Insights into Biomass Gasification Technology

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1. Need for development of Biomass Gasification based power plants:

India is the sixth largest energy consumer in the world, consuming about 3 per cent of the world's total energy per year. With a population of over one billion people living in an area of just under 3 million km², it is the second most populous country in the world next only to China. The population growth, coupled with continued economic growth, is driving energy demand to levels above the country's production capacity. Tough the annual electricity generation and consumption have nearly doubled since 1990 i.e. from 275.5 billion kilowatt-hours (kWh) to 547.2 kWh in 2004, the country has been facing peak level electricity shortage to the extent of 11-18 percent. Of the half a million or so villages in India, about 80,000 remain completely un-electrified. Thus there is a need for development of long term sustainable solutions so that the non electrified villages have reliable, regular, adequate, or good quality power. Biomass gasification based decentralized standalone power plants is one of the solution for mitigating the problem.

2. Biomass Gasification:

Biomass gasification is a process wherein solid biomass fuel are broken in an oxygen-starved environment by the application of heat to produce a mixture of combustible gas. Fuels which are conducive to biomass gasification include dry materials such as dry wood, dried leaf, charcoal, rice husks, bagasse and coconut shells. The basic difference between biomass gasification and biogas production is that in biogas production wet organic feedstocks such as animal dung or stillage are worked upon by microbes for generating methane gas.

3. Components of a Biomass Gasification System:

The main component of the biomass gasification system is primarily the Reactor. It is basically a container into which fuel/feed stock is fed along with a limited (less than stoichiometric, that required for complete combustion) supply of air. The heat that is required for gasification is generated through partial combustion of the feed material. This incomplete combustion leads to chemical breakdown of the fuel through internal reactions resulting in production of a combustible gas usually called *Producer Gas.* The calorific value of this gas varies between 4.0 and 6.0 MJ/Nm³ or about 10 to 15 percent of the heating value of natural gas. Producer gas from different fuels produced in different gasifier types may considerably vary in composition. However, it consists always of a mixture of the combustible gases namely Hydrogen (H_2), Carbon Monoxide (CO), and Methane (CH_4) as well as incombustible gases such as Carbon Dioxide (CO_2) and Nitrogen (N_2). Because of the presence of CO, producer gas is toxic in nature. In its raw form, the gas tends to be extremely dirty, containing significant quantities of tars, soot, ash and water.

Reactors/ gasifiers can be of fixed-bed bed type, fluidized-bed or entrained flow type. However, for small scale

The different fixed-bed reactor types are often characterized by the direction of the gas flow through the reactor. Based on it they can be classified into :

1. Upward Gas Flow
2. Downward Gas Flow
3. Horizontal Gas Flow

or

on the respective directions of the solid flow and gas stream. Based on it they can be classified into:

1. Co-current Flow Type
2. Counter-current Flow Type
3. Cross–current Flow Type

In all the three types of reactors, the biomass fuel is fed in at the top of the reactor. The fuel then slowly moves down by gravity. During this downward

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movement, the fuel reacts with air (the gasification agent), which is supplied by the suction of a blower or an engine and is converted into combustible producer gas in a complex series of oxidation, reduction, and pyrolysis reactions. Ash is removed from the bottom of the reactor.

Updraft Gasifiers: Updraft gasifiers which use wood and other biomass as fuel, produce a hot gas (300-600^0 C) containing large amount of pyrolysis tar as well as ash and soot. This hot gas is suitable for direct combustion in a gas burner. However, for engine applications, the gas must be cooled, scoured of soot and ash, and cleaned of tars by condensation or any another method. Because the tars represent a considerable part of the heating value of the original fuel, removing them gives this process a low energy efficiency.

Downdraft Gasifiers: The temperature of the gas produced in these types of gasifiers has a temperature produce a hot (700-750^0 C), tar-free gas from wood and other biomass. After cooling and cleaning from ash and soot, the gas is suitable for use in internal combustion engines. Cross-draft gasifiers only produce a tar-free engine gas if fueled with good-quality charcoal (i.e. charcoal with a low content of volatile matter).

Typical Gas Composition for Different Fuels and Reactor Types:

Table- I

Gasifier type (moisture in feed - % wet basis)	Updraft: wood (10-20 %)	Downdraft: wood (10-20%)	Cross-draft: charcoal (5-10 %)
Hydrogen	8-14 %	12-20 %	5-10 %
Carbon monoxide	20-30 %	15-22 %	20-30 %
Methane	2-3 %	1-3 %	0.5-2 %
Carbon dioxide	5-10 %	8-15 %	2-8 %
Nitrogen	45-55 %	45-55 %	55-60 %
Oxygen 1-3 %	1-3 %	1-3 %	
Moisture in gas Nm^3H_2O/Nm^3 dry gas	0.20-0.30 %	0.06-0.12 %	<0.3 %
Tar in gas g/Nm^3 dry gas	2-10	0.1-3	<0.3
Lower heating value MJ/Nm^3 dry gas	5.3-6.0	4.5-5.5	4.0-5.2

Note : MJ = megajoule; Nm^3 = normal cubic meter.
(Source: World Bank Technical PaperNo. 296- Energy Series)

4. The "Turn-Down Ratio" Concept in Downdraft Gasifiers:

The downdraft reactors are not able to achieve tar-free gas production over the whole range of possible operating conditions. The lower the gas production (and the temperature) of the reactor, more likely it is that the producer gas will be laden with tar and sooth thereby making it unacceptable for direct use in internal combustion engines. This phenomenon is characterized by the value of the *"turn-down ratio"* . Turn–Down Ratio is defined as that minimum gas flow at which trouble-free operation of the internal combustion engine with acceptable level of tar production is possible. It is expressed as a ratio of minimum gas flow rate required for trouble free engine operation with acceptable level of tar content to the maximum gas flow for which the reactor is designed. Thus, a turn-down ratio of 1:3 means, that the minimum gas flow at which the gas can be directly applied in an engine is equal to one-third of maximum gas flow, which (in a well-matched gasifier / engine design) is also defined as the gas flow rate desired at maximum power output of the engine. If the gas production rate from the reactor is lower than the turn down ratio for long periods, then the engine used in combination with reactor is likely to get damaged due to excessive wear and tear due to tar contamination.

5. Application of Producer gas- Power Gasifiers and Heat Gasifiers:

Producer gas can be utilized successfully in several applications. Some of them are:

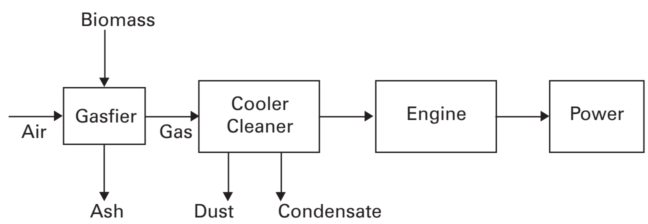
1. Application as fuel for running internal combustion (IC) engines to produce shaft power for generating electricity, water pumping, grain milling, sawing of timber *etc.* In such applications, the system is called power gasifier.
2. Application of producer gas to fuel external burners to produce heat for boilers, dryers, ovens, or kilns. In such applications, the gasifier is referred to as heat gasifier.

Because the two have different end-products, power and heat gasifiers are aimed at very different markets. One of the principal technical differences is that power gasifiers must produce clean gas because of the stringent fuel-quality demands of an IC engine.

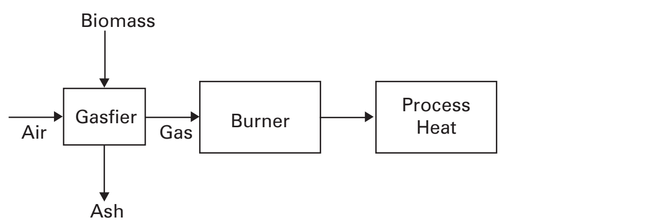
Thus, the resulting producer gas must be filtered, cooled, and conditioned in a gas-conditioning system, which is an integral part of a power gasifier. In contrast, producer gas undergoing combustion in external burners requires little or no gas conditioning. Because they do not require elaborate gas filtering and cleaning systems, heat gasifiers are less costly , simple to design, operate and maintain compared with power gasifiers.

The methodology used for describing the output of power and heat gasifiers also varies. The power output of a power gasifier is usually stated in terms of the **"Peak Electric Power (kW_{el}) "** that it can produce when connected to a generator set primed with an IC engine. In contrast, the power output of a heat gasifier is usually described as **"Thermal Value (kW_{th})"** of the gas produced at maximum output. Typical configurations of power and heat gasifiers are as shown below:

Thermal Value (kW_{th})



A Gasifier System for Power Generation
(Source: World Bank Technical PaperNo. 296- Energy Series)



A Gasifier System for Heat Generation
(Source: World Bank Technical PaperNo. 296- Energy Series)

6. Types and Characteristics of Engines Using Producer Gas

Spark-ignition or "Petrol" engines as well as compression ignition or "Diesel" engines can be operated using producer gas. Petrol engines can be operated solely using producer gas whereas in Diesel engines, the same must be operated on a "duel fuel mode" using a mixture of diesel fuel and producer gas. The latter requirement complicates the use of producer gas in diesel engines.

The temperature of the producer gas influences the power output that can be derived from a producer-gas operated IC engine. Highest power output is realized at lowest gas temperature. Thus, in power applications, it is advantageous to cool the gas as far as is practical. Cooling, however, leads the vaporized tars in the gas to condense on engine parts such as inlet manifolds and valve stems. Also, soot and ash particles in the gas may form deposits in the engine leading to excessive engine wear and tear. Therefore it is absolutely necessary to filter and clean the gas of soot, ash, and tar. The maximum engine power output of a producer gas run engine is lower than the output of an equivalent engine operated on conventional liquid fuel. This phenomenon is known as ***"Derating".*** Depending on type and size and rating, small petrol and diesel engines may have efficiencies in the range of 20 to 24 percent and 28 to 32 percent, respectively.

7. Biomass Fuels for Gasifiers

Several fuel types have been developed which have found considerable acceptance for gasification. They include woody stems of plants, lump charcoal, dry (less then 20 percent moisture content) wood blocks, dry coconut shells, and rice husks, coir pith (in briquette form), bagasse *etc.* The table given below presents a matrix of acceptable fuels and gasification systems.

8. Gasifier based power generation potential and achievements in the country:

At present, biomass contributes 14 per cent of the total energy requirement worldwide. 38 per cent of this energy is consumed in developing countries like ours and that too predominantly in the rural areas for undertaking activities in the traditional sectors of the economy. In India, fuel wood (200–300 million tonnes), animal waste (80–100 million tonnes) and crop residues (100–120 million tonnes) annually are consumed as the main biomass fuel. A development potential of 19,500 MW of power from biomass sources exists in the country. This includes generation of 3,500 MW of power from biomass cogeneration using fuel wood and crop residues in sugar industry.

As on date in the county, thirty-four bagasse-based cogeneration projects aggregating 210 MW capacity have been commissioned and 26 projects aggregating 237 MW are under implementation.

Gasification Systems and Gasifier Fuels

Table – II

Biomass Fuel	Gasifier type	Capacity range	Application
Power gasifiers			
Wood blocks	Fixed-bed/down-draft	< 500 kWel	Electricity / shaft power
Charcoal	Fixed-bed/down-draft	< 50 kWel	Electricity / shaft power
	Fixed-bed/cross-draft		
Rice husks	Fixed-bed/down-draft (also called Fixed-bed / open-core)	< 200 kWel	Electricity / shaft power
Coconut shells	Fixed-bed/down-draft	< 500 kWel	Electricity / shaft power
Heat gasifiers			
Wood / charcoal / coconut shells	Fixed-bed/cross-draft	< 5 MWth	Electricity / shaft power
	Fixed-bed/up-draft		Process heat

Note : kW_{el} = kilowatt electric; MW_{el} = megawatt electric.
(Source: World Bank Technical Paper No. 296- Energy Series)

Cogeneration projects with 60 ata and above boiler pressure have been commissioned in nine sugar mills in three states so far and projects in 11 sugar mills in four states are under implementation. Fifteen commercial grid-connected biomass-based power projects aggregating 63 MW capacity have been commissioned, and 29 projects of 136 MW capacity are under implementation.

9. Financial Incentives Available from MNES:

The various kinds of financial incentives available are tabulated below:

Financial Incentives/Subsidies available for Biomass Gasification

Table-III *(Contd.)*

	Type	Percent of Cost
A	**BIOMASS GASIFIER WITH REACTOR, BLOWER, MANUAL FEEDING AND MANUAL CUTTER ONLY :** For Projects upto 1MW capacity (3 MWth, 2.6 million kcal/hr) having CFA on benchmark on cost of Rs.4.25 lakhs for gasifier units of 100 KW	
A1	**Unit size upto 100 KWe (300 KWth, 2.5 lakhs kcal/hr)**	
	a) Owned by Co-operative Panchayat, NGOs & Central/State Agencies (Socially Oriented Projects)	50%
	b) Owned by Individual(s) / Entrepreneur(s)	30%
A2	**Unit Size > 100 kWe but < 200 kWe (600 KWth, 5.00 lakh kcal/hr)**	
	a) Owned by Co-operative Panchayat, NGOs & Central/State Agencies (Socially Oriented Projects)	55%
	b) Owned by Individual(s)/Entrepreneur(s)	35%
A3	**Unit Size > 200 Kwe**	
	a) Owned by Co-operative Panchayat, NGOs & Central/State Agencies (Socially Oriented Projects)	60%
	b) Owned by Individual(s) / Entrepreneur(s)	40%
B.	**HI-FOCUS AREAS, ISLANDS, NE STATES, LADAKH & SC/ST USERS**	
	Additional Financial Assistance(Over and above)	10%

Table-III *(Contd.)*

	Type	Percent of Cost
C.	**COMPULSORY ADD-ONS**	
I	Instrumentation for Online Monitoring (System > 100 KWe) a. Hours of Gasifier Operation (hours) b. Output (kW) c. Other Fuel (Diesel) Consumption (Ltrs/hr.)	25% subject to maximum of Rs.15000/-
II	Total AMC for 5 years (including warranty)	5% of A above
D.	**OPTIONAL ADD-ONS**	
I	Cooling and Cleaning Subsystem Minimum Performance Level for gas cleaning; a. Gas Quality : > 4.0 MJ/nm^3 b. Tar Content : < 100 mg / nm^3 c. Particulate Matter : < 50 mg / nm^3 Minimum Performance Level for gas cooling; Temperature at Engine Outlet: Ambient Temperature ± 5^{0}C or 40^{0}C (Maximum)	25% of the sub systems cost or Rs. 500/- per kWe/kWth whichever is less
II	Automation for Startup (Battery based), Feed Handling and Ash Handling - for systems of Unit Capacity > 200 kW	25% of the sub systems cost or Rs.500/- per kWe/kWth whichever is less
III	Biomass Pre Processing / Fuel Preparation Equipment – for systems of Unit Capacity > 200 kW	
	a) Preprocessing Equipment	25% of the sub systems cost or Rs. 500/- per kWe/kWth whichever is less
	b) Fuel Preparation (Briquetting) Equipment (only in case of village electrification projects of Unit Capacity ³ 500 kW).	25% of the sub-systems cost or Rs. 1000/- per kWe whichever is less
IV	Effluent treatment for the gasifier cooling water Treatment of gasifier cooling water for recycling	25% of the sub systems cost or Rs. 500/- per kWe/kWth whichever is less
E.	**OPTIONAL ADD-ONS FOR ELECTRIFICATION**	
I	Power Distribution Subsystem (Local) for village electrification projects.	100 %
II	Grid Inter-connection Subsystem	
	For electrification projects (> 100 kW e)	
	a) Socially oriented projects	50%
	b) Individual/Entrepreneurs	25%
	For industrial application projects (> 200 kWe)	25%
III	Cost of Gas Engine (peak power delivered to be Specified)	100 %
IV	Dual Fuel Gensets	
	a) For all village electrification projects.(Diesel replacement > 70%)	
	i) Socially oriented projects	50%
	ii) Individual/Entrepreneurs	25%
	b) For industrial applications > 200 kW	25%(or @ Rs. 5,000/- per kWe, whichever is less for all categories

Table-III *(Concld.)*

	Type	Percent of Cost
F.	**OPTIONAL ADD-ONS FOR PUMPSETS**	
I.	Cost of Pump-sets	
	Project Size above 25 HP(Diesel replacement > 70%)	25% of the cost of the pumpset or Rs.1500/- per HP whichever is less
	Project Size below 25 HP(Diesel replacement >70%)	25% of the cost of the pumpset or Rs.1200/- per HP whichever is less
G.	**OTHER FEATURES**	
1.	DPR for all project > 100 kWe necessary. CFA for DPR preparation for projects > 500 kW is Rs. 1.00 lakh, whereas for projects < 500 kW and > 100 kW is Rs. 50,000/-. No DPR for < 100 kW only basic information need be given on format.	
2.	One time need based funding upto Rs. 5.00 lakhs shall be given to approved manufacturers by MNES for establishing service centres in potential areas where minimum 10 gasifier systems have been set up.	
3	(a) CFA for professional technical services, including TEFR preparation @ upto Rs. 50,000/- per assignment plus TA as per actual (AC-First Class by Rail / Executive Class by Air excluded).	
	(b) Applied, associated, allied and other strategic studies on scientific, technical/engineering, management, financing, evaluation, industry-wise sectoral studies etc, as may be required shall be considered for CFA on case to case basis, upto a ceiling of Rs.10.00 lakh including innovative R&D, pilot projects involving technology validation *etc.* to be considered by an Expert Committee headed by Advisor & Head, Power Group.	
4.	10 training courses @Rs.1.00 lakh per training course shall be arranged to create trained manpower for different target groups.	
5.	10 numbers Business Meet, Seminars, Workshops, Orientation Programmes under publicity and awareness programme shall be arranged @Rs.1.00 lakh .	
6.	In High Focus Areas/Area based proposals, direct implementation through reputed NGOs will also be permitted.	
7.	Rupees 1000/kW up to a maximum of Rs.1 lakh for 1 MW shall be provided as implementation charges to SNAs only for promotion of power generation.	
8.	For village electrification projects, 25% of the cost of the system is to be additionally provided towards transportation, foundation & machine room, erection and commissioning of the project.	

(Source : MNES, GoI –Annual Report 2003-04)

10. Economics of Biomass Gasification Plant:

The cost of a 200 kW_{el} biomass gasification based decentralized power plant will be in the vicinity of Rs. 1.00 crore. This may include the cost towards site development, civil structure for housing the gasifier and IC engine cum genset, cost of plant and machinery *viz.* cost of a " open top down draft type of fixed bed gasifier with turn down ratio of 1: 4, closed coil cooling water system, cyclones and sand beds for cleaning the producer gas, IC engine of 1500 RPM, ash disposal mechanism, electrical works, auxiliary systems *etc.*,. The biomass consumption rate of such plants ate in the range of 1.25 kg/ hr per kW of electricity generated. The biomass energy conversion efficiency of such units are in the range of 75-80%, where as the daily water requirement is in the vicinity of 5000 liters/day. The cost of power generation of such units is in the vicinity of Rs. 3-3.25/ kWh. The IRR is around 27-28% and the repayment period of the loan varies from 6 to 7 years.

11. Summary

Thus it can be concluded that though various players associated with this sector have made earnest efforts, the same is to be augmented in qualitative and quantitative terms considering the vast biomass based power generation potentiality that exists in the country. It is high time that we rededicate ourselves in harnessing this wonderful gift of nature for our benefit and thereby try to mitigate the power crisis in the country.