NMBA
National Mission on Bamboo Applications

INFO - SHEET

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Gasification of Bamboo

Gasification of bamboo offers exciting prospects for value addition and utilisation for bamboo resources, through generation of power and thermal energy. Even waste bamboo generated from processing operations can be used for gasification. It reinforces a commitment to clean electrical and thermal energy from a highly renewable resource. It can substitute the use of fossil fuels, and lower operating costs.

Gasification is thermo-chemical conversion, carried out through process of oxidation and reduction with limited air supply, which generates a combustible gas and a by product of active charcoal. The gas obtained is known as producer gas, having characteristic fuel properties.

A gasification system consists of a reactor, (where the gas is generated) and a cooling and cleaning system (where the gas is cleaned). The clean combustible gas is then available for thermal or power generation applications.

- Requirement of dry biomass: 1.0 to 1.3 kg / kWh
- Ash Content in biomass: < 5%
- Every kg of dry bamboo generates about 2.8 m^3 of producer gas
- Stoichiometric air-to-fuel ratio for biomass gasification is 1:1.4 (against 1:6 required for combustion)
- Calorific value of producer gas: 4.5 to 5 MJ / m^3
- Composition of producer gas: CO = 20 ± 2 %, H_2 = 18 ± 2 %, CH_4 = 2 ± 0.5 %, CO_2 = 12 ± 2 %, H_2O = 2 %, Rest N_2; Maximum quantity of particulates and tar after cleaning and cooling: 50 mg / m^3
- Heat and 5 - 15 % of charcoal / active charcoal as by-products

Bamboo as a Feed Material for Gasification

Thermochemical characterisation of bamboo and bamboo dust has been carried out by the Indian Institute of Science, Bangalore and IIT, Bombay. The results have confirmed the suitability of bamboo for energy related applications.

Proximate analysis (%)

Feed	Moisture	Volatiles (dry basis)	Fixed carbon	Ash (dry basis)
Bamboo	13.0	80.6	15.6	3.9
Bamboo dust	11.1	79.8	15.9	4.3

Elemental analysis (%)

Feed	Carbon	Hydrogen	Nitrogen	Sulphur
Bamboo	43.8	6.6	0.4	nil

Other Properties

Calorific Value	16.2 MJ / kg	Ash deformation temperature	1300 - 1350 ^{0}C
Bulk density	~ 300 kg / m^3	Ash fusion temperature	1400 - 1450 ^{0}C

The technical feasibility of using bamboo in biomass gasifiers has been tested and validated by the Indian Institute of Science, Bangalore. The gasifier operation was found to be smooth and consistent. Reactor pressure drop, which reflects the health of the reactor, was found to be satisfactory. No issue was reflected regarding ash fusion / ash melting. The presence of hydrogen of around 20 - 23 % in the producer gas indicates gas being energetic. Producer gas composition was of reasonable consistency and gas quality, in terms of contaminants, was not substantially different from that produced with other woody biomass.

Energy and By Product Options

Bamboo gasification systems are available in capacities ranging from 10 Kwe to 1 Mwe (electrical applications) and with different combinations of energy and by products. The selection of configuration would depend on the availability and cost of bamboo / bamboo waste, load assessments, source of power already available and user requirements.

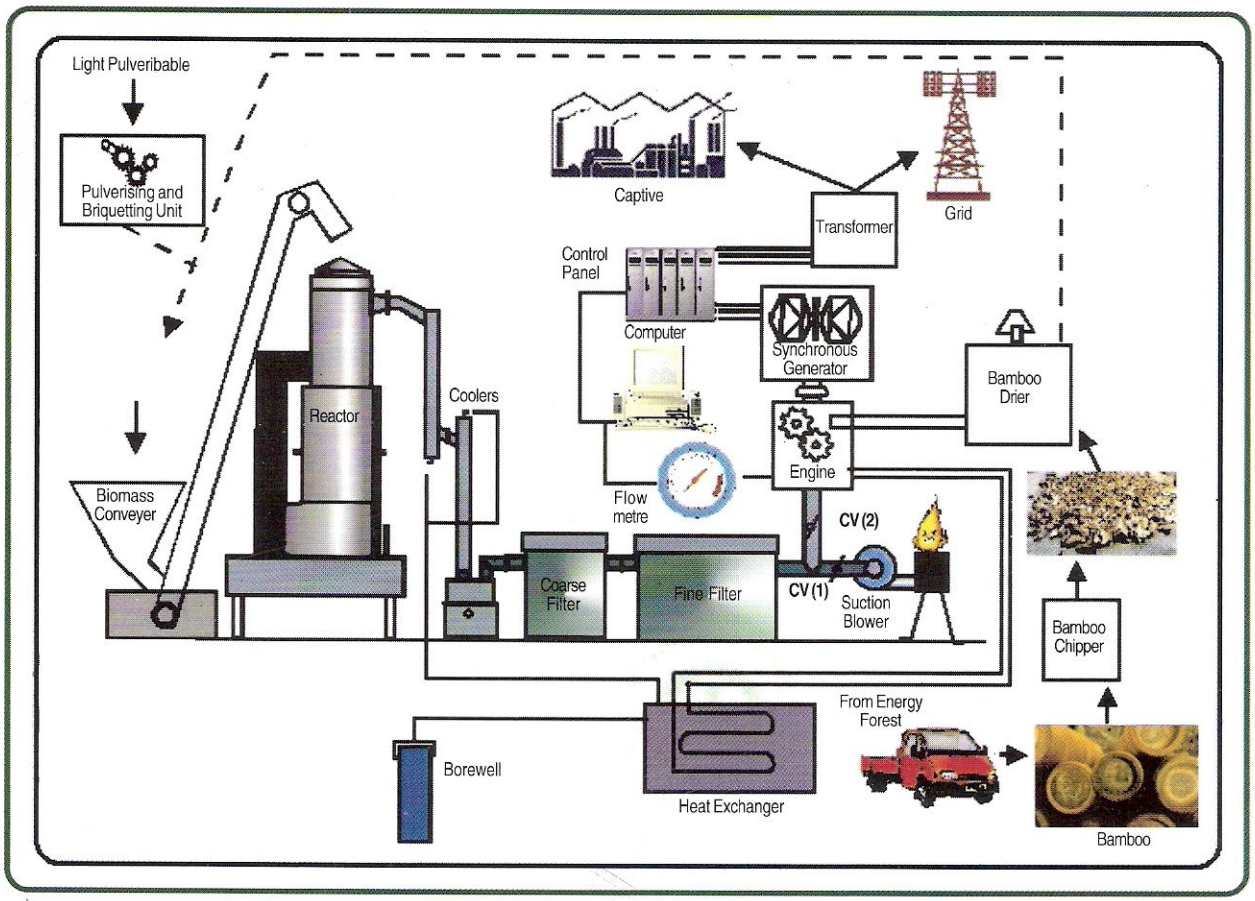
Combinations	Bamboo (Dry)	By Products
Electricity + activated carbon	150 kg / hr	7.5 kg / hr activated carbon (iodine value - 650 - 700)
Electricity + charcoal	135 kg / hr	15.0 kg / hr charcoal (iodine value - 100 - 150)
Heat + Charcoal	200 kg / hr	Around 6 lakh kcal / hr + 25 kg / hr charcoal (iodine value - 100 - 150)

For bamboo waste in the form of dust and chips, additional 15 - 20 % bamboo is required for drying and briquetting.

Gasification Process Technology – Open top down draft reburn gasifier

This is an open top downdraft system, where both gas and feed stock move downward as the reaction proceeds. The air required for gasification is partly drawn from the top, and the remaining from the air nozzles surrounding the combustion zone and central air nozzle directed to the reactor core. The required suction for this process is obtained from the engine (or the blower depending on the mode of operation). In the reactor the biomass after drying and pyrolysing in the upper zone of the reactor undergoes volatile combustion becoming char by the time it reaches the oxidation zone. In the oxidation zone the volatiles undergo oxidation with the release of CO_2 and H_2O. These gases undergo reduction, in the presence of a hot bed of charcoal, and yield a combustible gas mixture. The hot gas exiting at the reactor bottom passes through a cooling and cleaning system consisting of water sprays, scrubbers and fabric filters depending

upon the requirements. The gas flows further through the primary blower and then branches into two streams, one stream leads to the pilot burner and another to the engine. Water used for cooling the gas can be used either as a single pass or re-circulated by using a water treatment plant.



Applications of Producer Gas

The producer gas obtained by the process of gasification can be used either for thermal application or for mechanical / electrical power generation. Being a gaseous fuel, producer gas gives better power control compared to solid fuel, and provides smokeless and sootless combustion in an efficient and environment friendly operation. Thermal applications like dryers, kilns and furnace are suitable using producer gas. Using producer gas it possible to operate a diesel engine on dual fuel mode with marginal changes to the air inlet or a gas alone engine. Diesel substitution of the order of 80 to 85 % can be obtained at nominal loads in the dual fuel mode. Recent developments have made possible the operations of spark ignited gas engine using producer gas alone. The mechanical energy thus derived can be used either for energizing a water pump set for irrigational purpose or by coupling with an alternator for electrical power generation, either for local consumption or for grid synchronisation.

135 kg / hr bamboo based gasifier plant with 100 Kwe delivered in producer gas engine

Requirements

Land: 200 m^2 of covered area (15m x 13m) to house the system along with storage area (top covered) for biomass. The system shed should have a minimum height of 11m.

Biomass: Sustained availability of 72 tonnes of bamboo per month (two trucks a week) having moisture content of less than 15 % if the gasifier is operated for two shifts a day. The bamboo should be sized into small pieces of maximum 75 mm length.

Water: Sustained availability of water (13m^3 / hr) is required in the cleaning and cooling system. The water is recirculated after treatment. Some additional make up water is also required.

Operation & Maintenance

Loading of Reactor: About 50 kg of bamboo pieces should be loaded every half hour for smooth operation. The level of bamboo should not drop below 400 mm from the top. Care has to be taken that extraneous material like stones and sand are not mixed with the feed. During initial running, the system has to part loaded with charcoal to prevent tar formation and fouling of channels.

Turn-Down ratio: The system has a turn down ratio of 4:1, indicating that the minimum operating capacity is one-quarter of the maximum.

Start up & Shut down: The gasifier takes about 10 - 15 minutes for start up and stabilization. Shut down is almost immediate. The system can be run continuously for about 6 – 8 weeks, after which it would need to be shut down for a shift for cleaning.

Cleaning & Maintenance: Solid residues from the bottom hopper should be removed before the system is started. The filter and valves should be cleaned once in three weeks of operation. The system needs to be taken up for maintenance every 1500-2000 hours of operation.

Manpower: Two operators and two unskilled workers are required for running the system.

Ash Removal: The ash should be removed every 6 - 8 hrs of operation. Care should be taken to close the reactor bottom valve while removing the ash.

Indicative Cost Estimate

Details	Cost (Rs.)
Gasification system with accessories	35,50,000
Producer gas engine	25,00,000
Building (estimated)	7,00,000
Transportation (estimated)	2,00,000
Total	**69,50,000**

Indicative Working Details

Assumptions		
Capacity of power generation / producer gas engine	Kwe	120
Captive power consumption (parasitic load)	Kwe	20
Available power	Kwe	100
Annual hours of operation	hours	6000
Annual power generation	unit	6,00,000
Bamboo consumption	Kg / kw	1.2
Cost of bamboo	Rs / tonne	1000
Operations and Maintenance cost	Rs / unit	1
Annual biomass consumption	tonne	900
Cost of power from alternate source / DG set	Rs / unit	6
Indicative Running cost		
Annual cost of bamboo	Rs	9,00,000
Annual Operation and Maintenance cost	Rs	6,00,000
Depreciation cost for gasifier and engine	Straight line method with 10 % salvage value and life of 15 years	3,60,000
Total cost of power generation per annum	Rs	18,60,000
Indicative Earnings		
Charcoal generation per annum	tonnes	90
Sale price of charcoal	Rs / tonne	5000
Earnings from charcoal per annum	Rs	4,50,000
Net running cost per annum	Rs	14,10,000
Net cost of gasifier power	Rs / unit	2.35
Savings compared to DG power	Rs / unit	3.65
Net savings per annum as compared to DG power	Rs	21,90,000

Indicative Estimate of equipment cost inclusive of gasifier system and gas engine for other capacities

The capacity of systems are determined by the available capacities of producer gas engines. For higher capacity systems, two or more engines should be combined.

Gasifier Capacity	Producer Gas Engine Rating	Approximate Cost of Equipment (Lakhs)
1kg/hr (mobile gasifier)	0.5Kwe	2.5
35kg/hr	25Kwe	18.5
90kg/hr	70Kwe	42

Need for Captive Plantation

Bamboo based gasification system is most suitable for economic utilization of bamboo waste, flowered bamboo or bamboo sourced from existing plantations / natural forests. To run the system over a long period on a sustainable basis, it captive plantation of bamboo should be raised to feed the system, with yearly rotational extraction. To operate 135kg / hr system on a sustainable basis, a plantation of 50 ha would be sufficient. Details of the cost of such plantation including economic viability are as follows:

Species of Captive Plantation	*Bambusa balcooa*
Annual requirement of bamboo as biomass to feed 135 kg / hr plant	720 MT
Assuming productivity of 15 tonnes / hectare, captive bamboo plantation required to feed the plant	50 ha
Cost of raising captive plantation (@Rs.40,000 / ha up to 3 years)	Rs 20 lakhs
Cost of management of plantation / annum (after 3 years)-@Rs.6000 / ha	Rs 3 lakhs
Benefits / year for 750 MT bamboo @ Rs.1500 / MT	Rs 11.25 lakhs
B - C ratio (for 30 year duration of plantation)	1.86

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