Symmetrical Analysis of Bio Mass Gasification Techniques

Abstract: *Modern age of agriculture is an extremely energy productive process. High agricultural productivities and subsequently the growth of green revolution have been made possible only by large amount of energy inputs, especially those from primary fossil fuels [1]. With recent price variation and scarcity of these fuels there has been a trend towards use of alternative energy sources like solar, wind, geothermal etc [2]. However these energy resources have not been able to provide an economically viable solution for agricultural applications. Biomass energy based system, which has been proven reliable and had been extensively & widely used for transportation and on farm systems during World War II is wood or biomass gasification. Biomass gasification means incomplete combustion of biomass resulting in production of combustible gases consisting of Carbon monoxide (CO), and traces of Methane (CH_4),Hydrogen (H_2).This mixture is called generator gas. generator gas can be used to run internal engines (both compression and spark ignition), and can be used as substitute for furnace oil. in direct heat applications and can be used to produce, since any biomass material can undergo gasification, which is much more attractive than ethanol production or biogas where only selected biomass materials produce the fuel. It focused on improving efficiency of traditional available technologies, enhancing supply of biomass, introducing modern biomass technologies to provide reliable energy services at competitive prices [3]. In this paper symmetrical analysis of techniques available for gasification has been done.*

Keywords*: Biomass, Gasification, biofuels, Incineration*

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1 INTRODUCTION

Biomass is a renewable energy resource derived from the carbonaceous waste of various human and natural activities. It is derived from numerous sources, including the by-products from the timber industry, agricultural crops, raw material from the forest, major parts of household waste and wood [4]. Biomass is an important source of energy and the most important fuel worldwide after coal, oil and natural gas. Biomass fuels used in India account for about one third of the total fuel used in the country, being the most important fuel used in over 90% of the rural households and about 15% of the urban households.

The plants fix solar energy through the process of photosynthesis to produce biomass. This biomass passes through various cycles producing different forms of energy sources. For example, fodder for animals that in turn produce dung, agricultural waste for cooking. The current availability of biomass in India is estimated at about 120-150 million MT per annum covering agricultural and forestry residues corresponding to a potential of 16,000 MW. Existing waste-to-energy facilities must be in compliance with all applicable environmental regulations [4].

As per the National Biomass Resource Atlas prepared by the Indian Institute of Science, Bangalore, under a project sponsored by the Ministry, a cumulative biomass power potential of about 18,000 MWe from surplus agro-residues has been estimated in the country.The total technical biomass potential from residues and energy crops in India is estimated to be around 66,880MW.

2. THEORY OF GASIFICATION

Gasification of biomass can be done by thermal or by bio conversion techniques. In the thermal process, the production of generator gas (producer gas) is due to partial combustion of solid fuel (biomass) and takes place at temperatures of about 1000^{o}C.

The reactor is called a gasifier in which the biomass is gasified in to energy rich gas having composition of CO, CH_4, H_2 etc, which is generated by incomplete combustion of biomass. Complete combustion of biomass generally contain nitrogen, water vapor, carbon dioxide and surplus of oxygen [5].

3. TECHNOLOGY FOR PRODUCTIVE USE OF BIOMASS

Technologies that enable efficient use of biomass are becoming prevalent in rural areas.

The efficiency of fuel usage is increased by

- Use of improved designs of stoves which double the efficiency such as smokeless energy efficient chulhas.
- Compressing the biomass to form briquettes which not only occupy lesser space but also are more efficient.
- Conversion of organic matter into biogas through anaerobic digestion which apart from meeting fuel needs also gives digested manure for farms.
- conversion of biomass into producer gas through partial combustion of biomass under controlled air supply

4. BIOFUELS

Biofuels are predominantly produced from biomass feed stocks or as a by-product from the industrial processing of agricultural or food products, or from the recovery and reprocessing of products such as cooking and vegetable oil. Biofuel contains no petroleum, but it can be blended at any level with petroleum fuel to create a biofuel blend. It can be used in conventional healing equipment or diesel engine with no major modification. Biofuel is simple to use, biodegradable, non-toxic and essentially free of Sulphur and aroma.

A. Bio Mass Resources

a) Herbaceous Energy Crops

Herbaceous energy crops are perennials that are harvested annually after taking two to three years to reach full productivity. These include such grasses as switch grass, miscanthus (also known as Elephant grass or e-grass), bamboo, sweet sorghum, tall fescue, kochia, wheatgrass, and others.

b) Woody Energy Crops

Woody crops are fast growing hardwood trees harvested within five to eight years after planting. These include hybrid poplar, hybrid willow, silver maple, eastern cottonwood, green ash, black walnut, sweet gum, and sycamore.

c) Industrial Crops

Industrial crops are being developed and grown to produce specific industrial chemicals or materials.Examples include kenaf and straws for fiber, and castor for ricinoleic acid.

d) Agricultural Crops

These feed stocks include the currently available commodity products such as cornstarch and corn oil; soybean oil and meal; wheat starch, other vegetable oils, and any newly developed component of future commodity crops. They generally yield sugars, oils, and extractives, although they can also be used to produce plastics and other chemicals and products.

e) Aquatic Crops

A wide variety of aquatic biomass resources exist such as algae, giant kelp, other seaweed, and marine microflora. Commercial examples include giant kelp extracts for thickeners and food additives, algal dyes, and novel biocatalysts for use in bioprocessing under extreme environments.

f) Agriculture Crop Residues

Agriculture crop residues include biomass, primarily stalks and leave, not harvested or removed from the fields in commercial use. Examples include corn stover (stalks, leaves, husks and cobs), wheat straw, and rice straw. With approximately 80 million acres of corn planted annually, corn stover is expected to become a major biomass resource for bioenergy applications

g) Forestry Residues

Forestry residues include biomass not harvested or removed from logging sites in commercial hardwood and softwood stands as well as material resulting from forest management operations such as pre-commercial thinning and removal of dead and dying trees.

h) Municipal Waste

Residential, commercial, and institutional post-consumer wastes contain a significant proportion of plant derived organic material that constitutes a renewable energy resource. Waste paper, cardboard, wood waste and yard wastes are examples of biomass resources in municipal wastes.

i) Biomass Processing Residues

All processing of biomass yields by products and waste streams collectively called residues, which have significant energy potential.[6] Residues are simple to use because they have already been collected. For example, processing of wood for products or pulp produces sawdust and collection of bark, branches and leaves/needles.

j) Animal Wastes

Farms and animal processing operations create animal wastes that constitute a complex source of organic materials with environmental consequences. These wastes can be used to make many products, including energy.

B. Optimum Yields per Hectare

- Producer Gas: 40,000 cum @ 2500 cum/MT of dry wood
- Bio Fuel: 1.5 Tons @ 300 Kg/MT of Oil Seeds

C. Optimum Energy Yields Per Hectere

- Producer Gas : 16 MWh Electricity + 14 million Kcal Thermal (for Combined heat and power-CHP)
- Bio Gas : 20 MWh Electricity + 18 million Kcal Thermal (CHP)
- Bio Fuel : 5.4 MWh Electricity + 6 million Kcal Thermal (CHP*)*

Biomass if duly processed, can be used as a replacement to fossil fuel in field proven equipment

- Rankine Cycle

  Biomass Boilers + Steam Turbines

- Otto Cycle

  Gas Engines (with upstream Biomass Gasifiers/ Bio-gas Plants)

- Bratyon Cycle
- Gas Turbines (with upstream Bio-Oil Refinery pyrolysis unit

5. BIOMASS – INDIAN SCENERIO

Biomass contributes to about 14% of the total energy supply worldwide. India, being a tropical country, has tremendous potential for energy generation through biomass and its residues. Biomass energy is normally produced from firewood, agricultural residues such as bagasse, crop stalks, animal dung and wastes generated from agro-based industries.[11] In India, biomass energy is being utilized mainly for domestic, commercial and industrial applications. Globally, India is in the fourth position in generating power through biomass and with a huge potential, is poised to become a world leader in utilization of biomass. Over 40 percent still lack access to electricity, 74 percent or rural India depend on biomass, and most of the growth in electricity consumption has served the upper and middle classes

- MNRE estimate for 2032, includes 73,000 MW for Biomass (including Bagasse Cogeneration and Waste to Energy)

Table 1: Estimated potential for Power generation from renewable energy sources by the year 2032 (source MNRE)

Sources/Systems	Estimated potential- MW
Wind	45000
Bio-Power (Agro residues)	61000
Co-generation Bagasse	5000
Small Hydro (up to 25 MW)	15000
Solar Photovoltaic	50000
Waste to Energy	7000
TOTAL	183000

6. BIOMASS ENERGY AND COGENERATION

The availability of biomass in India is estimated at about 540 million tons per year covering residues from agriculture, forestry, and plantations. Principal agricultural residues include rice husk, rice straw, bagasse, sugar cane tops and leaves, trash, groundnut shells, cotton stalks, mustard stalks, etc. It has been estimated that about 70- 75% of these wastes are used as fodder, as fuel for domestic cooking and for other economic purposes leaving behind 120- 150 million tons of usable agricultural residues per year which could be made available for power generation [5]. By using these surplus agricultural residues, more than 16,000 MW of grid quality power can be generated with presently available technologies. In addition, about 5000 MW of power can be produced, if all the 550 sugar mills in the country switch over to modern techniques of co-generation. Thus, the country is considered to have a biomass power potential of about 21,000 MW. The gas was found to be similar to synthesis gas from coal and presented no difficulty in synthesis [6].

7. BIOMASS GASIFICATION

Biomass Gasification process yields producer gas as a result of a thermo- chemical reaction. This producer gas contains, by volume, 13- 15% hydrogen, 18- 25% carbon mono- oxide, 5- 10% carbon dioxide and 48-54% nitrogen. Its calorific value is 5,500kJ/Nm^3. The gas can either be burnt directly for thermal applications or used in dual- fuel or 100% gas engines for mechanical and electrical applications.

A number of gasification and biomass briquetting technologies have been indigenously developed. Some leading institutions in India are being supported to conduct research and development to further improve these technologies. India today ranks among the technology leaders in the world. Biomass gasifiers capable of producing power from a few KW up to 550 KW have been developed indigenously. They have successfully undergone stringent testing abroad, and are being exported to countries in Asia, Latin America, Europe and USA. A large number of installations for providing power to small scale industries and for electrification of a village or group of villages have been undertaken.

Table 2: Biomass Gasification Initiatives in India {Achievements as on 31.12.2009}

	Achievements during 2009-10 (up to 31.12.2009)	Cumulative Achievements up to 2009
Grid-interactive: Biomass Power (Agro residues)	131.50 MW	834.30 MW
Off-grid/Distributed Renewable Power (including Captive/ CHP plants): A. Biomass Power / Cogen.(non-bagasse)	39. 8 MW	210.57 MW
Biomass Gasifier	4.10 MWeq.	109.62 MWeq

A. Incineration

- It is the process of direct burning of biomass in the presence of excess air (oxygen) at temperatures of about 800°C and above, liberating heat energy, inert gases and ash.
- Controlled combustion of waste.

B. Combustion technologies available:

- Unprocessed solid waste combustion technology (also known as mass burning)
- Processed solid waste combustion technology (also known as RDF burning).

Merits

- Thermal Energy recovery for direct heating / power generation
- Relatively noiseless and odorless and Hygienic
- Low land area requirement
- Can be located within city limits, reducing cost of waste transportation.

Demerits

- High Capital and O & M Cost.
- Ash disposal problem
- Least suitable for high moisture content.

C. Anaerobic Digestion

- Organic fraction kept in hydrolysis tank for breaking into smaller molecules
- Hydrolyzed fraction is digested in bio-reactor to produce combustible gas i.e. methane
- Gas feed to gas engine for power

Merits

- Biogas & Compost are obtained
- No release of GHG to environment
- No problem of real estate loss

Demerits

- It is a slow process and cannot accept impulse loading

- Non-biodegradable organic fraction cannot be digested

8. GASIFICATION TECHNOLOGY

Biomass gasification can be used for both thermal and electrical applications.

- Biomass gasification is a process of converting biomass to a combustible gas in a reactor, known as gasifier, under controlled conditions.
- The combustible gas, known as producer gas has a composition of approx. 19% CO, 10% CO2, 50% N2, 18% H2 and 3% CH4.This gas which has a calorific value of 4.5 - 5.0 MJ/cubic meter is then cooled and cleaned prior to combustion in internal combustion engines for power generation purposes.
- Generally, firewood, agricultural residues such as rice husk, cashew shell etc., are being used in biomass gasifiers. In India, there is wide range of gasifiers available with capacities varying from 20 kW to 500 kW for electrical applications. Largest biomass thermal gasifier used in India for industrial application has been of 1.0 MW capacity. This has substituted conventional fuel (furnace oil).
- Thermal gasifiers finds applications in industries like steel re-rolling, engineering industries, tiles manufacturing, brick kilns, chemical Industries and characteristics of biomass is given here[7].

A. *Why gasify biomass?*

- Producer gas can be used as a fuel in place of diesel in suitably designed/adopted internal combustion (IC) engines coupled with generators for electricity generation.
- Producer gas can replace conventional forms of energy such as oil in many heating applications in the industry.
- The gasification process renders use of biomass relatively clean and acceptable in environmental terms.
- Large monetary savings can be obtained through even partial substitution of diesel in existing diesel generator (DG) sets.

Most commonly available gasifiers use wood/ woody biomass; some can use rice husk as well. Many other non-woody biomass materials can also be gasified, although gasifiers have to be specially designed to suit these materials and the biomass may have to be compacted in many cases.

Table 3: Biomass Characteristics

	Bagasse	Paddy Straw	Rice Husk	Coconut Husk	Cotton Stalk
Carbon	23.50	44.7	39.6	39.4	45.67
Hydrogen	3.40	3.94	4.45	4.86	3.85
Nitrogen	0.00	0.47	2.55	2.12	0.1
Ash	1.50	15.87	17.4	7.36	4.48
Moisture	50.00	5.52	3.6	13.33	13.89
Sulphur	0.05	0.96	0.1	0.08	0.16
Oxygen	21.55	28.54	32.3	32.85	31.85
GCV [Kcal/Kg]	2270	3400	3250	3602	3740

B. *Types of gasifiers*

1. Slagging gasifier & Non-Slagging gasifier (on basis of ash removal)
2. Up-draft gasifier & Down-draft gasifier (on the basis of gas flow)

Gasifiers can be of ‘updraft’ or ‘downdraft’ types. In the downdraft type of gasifier, fuel and air move in a co-current manner. In updraft gasifiers, fuel and air move in counter-current manner. However, the basic reaction zones remain the same.

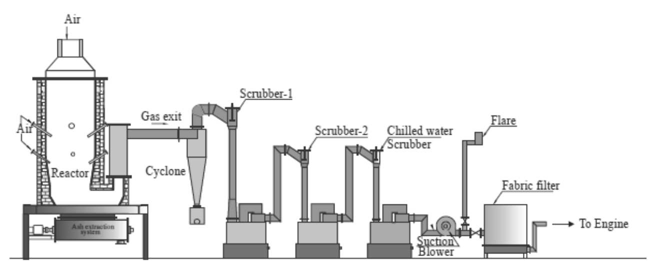

Fig. 1

Fuel is loaded into the reactor from the top. As the fuel moves down, it is subjected to drying and pyrolysis. Air is injected into the reactor in the oxidation zone, and through the partial combustion of pyrolysis products and solid biomass, the temperature rises to 1100 °C. Syngas (H_2 and CO) can be produced from bio-oil by two gasification processes, also called reforming processes [9]. This helps in breaking down heavier hydrocarbons and tars. As these products move downwards, they enter the reduction zone where producer gas is formed by the action of carbon dioxide and water vapour on red-hot charcoal. The hot and dirty gas is passed through a system of coolers, cleaners, and filters before it is sent to engines

The clean producer gas can be used for electrical power generation, either through dual-fuel IC engines (where diesel oil is replaced to an extent of 60%–80%), or through 100% gas-fired spark ignition engines. The producer gas can also be used for heating to replace conventional forms of energy in many applications like small boilers, furnaces, hot air generators, dryers, etc [12].

Biomass gasifier-based systems are being made in capacities ranging from a few kilowatts to a megawatt of electricity equivalent. For heating applications, the current upper limit on the unit size is equivalent to 200–300 kg/h of oil consumption.

The typical costs of biomass gasifier-based electricity generation systems range from Rs 4 crores/ MWe to Rs 4.5 crores/MWe. The cost of power generation depends on cost of biomass, plant load factor, etc., and is estimated to be between Rs 2.50/kWh and Rs 3.50/kWh. Hydrogen yield increases with temperature via steam reforming of CH_4 and C_2H_2 and with water gas shift reaction For thermal applications, the capital costs are estimated to be about Rs 0.5–0.7 crores for each 1 million kcal capacity[9].

C. *Wood Gasifier*

This system is meant for biomass having density in excess of 250 kg/m3. Theoretically, the ratio of air-to-fuel required for the complete combustion of the wood, defined as stoichiometric combustion is 6:1 to 6.5:1, with the end products being CO_2 and H_2O. Whereas, in gasification the combustion is carried at sub-stoichiometric conditions with air-to-fuel ratio being 1.5:1 to 1.8:1. The elemental stage of CH_4 –(17.90 - 17.90) kcal/mol @ 298°K, (44.49 44.46) cal/mol-k @298° K[10].

The product gas thus generated during the gasification process is combustible. This process is made possible in a device called gasified, in a limited supply of air. A gasifier system (Fig. 1) basically comprises of a reactor where the gas is generated, and is followed by a cooling and cleaning train which cools and cleans the gas. The clean combustible gas is available for power generation in diesel-gen-set. Whereas, for thermal use the gas from the reactor can be directly fed to the combustor using an ejector

D. GASIFIER FUEL CHARACTERISTICS

Almost any carbonaceous or biomass fuel can be gasified under experimental or laboratory conditions. However the real test for a good gasifier is not whether a combustible gas can be generated by burning a biomass fuel with 20-40% stoichiometric air but that a reliable gas producer can be made which can also be economically attractive to the customer. Towards this goal the fuel characteristics have to be evaluated and fuel processing done. The gas leaves the gas producer at a moderate temperature and is practically tar free. Final cleaning,mainly from dust, is carried out by a very simple and cheap three stages system, made up of a cooling and scrubbing unit, a demister and a final filter [7].

Many a gasifier manufacturers claim that a gasifier is available which can gasify any fuel. There is no such thing as a universal gasifier. A gasifier is very fuel specific and it is tailored around a fuel rather than the other way round.

9. GASIFIER SPECIFICATION

Table 4: Comparasion between Bagasse and Biomass fired boiler

Particulars	Conventional Bagasse fired Boiler	Biomass fired Boiler
Boiler Parameters	50 TPH, 67 kg/cm2, 510 Deg C	50 TPH, 67 kg/cm2, 475 Deg C
Grate Area (m^2)	23.70	28.15
Furnace Exist Gas temp. (Deg C)	880	775
Furnace Height (meter)	16.5	19
Superheater Area ($meter^2$)	581	712
Superheater pitch (mm)	110/132	154 /132

A. *Benefit From Biomass*

Energy security: Domestic biomass energy could help our nation to substantially reduce dependence on fossil fuels. In table 4 comparison of Bagasse and Biomass fired boiler is given. Rural economic growth: Biomass energy could stimulate growth in farming, forestry and rural industry leading to overall rural development. Open-loop biomass from a forestry source is any waste material (solid, cellulosic or lignin) derived

Table 5: Gasifier Specificatio

Parameter	100kWe	20kWe
Power rating	100kWe	20 KWe
Reactor	Ceramic & Stainless Steel	
Feed stock	Density is over 300 kg/m3, having a moisture content of 10-15%, (Max 20%) cut to Sizes up to 60 mm-a mix of Sizes	
Turn Down Ratio	4	
Gas Consumption	CO:20+-1%; H2:20+-1%,CH4:3+-1%, CO2:12+-1% and the rest N2	
Lower Calorific Value of Gas	4.6+0.2 MJ/Kg	
Cooling water	60/30 LPM	60/30 LPM
Filter	250 μm sized sand particles	
Over all dimension (for Gasifier only)	5 m (length) × 4 m (wide) × 6 m (height)	4 m (length)× 4m (wide) × 6 m (height)
Wood Consumption Rate	1.0-0.1 Kg/Kwh	
Application	To be used as a fuel gas for operating diesel engine on dual fuel mode. The motive power thus generated could be used for shaft power application or for electrical power generation, to be used either for captive consumption or grid paralleling. The Extent of diesel saved is 80-85% at nominal loads	

from "mill and harvesting residues, precommercial thinnings, slash, and brush [11]. Biomass energy could also provide a productive avenue for using agricultural and forestry wastes, besides plantations.

Biogas comprises of 60-65% methane, 35-40% carbon dioxide, 0.5-1.0% hydrogen sulphide, rests of water vapors etc. It is almost 20% lighter than air. Biogas, like Liquefied Petroleum Gas (LPG) cannot be converted into liquid state under normal temperature and pressure. Removing carbon dioxide, Hydrogen Sulfide, moisture and compressing it into cylinders makes it easily usable for transport applications & also for stationary applications [13].

Table 6: Average Lower Heating Values

Fuel	Moisture conent, % dry basis	Lower heating value, MJ/kg
Wood	20-25	13-15
Charcoal	2-7	29-30
Peat	35-50	12-14
Coconut husks	5-10	16-17
Rice hulls	9-11	13-15
Wheat straw	15	18-19

The main components of biogas bottling projects (BGFP) are given below:

a) Pre-treatment system
b) Biogas generation system
c) Biogas Storage system
d) Biogas purification system
e) Biogas Bottling system
f) Slurry handling system etc.

The first biogas bottling project sanctioned to Ashoka Biogreen Pvt. Ltd. of 500 m3/day capacity at Vill.- Talwade, Dist.-Nashik (Maharashtra) was commissioned on 16.03.2011.So far 21 numbers of BGFP projects with aggregate capacity of 37016 cubic meters per day have been sanctioned in ten states namely Chhattisgarh, Gujarat, Haryana, Karnataka, Maharashtra, Punjab, Madhya Pradesh, Andhra Pradesh, Uttar Pradesh and Rajasthan for their implementation

During the year 2008-09, a new initiative was taken for demonstration of Integrated Technology-package, in entrepreneurial mode, for installation of medium size mixed feed biogas fertilizer plants (BGFP) for generation, purification/ enrichment, bottling and piped distribution of biogas under RDD&D policy of MNRE. Installation of such plants aims at production of CNG quality of Compressed Biogas (CBG) to be used as vehicular fuel in addition to meeting stationary & motive power and electricity generation needs in a decentralized manner through establishment of a sustainable business model in this sector.

CONCLUSION

There is a huge potential of installation of medium size biogas plants in various villages and other areas and agro/ food processing industry of the country. There are many option for bio mass gasification technology. Analysis done in this paper may be helpful to the people in technology selection.

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