plans to free the movement of ethanol across the country and eliminate local taxes thereby increasing its usage.
- Close on the heels of the Kyoto protocol recommending a phased changeover to bio-diesel through blending, the Government of India has taken a number of initiatives to promote bio-fuels.
- The availability of biomass in India is estimated at about 540 million tones per year covering residues from agriculture, forestry, and plantations. By using these surplus agriculture residues, more than 16,000 MW of grid quality power can be generated.
- India has approximately 50 million hectares of degraded wasteland that lie outside the areas demarcated as national forests, and another 34 million hectares of protected forest area, in much of which tree cover is severely degraded.
- In addition, about 5,000 MW of power can be produced from sugar mills residues. Thus the estimated biomass power potential is about 21,000 MW.
- Promotional Policies:
- Besides the Central Financial Assistance, fiscal incentives such as 80% accelerated depreciation, concessional import duty, excise duty, tax holiday for 10 years etc., are available for Biomass power projects. The benefit of concessional custom duty and excise duty exemption on equipment is also available.
- In addition, State Electricity Regulatory Commissions have determined preferential tariffs and Renewable Purchase Standards (RPS).
- Indian Renewable Energy Development Agency (IREDA) provides loan for setting up wind power and Bagasse cogeneration projects.
- In addition, capital subsidies area also given for the establishment of Bagasse and Biomass based units.

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
Urban Wastes		
MSW	3190	9
MLW	361	1
Subtotal	3551	10
Grand Total	**34961**	**100**

Table 1.1: Estimate of Current Biomass Potential in India (2012)

State	Area (KHa)	Crop Productivity (million T/ yr)	Biomass Generation (million T/ yr)	Biomass Surplus (million T/yr)	Power (Mw)
Andhra Pradesh	2,540.20	3.23	8.30	1.17	150.20
Assam	2,633.10	6.08	6.90	1.40	165.50
Bihar	5,833.10	13.82	20.44	4.29	530.30
Chhattisgarh	3,815.50	6.14	10.12	1.91	220.90
Goa	156.30	0.55	0.83	0.13	15.60
Gujarat	6,512.90	20.63	24.16	7.51	1,014.10
Haryana	4,890.20	13.52	26.16	9.80	1,261.00
Himachal Pradesh	710.30	1.33	2.67	0.99	128.00
Jammu	368.70	0.65	1.20	0.24	31.80
Jharkhand	1,299.80	1.51	2.19	0.57	66.80
Karnataka	7,277.30	38.64	23.77	6.40	843.40
Kerala	2,041.70	9.75	9.42	5.70	762.30
Madhya Pradesh	9,937.00	14.17	26.50	8.03	1,065.40
Maharashtra	15,278.00	51.34	36.80	11.80	1,585.00
Manipur	72.60	0.16	0.32	0.03	4.10
Meghalaya	0.80	0.01	0.04	0.01	1.10

Nagaland	27.10	0.09	0.15	0.03	3.10
Orissa	2,436.60	3.63	5.35	1.16	147.30
Punjab	6,693.50	27.81	46.34	21.27	2,674.60
Rajasthan	12,537.50	93.65	204.89	35.53	4,595.00
Tamil Nadu	2,454.00	24.54	15.98	6.66	863.70
U.P	12,628.20	46.80	50.42	11.73	1,477.90
Uttaranchal	66.40	0.14	0.16	0.05	6.60
West Bengal	5,575.60	21.06	23.32	2.96	368.30
	105,786.4	399.25	546.41	139.35	17,982.0

Table 1.2: State wise estimate of Current Biomass Potential in India (2012)

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

2. LITERATURE REVIEW

2.1. Critical components

In order to analyse the use of biomass for power generation, it is important to consider three critical components of the process:

» **Biomass feedstocks:** These come in a variety of forms and have different properties that impact their use for power generation.

» **Biomass conversion:** This is the process by which biomass feedstocks are transformed into the energy form that will be used to generate heat and/or electricity.

» **Power generation technologies:** There is a wide range of commercially proven power generation technologies available that can use biomass as a fuel input.

The source and sustainability of the biomass feedstock is critical to a biomass power generation project's economics and success. There are a wide range of biomass feedstocks and these can be split into whether they are urban or rural (table 2.1).

A critical issue for the biomass feedstock is its energy, ash and moisture content, and homogeneity. These will have an impact on the cost of biomass feedstock per unit of energy, transportation, pre-treatment and storage costs, as well as the appropriateness of different conversion technologies. Bioenergy can be converted into power through thermal-chemical processes (i.e. combustion, gasification and pyrolysis) or bio-chemical processes like anaerobic digestion (table 2.2).

Rural	Urban
Forest residues and wood waste	Urban wood waste (packing crates, pallets, etc)
Agricultural residues (corn stovers, wheat stalks, etc)	Waste water and sewage biogas
Energy crops (grasses or trees)	Landfill gas
Biogas from liverstock effluent	Municipal solid waste food processing residues

Table 2.1: Biomass feedstock

2.2. Biomass power generation technologies

Thermo-Chemical Process	
Combustion	The cycle used is the conventional rankine cycle with biomass being burned (oxidised) in a high pressure boiler to generate steam. The net power cycle efficiencies that can be achieved are about 23% to 25%. The exhaust of the steam turbine can either be fully condensed to produce power or used partly or fully for another useful heating activity. In addition to the exclusive use of biomass combustion to power a steam turbine, biomass can be co-fired with coal in a coal-fired power plant. Direct co-firing is the process of adding a percentage of biomass to the fuel mix in a coal-fired power plant. It can be co-fired up to 5-10% of biomass (in energy terms) and 50-80% with extensive pre-treatment of the feedstock (i.e. torrefaction) with only minor changes in the handling equipment. For percentages above 10% or if biomass and coal are burning separately in different boilers, known as parallel co-firing, then changes in mills, burners and dryers are needed.
Gasification	Gasification is achieved by the partial combustion of the biomass in a low oxygen environment, leading to the release of a gaseous product (producer gas or syngas). So-called "allothermal" or indirect gasification is also possible. The gasifier can either be of a "fixed bed", "fluidised bed" or "entrained flow" configuration. The resulting gas is a mixture of carbon monoxide, water, CO_2, char, tar and hydrogen, and it can be used in combustion engines, micro-turbines, fuel cells or gas turbines. When used in turbines and fuel cells, higher electrical efficiencies can be achieved than those achieved in a steam turbine. It is possible to co-fire a power plant either directly (i.e. biomass and coal are gasified together) or indirectly (i.e. gasifying coal and biomass separately for use in gas turbines).
Pyrolsis	Pyrolsis is a subset of gasification systems. In pyrolysis, the partial combustion is stopped at a lower temperature (450°C to 600°C), resulting in the creation of a liquid bio-oil, as well as gaseous and solid products. The pyrolysis oil can then be used as a fuel to generate electricity.
Bio-Chemical Process	
Anaerobic Digestion	Anaerobic digestion is a process which takes place in almost any biological material that is decomposing and is favored by warm, wet and airless conditions. The resulting gas consists mainly of methane and carbon dioxide and is referred to as biogas. The biogas can be used, after clean-up, in internal combustion engines, micro-turbines, gas turbines, fuel cells and stirling engines or it can be upgraded to biomethane for distribution.

Table 2.2: Thermo-chemical and Bio-chemical conversion process for biomass feedstock

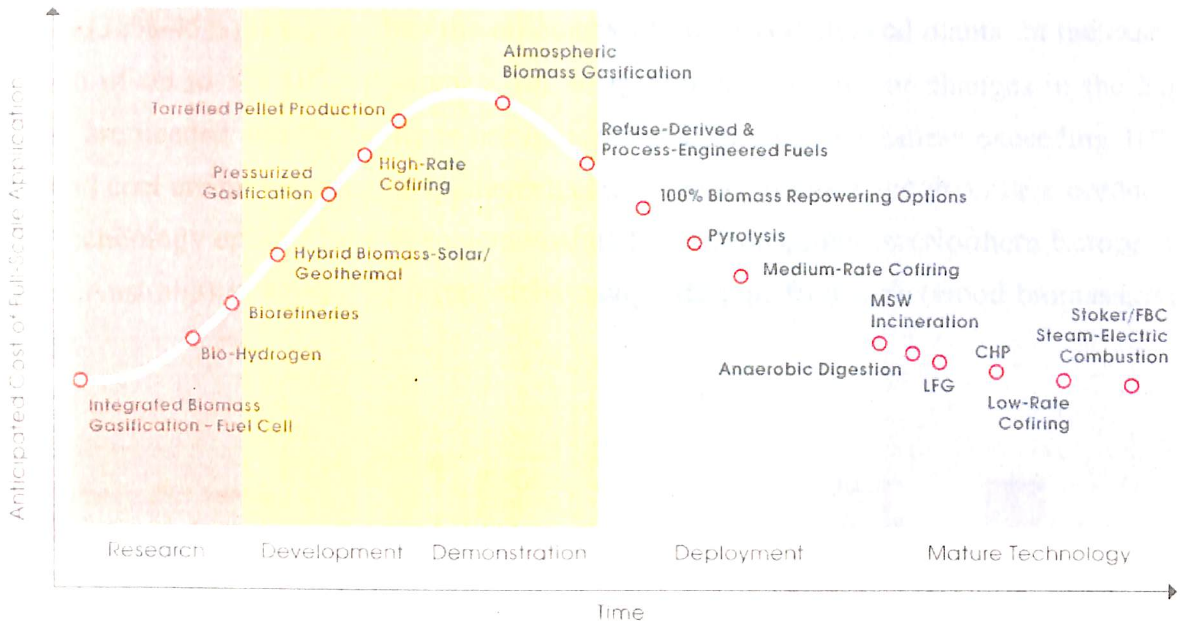

Figure 2.1: Biomass power generation technology maturity status

2.2.1. Combustion

- 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

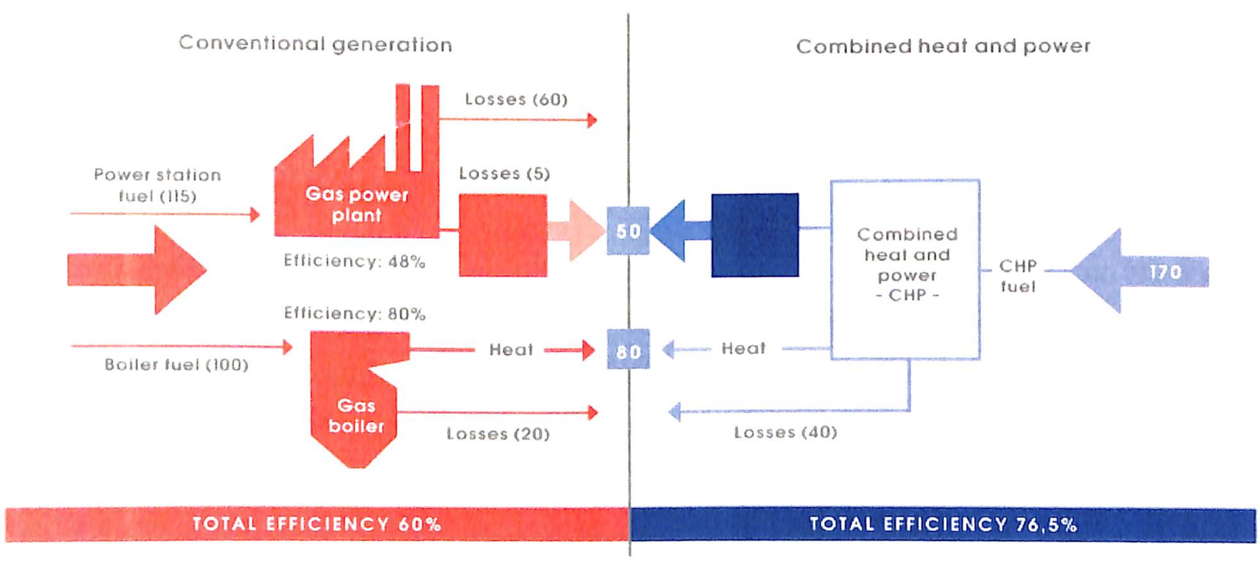

Figure 2.2: Conventional and combined generation

Co-firing – This is a sub-set of combustion based power production. Some of the modern coalfired power plants use biomass for co-firing along with coal. It is quite efficient, cost-effective and requires moderate additional investment. In general, combustion efficiency of biomass can be 10 percentage points lower than for coal at the same installation, but co-firing efficiency in large-scale coal plants (35%-45%) is higher than the efficiency of biomass-dedicated plants. In the case of co-combustion of up to 5%-10% of biomass (in energy terms) only minor changes in the handling equipment are needed and the boiler is not noticeably de-rated. For biomass exceeding 10% or if biomass and coal are burned separately, then changes in mills, burners and dryers are needed. Many co-firing technology options have been demonstrated in several countries (Northern Europe, United States and Australia) in some 150 installations using different feedstock (wood biomass, residues and crops).

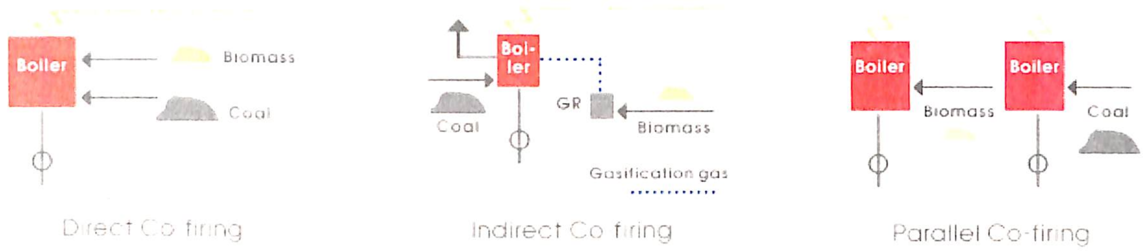

Figure 2.3: Conventional and combined generation

Cogeneration – When bagasse is also used as a feedstock for steam generation in boilers in sugar mills, the main objective is process heating, and thus power production is only an ancillary benefit (which is why the term cogeneration – generation of both heat and power). As a result, the capacity of the power production is set based on the heating requirements. Thus, during the cane season, these mills have enough bagasse to be used for both heating and power production. During the non-cane season, typically coal is used for power production, as there are no heating requirements.

In the case of combustion, the biomass is fired to generate steam which turns a turbine for power production. In the case of gasification, the biomass is gasified into a mixture of CO and H2 in a gasifier. This gas is fed to a gas engine that produces electricity.

Biomass gasification refers to the incomplete combustion of biomass resulting in production of combustible gases consisting of Carbon monoxide (CO), Hydrogen (H2) and traces of Methane (CH4). 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.

Gasifiers 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, excluding biomass cogeneration). Works best for woody biomass, but latest gasifiers also work reasonably well with nonwoody (including fine biomass).

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 CO_2 and a small amount of hydrogen sulphide and ammonia). Anaerobic digestion is also the basic process for landfill gas production from municipal green waste. It has significant potential in India as well as worldwide. Anaerobic digestion is increasingly used in small size, rural and off-grid applications at the domestic and farm-scale. The rising cost of waste disposal may improve its economic attractiveness. Anaerobic digesters are used both at small-scale and large-scale levels. Small scale biogas for household use is a simple, low-cost, low-maintenance technology, which has been used for decades. It usually concerns rural areas and communities without connection to the grid.

Industrial applications mainly process huge amounts of feedstock. This would require a well-developed logistical system for feedstock collection and effluent disposal. The feasibility of such plants depends on the availability of cheap and free feedstock due to costs. (IEA Bioenergy, 2009) 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. Recycling/recovery/re-use of products from the wastes of such small-scale units by adopting suitable technology could be a viable proposition. Generation of energy using anaerobic digestion process has proved to be economically attractive in many such cases. Overall, power production from anaerobic digestion is quite well established as a technology, though the economics of this route are still evolving.

2.2.2. Pyrolysis

Pyrolysis as a method for power production is not well established currently in India or elsewhere in the world.

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, 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.

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.

Slow Pyrolysis

In the case of slow pyrolysis when you get an organic gas and charcoal. The gas can be cooled and fed to a gas engine for power production. Cooling this gas however results in a significant amount of hydrocarbons being removed. Thus most of the energy is wasted away. A more efficient idea that is being explored is to use this heterogeneous gas straight for combustion of boilers and running a steam cycle. Charcoal is a valuable product, which fetches anywhere between Rs 10-Rs 25 per Kg. It has a much better calorific value than coal and people in many places use charcoal because coal might not be available in those places.

Fast Pyrolysis

Fast pyrolysis is a process in which organic materials are rapidly heated to 450 - 600°C in absence of air. Under these conditions, organic vapours, permanent gases and charcoal are produced. The vapours are condensed to pyrolysis oil. Typically, 50 - 75 wt % of the feedstock is converted into pyrolysis oil. The pyrolysis oil can be used as a replacement for furnace oil.

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2.2.3. Gasification

Gasification plants consist of several process steps. The solid biomass fuel delivered needs to be adjusted (fuel conditioning and handling) to the fuel characteristics (particle size, water content) required for the gasification process. The conditioned fuel enters the gasification process, which produces raw product gas. The raw product gas needs to be cleaned in order to achieve the product gas quality needed for further utilization. The cleaned product gas is used for the production of electric power, heat and fuel based on different technologies.

During the thermo-chemical biomass gasification process solid biomass is cracked by thermal energy and a fumigator and converted into a product gas. The product gas is cleaned and used for the production of heat and power e.g. by gas engines (biomass CHP).

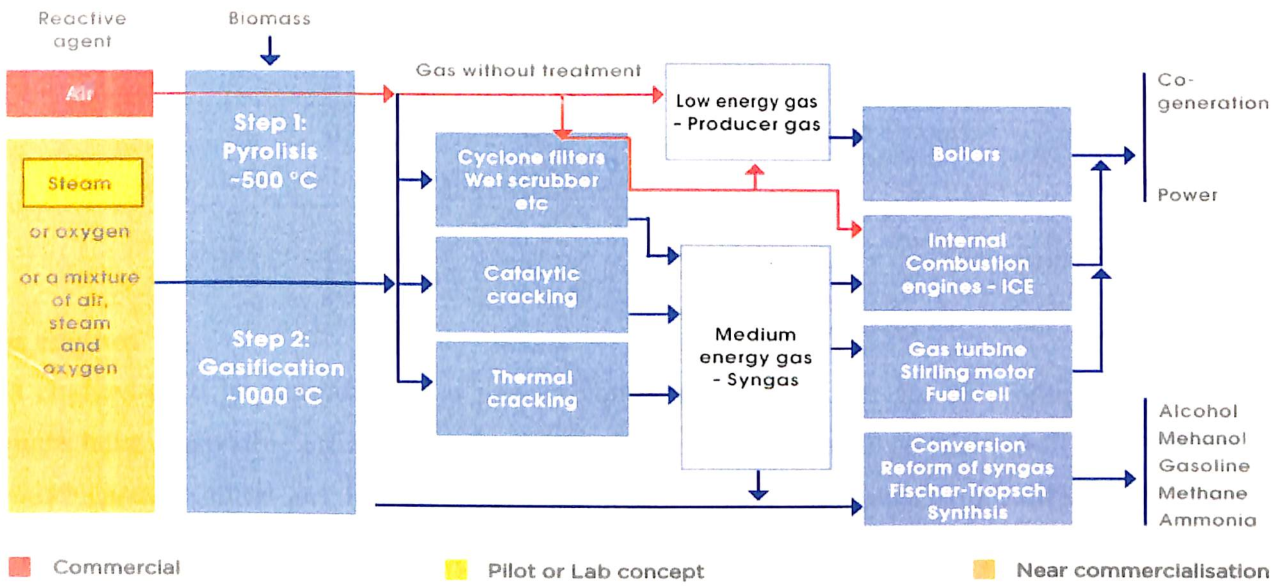

Figure 2.4: Schematics of gasification process

Gasifiers

Biomass gasifiers are reactors that heat biomass in a low-oxygen environment to produce a fuel gas that contains from one fifth to one half (depending on the process conditions) the heat content of natural gas. The gas produced from a gasifier can drive highly efficient devices such as gensets, turbines and fuel cells to generate electricity.

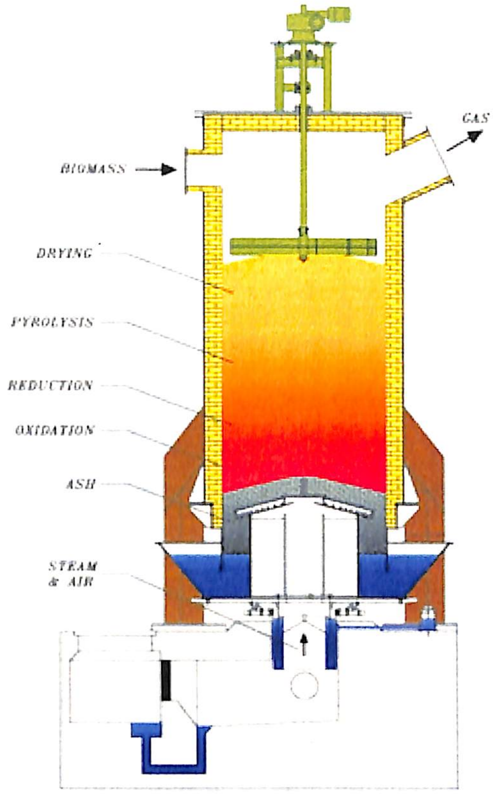

Figure2.5: Biomass Gasifier

Gas engines

Gas engines used in the gasification power plants run on producer gas to produce power. These engines have reasonable efficiencies. Producer gas has a very low air to fuel ratio (1.3:1) compared to other gases (Natural gas 17:1). Hence the engine has to be operated with a different carburettor for producer gas and natural gas. Also, the producer gas can be operated in an engine which has a higher compression ratio. Engines used for producer gas have generally lower in efficiency and they are cheaper. The efficiency of these engines is more than 30%.

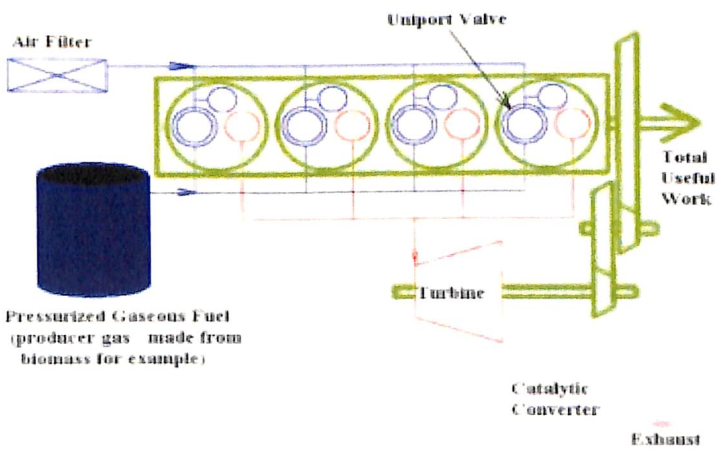

Figure 2.6: Gas Engine

Power evacuation system

Suitable evacuation systems need to be provided in order to transmit the electricity to the grid (if it is grid connected) or to the location where it is required (if it is captive).

There are two principal types of gasifiers, namely:

- Fixed-bed type
- Fluidized-bed type

The fixed bed gasification system consists of a reactor/gasifier with a gas cooling and cleaning system. The fixed bed gasifier has a bed of solid fuel particles through which the gasifying media and gas move either up or down. It is the simplest type of gasifier consisting of usually a cylindrical space for fuel feeding unit, an ash removal unit and a gas exit. In the fixed bed gasifier, the fuel bed moves slowly down the reactor as the gasification occurs. The fixed bed gasifiers are of simple construction and generally operate with high carbon conversion, long solid residence time, low gas velocity and low ash carry over. In fixed bed gasifiers, tar removal used to be a major problem, however recent progress in thermal and catalytic conversion of tar has given credible options.

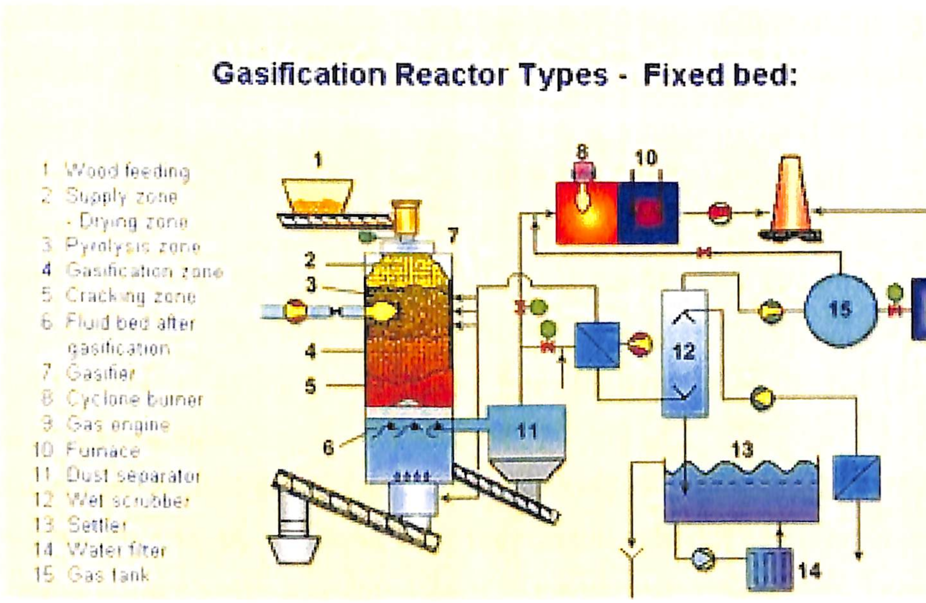

Figure 2.7: Fixed bed gasification reactor

Fixed bed gasifiers are the most commonly ones. These are in turn available under two important categories depending on the direction of the gas flow through the reactor:

- Updraft gasifiers
- Downdraft gasifiers

Updraft – mainly done for coal gasification; Indian gasifiers are mainly downdraft. For updraft, the tar formation will be much higher (10 times or more) than for the downdraft. In India, most gasifiers used are of the downdraft type.

Advantages of downdraft over updraft

Downdraft – gas with less tar, but with some particulates, so producer gas more suitable for use in gas engines Updraft – more suitable with some thermal applications

Updraft Gasifiers

Fuel flexibility is the main feature of updraft multifuel gasifiers. These gasifiers can operate on either coal or biomass and fuel switching does not require any changes in the reactor. Updraft gasifiers tolerate higher ash content, higher moisture content and greater size variation in fuel as compared to downdraft gasifiers.

In updraft gasifiers, gas is drawn out of the gasifier from the top of the fuel bed while the gasification reactions take place near the bottom. As the producer gas passes through the fuel bed, it picks-up volatile matter (tars) and moisture from the fuel. Therefore, the gas from the updraft gasifier contains condensable volatiles. The design and operation of the gasifiers is such that the gas comes out at 200-400 C temperature. At this temperature, most of the volatile hydrocarbons are in vapor form, which add to the energy content of the gas. It is most appropriate to utilize updraft gasifiers in close-coupled-hot gas mode for direct heating applications. However, if the application warrants, the scrubbing of gas to remove the volatiles/tars is also carried out.

Downdraft Gasifiers

Downdraft gasifiers are fuel specific. Downdraft wood gasifiers can operate on wood like biomass materials and biomass briquettes with a minimum bulk density of 250 kg/m3 and ash content of less than 5%. In downdraft gasifiers, gas is drawn from the bottom of the reactor while the hottest reaction zone is in the middle.

The volatile matter in the fuel gets cracked within the reactor and therefore the output gas is almost tar-free. However, the gas, as it comes out of the reactor, contains small amounts of ash and soot. The gas comes out of the gasifier at 250-450° C. This gas can also be used either in hot condition (after preliminary cleaning) or in cold-clean condition (after appropriate gas clean-up arrangement). The gas from the downdraft gasifiers can be cleaned to very high purity such that it can be used in IC engines or for direct heating applications where purity of gas is a critical requirement.

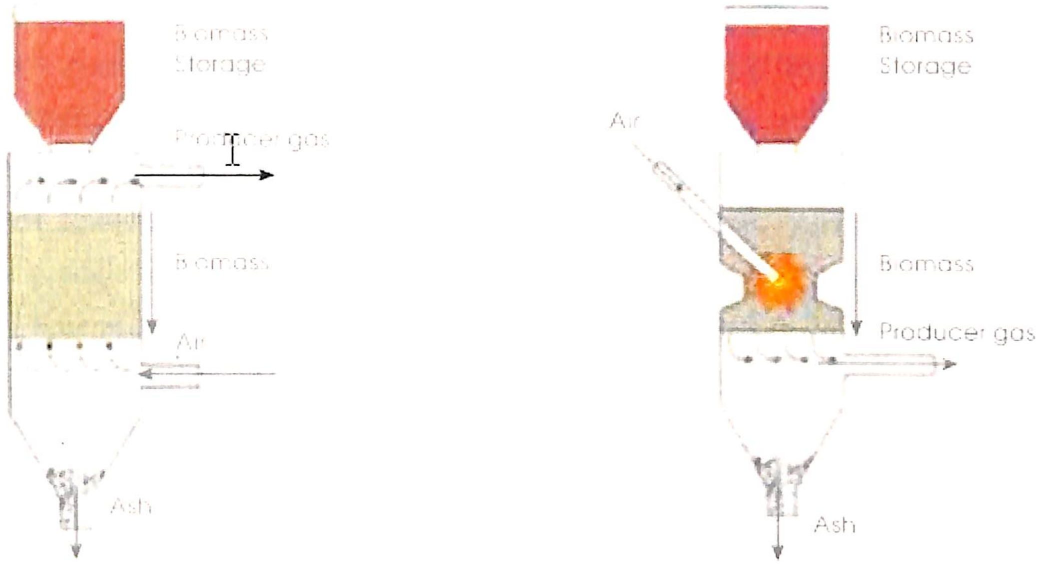

Figure 2.8: Fixed bed updraft and downdraft gasifiers

In fluidized bed gasifiers, the biomass is brought into an inert bed of fluidized material (e.g. sand, char, etc.). Such systems are less sensitive to fuel variations but produce larger amounts of tar and dust. They are more compact but also more complex, and usually used at larger scales. Fluidized bed gasifiers are operated with significantly higher gas flow velocities than fixed bed gasifiers. The fuel bed and a carrier material (e.g. sand) are fluidized by the gas flow (fumigator and recirculated product gas). Thus, the gasification reaction takes place in a fluidized bed but only 5-10% wt of the bed is fuel.

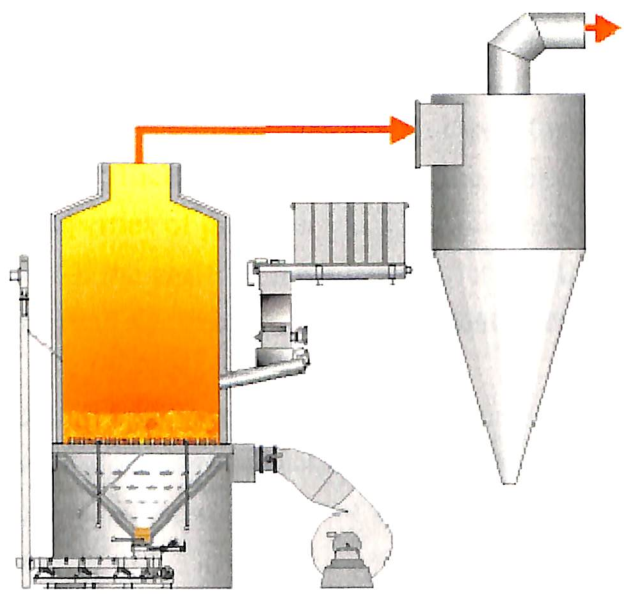

Figure 2.9: Fluidized bed Gasifier

The fuel is fed into the system either above-bed or directly into the bed, depending upon the size and density of the fuel and how it is affected by the bed velocities. During normal operation, the bed media is maintained at a temperature between 1000EF and 1800EF. When a fuel particle is introduced into this environment, its drying and pyrolyzing reactions proceed rapidly, driving off all gaseous portions of the fuel at relatively low temperatures. The remaining char is oxidized within the bed to provide the heat source for the drying and de-volatilizing reactions to continue. In those systems using inert bed material, the wood particles are subjected to an intense abrasion action from fluidized sand. This etching action tends to remove any surface deposits (ash, char, etc.) from the particle and expose a clean reaction surface to the surrounding gases. As a result, the residence time of a particle in this system is on the order of only a few minutes, as opposed to hours in other types of gasifiers. Thus, higher fuel throughput rates are achievable.

Since the fluidized bed allows an intensive mixing and a good heat transfer, there are no distinguished reaction zones. Hence, drying, pyrolysis, oxidation and reduction reactions take place simultaneously. The temperature distribution in the fluidized bed is relatively constant and typically ranges between 700°C and 900°C. The large thermal capacity of inert bed material plus the intense mixing associated with the fluid bed enable this system to handle a much greater quantity and, normally, a much lower quality of fuel.

Common Limitations

- Gasification is a complex and sensitive process. There exists high level of disagreement about gasification among engineers, researchers, and manufacturers. Several manufacturers claim that their unit can be operated on all kinds of biomass. But it is a questionable fact as physical and chemical properties varies fuel to fuel.
- Gasifiers require at least half an hour or more to start the process. Raw material is bulky and frequent refueling is often required for continuous running of the system. Handling residues such as ash, tarry condensates is time consuming and dirty work. Driving with producer gas fueled vehicles requires much more and frequent attention than gasoline or diesel fueled vehicles.
- Getting the producer gas is not difficult, but obtaining in the proper state is the challenging task. The physical and chemical properties of producer gas such as energy content, gas composition and impurities vary time to time. All the gasifiers have fairly strict requirements for fuel size, moisture and ash content. Inadequate fuel preparation is an important cause of technical problems with gasifiers.
- Gasifier is too often thought of as simple device that can generate a combustible gas from any biomass fuel. A hundred years of research has clearly shown that key to successful gasification is gasifier specifically designed for a particular type of fuel. Hence, biomass gasification technology requires hard work and tolerance.

Gasifiers - Technology Specific Limitations

Fixed Bed - Updraft fixed bed gasifiers

Major drawbacks are the high amounts of tar and pyrolysis products that occur because the pyrolysis gas does not pass the hearth zone and therefore is not combusted. This is of minor importance if the gas is used for direct heat applications in which the tar is simply burned. But when the gas is used for engines, extensive gas cleaning is required.

Fixed Bed - Downdraft fixed bed gasifiers

- High amounts of ash and dust particles remain in the gas because the gas has to pass the oxidation zone, where it collects small ash particles
- Fuel requirements are relatively strict; fuel must be uniformly sized from 4 to 10 cm so as not to block the throat and allow pyrolysis gases to flow downward and heat from the hearth zone to flow upward; therefore, pelletization or briquetting of is often necessary.
- The moisture content of the biomass must be less than 25 percent (on a wet basis).
- The relatively high temperature of the exit flue gas results in lower gasification efficiency.

Fluidized bed gasifiers

- High tar and dust content of the producer gas could result in problems while using the gas in the engines.
- High producer-gas temperatures, which leave alkali metals in the vapor state
- Incomplete carbon burnout results in lesser energy output
- Complex operation because of the need to control the supply of both air and solid fuel
- Need for power consumption for the compression of the gas stream.

Even though biomass gasification provides the benefits of a well proven technology that can produce power at small scales using locally available resources, the total amount of power production from biomass gasification in India is relatively low. EAI estimates that the total installed capacity of biomass gasification based power production in India will be about 140 MW, out of a total of about 2600 MW of biomass based power (cumulative of grid connected and off grid). Of the total, bagasse based power generation has the lion's share (about 1400 MW), followed by combustion-based biomass power production (about 875 MW).

Currently, most power production systems in India using biomass gasification are off-grid and have been for captive consumption for an industry or for a community.

Size	Combustion	Gasification
Small (10 kW – 25kW)	Not prevalent	Prevalent
Small-medium (25kW – 250kW)	Not prevalent	Prevalent
Medium (250 kW – 2MW)	Not prevalent	Prevalent
Large (2 MW and above)	Prevalent	Not prevalent

Table 2.3: Size (Capacity) Distribution for Gasification and Combustion Technologies

2.3. Biomass Gasification Plants in India

The table below provides the total capacity of biomass based power plants operating in the various Indian states. Please note that this list includes all forms of power production –combustion, gasification and cogeneration. Of the total (2600 MW), biomass gasification forms only a small part (less than 125 MW).

State	**Upto 31.3.2003**	**2003-2004**	**2004-2005**	**2005-2006**	**2006-2007**	**2007-2008**	**2008-2009**	**2009-2010**	**2010-2011**	**Total (MW)**
Andhra Pradesh	160.05	37.7	69.5	12	22	33	9	20	--	363.25
Bihar	--	--	--	--	--	--	--	--	9.5	9.5
Chattisgarh	11	--	--	16.5	85.8	33.5	9.8	43.8	--	199.9
Gujarat	0.5	--	--	--	--	--	--	--	--	0.5
Haryana	4	--	2	--	--	--	--	1.8	28	35.8
Karnataka	109.38	26	16.6	72.5	29.8	8	31.9	42	--	336.18
Madhya Pradesh	--	1	--	--	--	--		--	--	1
Maharashtra	24.5	--	11.5	--	40	38.5	71.5	33	10	288.5
Punjab	22	--	--	6	--	--	--	34.5	--	62.5
Rajasthan	--	7.8	--	7.5	8	--	8	--	28	59.3
Tamil Nadu	106	44.5	22.5	--	42.5	75	43.2	62	23.5	419.2
Uttar Pradesh	46.5	12.5	14	48.5	--	79	172	194.5	14	581
West Bengal	--	--	--	--	--	--	--	16	--	16
Total	**483.93**	**129.5**	**136.1**	**163**	**228.1**	**266**	**345.4**	**447.6**	**113**	**2312.63**

Table 2.4 State-wise/Year-wise list of commissioned biomass power/co-generation projects as on 30.06.2010

2.4. Benefits of biomass power

In many ways, biomass is a new source of power. While wood has always served as a fuel source for fires and ovens and conventional heating methods, biomass energy advancements are a few steps beyond that. Now these biomass fuel products are harvested and mass-produced and used in everything from engines to power plants.

i. No harmful emissions: Biomass energy, for the most part, creates no harmful carbon dioxide emissions. Many energy sources used today struggle to control their carbon dioxide emissions, as these can cause harm to the ozone layer and increase the effects of greenhouse gases, potentially warming the planet. It is completely natural, has no such carbon dioxide side effects in its use.

ii. Clean energy: Because of its relatively clean use, biomass energy, when used in commercial businesses such as airlines, receives tax credit from the US government. This is good for theenvironment and good for business. It does release carbon dioxide but captures carbon dioxide for its own growth. Carbon dioxide released by fossil fuel are released into the atmosphere and areharmful to the environment.

iii. Abundant and Renewable: Biomass products are abundant and renewable. Since they come from living sources, and life is cyclical, these products potentially never run out, so long as there is something living on earth and there is someone there to turn that living things components and waste products into energy. In the United Kingdom, biomass fuels are made from recycled chicken droppings. In the United States and Russia, there are plentiful forests for lumber to be used in the production of biomass energy.

iv. Reduced dependency on fossil fuels: It has developed as an alternate source of fuel for many homeowners and have helped them to reduce their dependency on fossil fuels.

v. Reduce landfills: Another benefit of this energy is that it can take waste that is harmful to the environment and turn it into something useful. For instance, garbage as landfill can, at least partially, be burned to create useable biomass energy.

vi. Can be used to create different products: Biomass energy is also versatile, as different forms of organic matter can be used to create different products. Ethanol and similar fuels can be made from corn and other crops. With so many living things on the planet, there is no limit to how many ways it can be found and used.

vii. Distributed generation: Because biomass is available in almost all places, and especially in rural areas, and more important, as gasification based power production can be done on small scales (as low as 20 kW), this process can be used for distributed generation of power as against the centralized power production method followed today.

viii. Base load power – Many renewable energy sources such as solar and wind cannot be used for base load power generation due to their intermittency and variability. Biomass based power generation, on the other hand, can be used for base load power generation.

ix. Suited for rural areas – Biomass based power is well suited to remote villages with no access to grid but access to significant amounts of biomass

x. Ability to have small, kW scale power production – Biomass gasification based power production can be done at small scales – as small as 20 kW – unlike other sources of power (say, nuclear) that require much larger scales. This will ideally suit small villages that have only a few households.

xi. Rural economic upliftment - Also the possibility of increasing the prosperity of rural areas especially if dedicated energy crops become common for biomass based power production – Currently, most biomass based power production uses waste biomass such as agro waste and waste from agro processing units. However a trend is emerging in which companies are exploring the use of dedicated energy crops for biomass power production. This has the twin benefits of a more reliable biomass supply chain and at the same time providing the much needed employment for the rural masses. Given that a 1 MW biomass based power generation could require biomass growth in over 150 hectares, the opportunities for rural employment are indeed significant.

xii. Carbon neutral - Biomass power results in no new net GHG emissions as it is part of the carbon cycle. Unlike coal and other forms of fossil fuel which have been buried millions of years ago and burning them adds to carbon in the atmosphere, whereas biomass energy generation results in no new carbon emission or pollution

xiii. Efficient utilization of renewable biological sources - Biomass power is an efficient process which results in the use of mostly animal and crop wastes which would be converted into carbon dioxide anyway.

xiv. Large variety of feedstock – Biomass power can use a large variety of feedstock such as wood pellets, rice husk, bagasse etc.

xv. Reduces methane, a major GHG gas – Decomposition of organic matter releases methane. Capturing this methane yields energy while protecting the atmosphere. The animal industry and landfills produce significant amounts of methane.

2.5. Key bottlenecks and challenges in biomass power generation

Besides above advantages, there are also some downsides to it. Let's see below some of its disadvantages.

i. Expensive: Firstly, it is expensive. Living things are expensive to care for, feed, and house, and all of that has to be considered when trying to use waste products from animals for fuel.

ii. Inefficient as Compared to Fossil Fuels: Secondly, and connected to the first, is the relative inefficiency of biomass energy. Ethanol, as a biodiesel is terribly inefficient when compared to gasoline, and it often has to be mixed with some gasoline to make it work properly anyway. On top of that, ethanol is harmful to combustion engines over long term use.

iii. Harmful to Environment: Thirdly, using animal and human waste to power engines may save on carbon dioxide emissions, but it increases methane gases, which is considered very harmful in the atmosphere as a greenhouse gas - approx. 30 times worse than CO2.. So really, we are no better off environmentally for using one or the other. And speaking of using waste products, there is the smell to consider. While it is not physically harmful, it is definitely unpleasant, and it can attract unwanted pests (rats, flies) and spread bacteria and infection.

iv. Consume More Fuel: Finally, using trees and tree products to power machines is inefficient as well. Not only does it take a lot more fuel to do the same job as using conventional fuels, but it also creates environmental problems of its own. To amass enough lumber to power a nation full of vehicles or even a power plant, companies would have to clear considerable forest area. This results in major topological changes and destroys the homes of countless animals and plants.

v. Require More Land: Combustion of biomass products require some land where they can easily be burnt. Since, it produces gases like methane in atmosphere; therefore it can be produced in those areas which are quite far from residential homes.

These are all things that have to be carefully considered and weighed when determining if biomass energy is a viable alternative energy source.

3. RESEARCH DESIGN, METHODOLOGY AND PLAN

3.1. State-wise list of existing power plants in India

(IN MW)

S.No.	State	Upto 31.03.2003	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	Total
1	Andhra Pradesh	160.05	37.70	69.50	12.00	22.00	33.00	9.00	20.00	..	363.25
2	Bihar		--	--	--	--	--	--	--	9.50	9.50
3	Chattisgarh	11.00	--	--	16.50	85.80	33.00	9.80	43.80	32.00	231.90
4	Gujarat	0.50	--	--	--	--	--	--	--	--	0.50
5	Haryana	4.00	--	2.00	--	--	--	--	1.8	28.00	35.80
6	Karnataka	109.38	26.00	16.60	72.50	29.80	8.00	31.90	42.00	29.00	365.18
7	Madhya Pradesh		1.00	--	--	--	--	--	--	--	1.00
8	Maharashtra	24.50	--	11.50	--	40.00	38.00	71.50	33	184.50	403.00
9	Punjab	22.00	--	--	6.00	--	--	--	34.50	12.00	74.50
10	Rajasthan		7.80	--	7.50	8.00	--	8.00	--	42.00	73.30
11	Tamil Nadu	106.00	44.50	22.50	--	42.50	75.00	43.20	62.00	92.50	488.20
12	Uttarakhand	--	--	--	--	--	--	--	--	10.00	10.00
13	Uttar Pradesh	46.50	12.50	14.00	48.50	--	79.00	172.00	194.50	25.50	592.50
14	West Bengal		--	--	--	--	--	--	16.00	--	16.00
	Total	483.93	129.50	136.10	163.00	228.10	266.00	345.40	447.60	465.00	2664.63

Table 3.1 state wise power plant list

3.2. Cost parameters including capital cost, subsidy, equity, etc

3.2.1. Biogas based power projects

Description	Specification	Remarks	Other remarks
Plant Capacity	100 KW	Pure gas based plant	
Capital Cost	INR 29.06 lakhs	Approximate	The capital cost includes all equipment, building and project development. It does not include the costs

			of land and grid connection, if any.
Capital Subsidy	a) INR 4.52 lakhs b) INR 5.65 lakhs	a) INR 20 lakhs x (MW capacity)^0.646 b) INR 25 lakhs x (MW capacity)^0.646	a) For all states except NE region, Sikkim, J&K,HP and Uttaranchal b) For special category states viz. NE region, Sikkim, J&K, HP and Uttaranchal
Capital Cost (after subsidy)	INR 24.54 lakhs	Considering only case (a)	Additionally, fiscal incentives such as 80% accelerated depreciation, concessional import duty, excise duty, tax holiday for 10 years, etc. are also available
Equity	INR 17.178 lakhs	70%	
Loan	INR 7.362 lakhs	30%	- Interest Rate – 13% (Why?) - Repayment Period – 10 years
EMI	a) INR 10992.00		
Average Load	80 KW		
Number of electricity units	384 MWh per annum	Assumed for 16 hours a day & 300 days a year	
Savings in - Diesel (Liters) - Diesel (INR) - O&M cost of DG set - CO2 emission	90264 liters INR 4.51 million INR 384000.00 267.40 tones of CO2 equivalent	@ 0.236 liter/KWh @ INR 50 / liter @ Re 1 / KWh / annum @ 73.3 kg of CO2/GJ of diesel consumption	Assuming a heat rate of 9500 KJ/KWh for diesel
Cost per unit - DG Set - Biogas plant	 INR 12.75 / unit INR 2.50 / unit	Costs considered include: - Cost of Biomass – INR 1100/ton - O&M – INR 1.92 lakhs per annum EMI	Biomass required is assumed to be 120 kg/hr

Table 3.2

In most of the Indian villages, DG sets are often the only source of power but power from biomass gasifier based plants is considerably cheaper where ever biomass is available. Even for dual fuel operation where 20 % diesel is used, the generation costs are lower, especially with high running hours and loads. The savings are dramatic when pure gas engines are used. Even when grid power is available, the actual cost of power at the point of consumption is very high largely due to line losses in transmission and distribution with government subsidies and financial losses of DISCOM's taking the brunt.

- The tariff fixed by commissions of different states ranges between INR 2.80 to 5.14 /KWh.
- Let's look at a typical example of a 100 KW biogas power plant (table 3.2).

3.2.2. Bagasse based co-generation projects

Bagasse based Cogeneration allows not only self-sufficiency to a sugar mill but also an increase in the electricity generation capacity of the country.

- The tariff fixed by commissions of different states ranges between INR 3.12 to 4.79 /KWh.
- Let's look at a typical example of a 10 MW bagasse based cogeneration power plant table 3.3).

Description	**Specification**	**Remarks**	**Other remarks**
Plant Capacity	10 MW		
Capital Cost	INR 47.5 Crore	Approximate	
Capital Subsidy	a) INR 66.39 lakhs b) INR 79.67 lakhs c) INR 2.12 – 3.18 crores	a) INR 15 lakhs x (MW capacity)^0.646 b) INR 18 lakhs x (MW capacity)^0.646 c) 40 lakhs to 60 lakhs x (Per MW of surplus power)	a) For all states except NE region, Sikkim, J&K, HP and Uttaranchal (Private Sugar Mills) For special category states viz. NE region, Sikkim, J&K, HP and Uttaranchal (Private Sugar Mills) For co-operative / public sector sugar mills
Capital Cost (after subsidy)	a) INR 46.84 crores	Considering only case (a)	Additionally, fiscal incentives such as 80% accelerated

			depreciation, concessional import duty, excise duty, tax holiday for 10 years, etc. are also available
Equity	a) INR 32.79 crores	70%	
Loan	a) INR 14.05 crores	30%	- Interest Rate – 8% (Why?) - Repayment Period – 10 years
EMI	a) INR 17.05 lakhs		
Captive consumption (MW)	Season – 4.70 MW Off season – 1.68 MW	- Season - 20304 MWh - Off season – 5645 MWh	- 320 days of operation (180 season days and 140 off season days), 24 hrs a day
Exportable surplus capacity, MW	Season – 5.30 MW Off season – 18.32 MW	- Season - 22896 MWh - Off season – 61555 MWh	- 320 days of operation (180 season days and 140 off season days), 24 hrs a day
Savings in CO2 emission	110400 tones of CO2 equivalent	@ 1 kg of CO2 e/KWh	

Table 3.3

3.2.3. Waste to Power (Urban) projects

Approximately, 50000 million tones of solid waste and 2500 million cubic meters of liquid waste are generated every year in the urban areas of the country which can be suitably recycled for power generation.

This is expected to increase at a per capitulate of approximately 1 to 1.33% annually.

By 2025, it is assumed that the urban municipal weight would double the current levels. Waste to power is one answer to this growing problem.

A total of 89.68 MW of electricity generation capacity is installed in India as on date from waste to power (urban) projects. Experts forecast a potential of 1700 – 2500 MW with the recycling of this urban, municipal and industrial waste in large cities and metros which indicates that India has so far realized only about 3 - 4% of its urban waste to energy potential. The capital cost to create this kind of generation capacity is estimated to be under INR 300 crores, resources for which could be generated through municipalities and local governments in metros and large townships with subsidy element coming towards such projects from state governments concern.

This form of energy is, therefore, not only important from the energy security point of view but also from the waste management and disposal point of view.

3.3. Government incentives, promotional policies & depreciation benefits

3.3.1. Scheme to support promotion of grid interactive biomass power and bagasse cogeneration in sugar mills in the country during 12th plan period:

The objectives of the scheme to support promotion of grid interactive biomass power and bagasse cogeneration in sugar mills of the Ministry are given below:-

(a) To promote setting up of biomass power projects with minimum steam pressure configuration of 60 bar and above for power generation (grid interfaced on commercial basis).

(b) To promote cogeneration projects for surplus power generation from bagasse in private/cooperative/public sector sugar mills with minimum steam pressure configuration of 40 bar and above (Grid interfaced on commercial basis).

(c) To promote bagasse cogeneration projects for surplus power generation in cooperative/public sector sugar mills with minimum stream pressure of 60 bar and above, taken up through BOOT/BOLT model by IPPs/State Govt. Undertakings or State Government Joint Venture Company (Grid interfaced on commercial basis).

3.3.2. Eligibility criteria for admissible projects with respect to

a. Types of Biomass Resources

- For biomass power projects:- Biomass will include Agro-based Industrial Residue, wood produced in Energy Plantations or recovered from wild bushes / weeds, wood waste produced in industrial operations; Crop / Agro Residues.
- For bagasse cogeneration projects: Bagasse during crushing season

b. Financing Institutions All registered financial Institutions Development / investment corporations; all nationalized bank, private banks, Central & State Cooperative Banks, State/Public Sector Leasing and Financing corporations.

c. Promoters include individual / independent registered companies, Joint Sector / public sector companies / state agencies and private and public sector investors having technical and managerial capabilities for implementing Biomass Power / Bagasse cogeneration projects on BOOT / BOLT or IPP basis or State Govt. undertaking or Sate Govt. supported Joint Venture Company/SPV Company.

d. Grid connected Biomass Power and Bagasse Cogeneration Projects with the following capacity/parameters will only be eligible under the scheme;

Biomass Power (combustion)	• Minimum 60 bar steam pressure • Maximum of upto 15% use of fossil fuel of total

	energy consumption in K. cals or as per DPR, whichever is less. • For only new boilers and turbines (capacity limited to in accordance with the estimated potential in a state)
Bagasse Co-generation by Private/cooperative / Public Sector Sugar Mill	• Minimum 40 bar steam pressure • Maximum of up to 15% use of fossil fuel of total energy consumption in K. cals. or as per DPR, whichever is less.
Bagasse Cogeneration through BOOT/BOLT model by IPP's /State Govt. undertaking / State Govt. Joint Venture Company	• Minimum 60 bar steam pressure • Maximum of upto 15% use of fossil fuel of total energy consumption in K. cals. or as per DPR, whichever is less, during crushing season. • Minimum export of power – 5 MW.
Bagasse Cogeneration in existing cooperative sugar mill employing boiler modification	• Minimum 40 bar steam pressure. • PPA as per SERC. • Maximum of up to 15% use of fossil fuel of total energy consumption in K. cals. or as per DPR, whichever is less, during crushing season. • Minimum export of power – 3 MW.

Table 3.4

3.3.3. Promotional policies

Besides the Central Financial Assistance mentioned in para 8, fiscal incentives such as 80% accelerated depreciation, concessional import duty, excise duty, tax holiday for 10 years etc., are available for Biomass power projects. The benefit of concessional custom duty and excise duty exemption are available on equipment required for initial setting up of biomass projects based on certification by Ministry. In addition, State Electricity Regulatory Commissions have determined preferential tariffs and Renewable Purchase Standards (RPS). Indian Renewable Energy Development Agency (IREDA) provides loan for setting up biomass power and bagasse cogeneration projects.

3.3.4. Central financial assistance and fiscal incentives

CFA for Biomass Power Project and Bagasse Cogeneration Projects by Private/Joint/Coop./Public Sector Sugar Mills

	Special Category States(NE Region, Sikkim, J&K, HP & Uttaranchal)	Other States

Project Type	Capital Subsidy	Capital Subsidy
Biomass Power projects	Rs.25 lakh X(C MW)^0.646	Rs.20 lakh X (C MW)^0.646
Bagasse Co-generation by Private sugar mills	Rs.18 lakh X(C MW)^0.646	Rs.15 lakh X (C MW)^0.646
Bagasse Co-generation projects by cooperative/ public sector sugar mills 40 bar & above	Rs.40 lakh *	Rs.40 lakh *
60 bar & above	Rs.50 lakh *	Rs.50 lakh *
80 bar & above	Rs.60 lakh *	Rs.60 lakh *
	Per MW of surplus power@ (maximum support Rs. 8.0 crore per project)	Per MW of surplus power@ (maximum support Rs. 8.0 crore per project)

Table 3.5

* For new sugar mills, which are yet to start production and existing sugar mills employing backpressure route/seasonal/incidental cogeneration, which exports surplus power to the grid, subsidies shall be one-half of the level mentioned above.

@ Power generated in a sugar mill (-) power used for captive purpose i.e. net power fed to the grid during season by a sugar mill.

3.3.5. CFA for Bagasse Cogeneration Project in cooperative/ public sector sugar mills implemented by IPPs/State Government Undertakings or State Government Joint Venture Company / Special Purpose Vehicle (Urja Ankur Trust) through BOOT/BOLT model

PROJECT TYPE	MINIMUM CONFIGURATION	CAPITAL SUBSIDY
Single coop. mill through BOOT/BOLT Model	60 bar & above 80 bar & above	Rs.40 L/MW of surplus power *Rs.50 L/MW of surplus power*(maximum support Rs.8.0 crore/ sugar mill)

Table 3.6

* Power generated in a sugar mill (-) power used for captive purpose i.e. Net power fed to the grid during season by a sugar mill.

3.3.6. CFA for Bagasse Cogeneration Project in existing cooperative sector sugar mills employing boiler modifications

PROJECT TYPE	MINIMUM CONFIGURATION	CAPITAL SUBSIDY
Existing Cooperative Sugar Mill	40 bar & above 60 bar & above80 bar & above	Rs.20 L/MW of surplus power * Rs.25 L/MW of surplus power* Rs.30 L/MW of surplus power*

* Power generated in a sugar mill (-) power used for captive purpose i.e. Net power fed to the grid during season by a sugar mill. CFA will be provided to the sugar mills who have not received CFA earlier from MNRE under any of its scheme.

Table 3.7

Note: CFA and Fiscal Incentives are subject to change.

3.3.7. Fiscal Incentives for Biomass Power Generation

Item	Description
Accelerated Depreciation	80% depreciation in the first year can be claimed for the following equipment required for co-generation systems: Back pressure, pass-out, controlled extraction, extraction–cum-condensing turbine for co-generation with pressure boilers Vapour absorption refrigeration systems Organic rankine cycle power systems Low inlet pressures small steam turbines
Income Tax Holiday	Ten years tax holidays.
Customs / Excise Duty	Concessional customs and excise duty exemption for machinery and components for initial setting up of Biomass power projects.
General Sales Tax	Exemption is available in certain States

Table 3.8

3.3.8. Depreciation Benefits

Biomass gasification based power plants can also avail of accelerated depreciation benefits, details of the same are provided below.

Accelerated Depreciation:

According to **IREDA (Indian Renewable Energy Development Agency),** 100 % depreciation in the first year can be claimed for the following power generation equipment

1. Fluidized Bed Boilers
2. Back pressure, pass-out, controlled extraction, extraction and condensing turbine for Power generation with boilers
3. High efficiency boilers
4. Waste heat recovery equipment

According to **MNRE (Ministry of New and Renewable Energy)**

80% depreciation in the first year can be claimed for the following equipment required

1. Back pressure, pass-out, controlled extraction, extraction–cum-condensing turbine for co-generation with pressure boilers
2. Vapour absorption refrigeration systems
3. Organic rankine cycle power systems
4. Low inlet pressures small steam turbines

Income Tax Holiday: Ten years tax holidays.

Customs and Excise Duty: Concessional customs and excise duty exemption for machinery and components for initial setting up of projects.

General Sales Tax: Exemption is available in certa

4. FINDINGS AND ANALYSIS (CASE STUDY, MALWA 7.5 MW POWER PLANT):

4.1. Project detail (Removal of barriers to biomass power generation in India):

With support from the Ministry of New and Renewable Energy, Government of India, this project was aimed to accelerate the use of environmentally sustainable biomass power and co-generation technologies in the country and improve electricity supply through renewable energy sources.

4.2. Project achievements:

- The project supported two categories of model investment projects (MIPs). In the first category, support is being provided to strengthen fuel linkages for existing biomass power projects. In the second category, support is being provided to new green field projects
- Demonstrated stronger fuel linkages for biomass combustion through MIPs, for example: Malwa Biomass Power Plant (MBPL), Muktsar, Punjab, a 7.5-MW biomass combustion based plant has employed close to 1,000 people from neighbouring villages in auxiliary activities such as in sourcing biomass through 25 biomass collection centres. They adopted a combination of fuels such as firewood, cotton stalk, wheat straw, dung cake and waste from saw mills.

- Demonstrated success in co-generation sugar mills, for example:
  With support from the project, Pandurang SSK Ltd, Shreepur, Maharashtra, a 9-MW cooperative cogeneration biomass power plant has demonstrated successfully the use of sugarcane waste as support fuel
- Demonstrated gasification of new projects MIP – new projects gasification with support from MNRE and the project, a 1.2-MW biomass plant set up in Sankheda tehsil in Gujarat has successfully demonstrated the operation of small capacity plants in rural areas using locally available agricultural residue and biomass. Ankur Scientific Pvt. Ltd. has now entered into a power purchase agreement to supply power to the grid and wheel it to M/s Aditya Nuva (Aditya Birla Group)
- As a result of the findings from a study commissioned, biomass power plants under capacity of 15 MW are now considered green projects, and are therefore exempt from environment impact assessments
- The project supported the preparation of a biomass roadmap which envisages adding

about 5,700 MW of biomass power by 2017, and a cumulative 20,000 MW by 2022

- Knowledge sharing enabled through a quarterly magazine on biomass power technologies, policy and regulatory issues and best practices published since 2009

4.3. Funding Support by

Donor Name	Amount Contributed
Global Environment Facility (GEF)	US$ 5,650,000

Table 4.1

4.4. Expenditure in Previous Fiscal Years

Year	Amount
2014	US$ 351,931
2013	US$ 258,530
2012	US$ 118,015
2011	US$ 359,856
2010	US$ -372,029
2009	US$ 367,566
2008	US$ 1,073,330
2008	US$ 594,870

Table 4.2

5. INTERPRETATION OF RESULTS

5.1. Success story of Sunkheda 1.2 MW Biomass power plant

In year 2013, The Union Ministry of New and Renewable Energy (MNRE) took a busload of entrepreneurs, academicians and experts in the field of renewable energy (RE) to the tribal belt of Sankheda taluka in Vadodara, for a field visit to the country's first gasification based 1.2MW biomass to power generation plant, named **Ankur Scientific Power Plant**.

However, what is mostly unknown about this two-year old, home grown, clean energy, sustainable, decentralized, third-party, grid connected power generation plant- the first of its kind venture in India-is that the technology used in the plant is also made by the owners, whose 80% of machinery is exported abroad. And, therein, lies the irony.

"The plant's feedstock comes from the crop residues of the common crops available in the 20km radius of the site, like cotton, tur and castor stalks and corncobs. The concept prevents burning of stalks in the field, and, rather, gives money to the farmers for selling this residue to us. It has also given birth to a chain of entrepreneurs among locals for secured and sustained fuel supply. Biochar, the by-product after power generation, is also sold back to farmers either for using as kitchen fuel or for enriching soil for the next sowing. But, despite this win-win concept in an agrarian country, the technology is not getting its due promotion for various reasons, including the preference for solar and wind power projects," asserts managing director Ankur Jain of Ankur Scientific Energy Technologies, manufacturers of the equipment.
The irony, is that the green power generation equipment plant, which was set up by his father, Dr B C Jain -- an alumnus of BITs Pilani and MIT Cambridge, who came back from the US in 1977, leaving a lucrative job behind to work in India-has helped set up similar plants of various capacities, more in countries abroad than in India.

Earlier he presented at MNRE and UNDP organized workshop on biomass power generation showed how the plant had bought feedstock from farmers and helped give employment to 60 locals, thereby, ploughing back nearly Rs 4 crore to the rural economy. Extension activities helped farmers to use biochar. "But, conditions like no payment for power feed above plant rating, difficulties in scheduling as stipulated by authorities and confusion within bureaucracy for any new venture, are some of the reasons why entrepreneurs get discouraged.

Apparently, India happens to have toughest of regulations which also prevents such plants for breaking even within 3-5 years, which is the norm in other countries.

Director, MNRE, V K Jain hopes Sankheda example would help more entrepreneurs become encouraged to set up similar plants in the country.

6. CONCLUSION AND SCOPE FOR FUTURE WORK

When seen from the limited perspective of standing crop, theoretical replenishabitity, and 'carbon neutral' character as a fuel, biomass appears to be a very attractive source of renewable energy. Biomass energy is indeed a sustainable option, and has proved to be so for thousands of years, but only as long as it is used to a very limited extent. The picture begins to change once the environment norms become stringent and likely impacts of biomass energy generation and utilization on the large scale presently envisaged are considered.

This report estimates the different forms of biomass that are theoretically utilizable as source of energy and catalogues the technological routes presently available to effect the utilization.

Moreover, the quantity of fossil fuel saved in the course of the production and the utilization of biofuels is not always greater than the quantity of fossil fuels used. These factors, besides the environmental degradation and ecological disruptions caused in the course of large-scale biomass cultivation, put serious question marks on the sustainability of the existing biomass-to-energy programmes.

Modernization in biomass energy use in India has happened in the last two decades along three routes –

i) improvement of technologies in traditional biomass applications such as for cooking and rural industries,

ii) process development for conversion of raw biomass to superior fuels (such as liquid fuels, gas and briquettes), and

iii) penetration of biomass based electricity generation technologies. These developments have opened new avenues for biomass energy in India.

Biomass use is growing globally. Despite advancements in biomass energy technologies, most bioenergy consumption in India still remains confined to traditional uses. The modern technologies offer possibilities to convert biomass into synthetic gaseous or liquid fuels (like ethanol and methanol) and electricity (Johansson et al, 1993). Lack of biomass energy market has been the primary barrier to the penetration of modern biomass technologies. Growing experience with modern biomass technologies in India suggests that technology push policies need to be substituted or augmented by market pull policies.

Land supply, enhanced biomass productivity, economic operations of plantations and logistics infrastructure are critical areas which shall determine future of biomass in India. Policy support for a transition towards a biomass based civilization in India should consider the following:

Short-term Policies (1 to 5 years):

i) Enhanced utilization of crop residues and wood waste,

ii) Information dissemination,

iii) Niche applications (e.g. remote and biomass rich locations),

iv) Technology transfer (e.g. high pressure boiler),

v) Co-ordination among institutions,

vi) Demonstration projects,

vii) Participation of private sector, community and NGOs,

viii) Waste land development, and

ix) Subsidy to biomass technologies to balance the implicit subsidies to fossil fuels.

Medium Term (5 to 20 years):

i) R&D of conversion technologies,

ii) Species research to Match agroclimatic conditions,

iii) Biomass Plantation,

iv) Scale economy based technologies,

v) Local Institutional Developments, and

vi) Removal of distortions in fossil energy tariffs.

Long term (over 20 years):

i) Infrastructure (logistics, T&D),

ii) Multiple biomass energy products (e.g. gas, liquid, electricity),

iii) Institutions and policies for competitive biomass energy service market, and

iv) Land supply for biomass generation

The government policies in India during the next decade shall play decisive role in penetration of biomass energy. Global climate change policies shall also have significant influence on future of biomass. Myriad economic, social, technological and institutional barriers remain to be overcome. Future of biomass technologies depends on will and ability to overcome these barriers. A key issue before Indian policy makers is to develop a fair market for biomass energy services.

As per our ex President of India Late Dr. APJ Abdul Kalam, our country has a huge potential of tapping energy from biomass, and rightly so we have been gone through this report. Both Biogas and bagasse based Co-generation power plants have a payback period of **7 – 12 years** with REC, Carbon credits and CDM mechanisms which may help to further reduce it. So, what is stopping us to promote, propagate, produce and purchase bio energy to its 100% potential?

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