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PROSPECTS OF BIOMASS GASIFICATION AS AN ENERGY SOURCE IN BANGLADESH

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ABSTRACT

Biomass gasification is quite new in Bangladesh and may be considered as a promising technology for the useful conversion of waste biomass. The fuel gas produced by gasification can run engines and thus generate electricity. In the present work, literature survey is performed to compare the available proven gasification technologies around the globe in terms of biomass quality and quantity, system complexities and capacity, and economic factors. The outcome of this study would identify a suitable gasification technology for Bangladesh. To explore the full potentials of biomass gasification, necessary data on biomass availability and quality is discussed. A case study is incorporated which applies biomass gasification technology in Bangladesh, to generate power from rice husk. This will provide a practical impression on the successful use of this technology in this country. Finally useful conclusions and possible recommendations are made in favor of adopting this technology in Bangladesh's perspective.

Keywords: Biomass, Gasification, Power generation.

1. INTRODUCTION

Electricity is the most useful form of energy. Since all industrial and other economic activities rely on electricity or other means of power, the availability of electrical energy can be considered as an indicator of a country's economic strength. In Bangladesh, the majority electricity is generated from fossil fuel sources: indigenous natural gas and imported petroleum fuels. However, only about 38% of its total population has access to the electricity. The energy situation in rural Bangladesh is characterized by low quality of fuel, low efficiency of use, low reliability of supply and limited access leading to lower productivity of land, water and human effort, ultimately leading to low quality of life and environmental degradation. Therefore access to quality, reliable and affordable energy is critical for promoting economic and social development in rural areas [1]. The Government of Bangladesh aims to provide electricity to its entire rural population by 2020 to help boost social development and economic growth. However, it would be unrealistic and infeasible to use grid electricity to reach the target. In addition to the expansion of the grid, it has to rely on non-grid options such as renewable energy-based small capacity independent power plants.

In supplementing the declining fossil fuel sources of energy, biomass has been recognized as a major renewable and sustainable source of energy with the highest potentials to contribute to the energy needs of modern society world-wide [2]. Like in other parts of the world, biomass has been proved to become the largest source of renewable and sustainable energy in Bangladesh. About 80% of her people live in rural areas, and the contribution of biomass energy is about 70% of the total national energy consumption in Bangladesh [3]. Different methods have been adopted in the last decades to utilize biomass as a useful source of energy with its full potentials. It includes direct combustion, anaerobic fermentation, briquetting, pyrolytic conversion and gasification. Being agriculture-based country, Bangladesh has huge potentials to utilize agricultural wastes as biomass sources. However, direct combustion is the most common method of biomass utilization in Bangladesh (especially in rural areas), which has very poor energy efficiency.

Amongst the bioenergy technologies, the biomass gasification option for meeting the rural electricity needs of domestic, irrigation and rural small and cottage industrial as well as thermal activities, is shown to have a large potential. Gasification is the technology capable of producing fuel gas from conversion of biomass, which can serve the need of energy in various forms. In recent years biomass gasification technology seems to have given concerns around the world. This technology serves following advantages:

- It uses biomass which is sustainable and renewable sources of energy
- It is an efficient way to utilize waste biomass and the gas produced from gasification can be used for generating electricity
- Gasification produces less harmful exhaust as biomass is very low in sulfur, chlorine or heavy metals, which are detrimental to the environment

- It contributes to global warming - when biomass is grown on a sustainable basis, it does not contribute to carbon dioxide emissions
- It can provide economic development and employment opportunities in rural areas
- The biggest advantage of gasification is the use of variety of feedstock and products, as the syngas can also be used for chemical industry along with power generation.

Biomass gasification is new in Bangladesh and may be considered as a promising technology for the utilization of waste biomass. The fuel gas produced by gasification technology can run internal combustion engines and thus generate electricity. In the present work, literature is reviewed to compare the available proven gasification technologies in terms of biomass quality and quantity, gasification system complexities, system capacity and the associated economic factors, around the world. The outcome of this review would identify a suitable gasification technology that can be adoptable in respect of this country. To explore the full potentials of biomass gasification, necessary data on biomass availability and quality have been incorporated. A case study is also added which is employing agricultural biomass such as rice husk for gasification technology to generate electricity. This is the first successful application of the technology in commercial sector in Bangladesh. This will provide a practical impression on the successful use of this technology in this country. Finally, useful conclusions and possible recommendations are made in favor of adopting this technology in Bangladesh's perspective.

2. FUNDAMENTALS OF BIOMASS GASIFICATOIN

In principle, gasification is the thermal decomposition of organic matter in an oxygen deficient atmosphere, producing a mixture of combustible and non-combustible gases. Typically the gas mixture includes carbon monoxide (CO), hydrogen (H_2), carbon dioxide (CO_2), methane (CH_4), traces of higher hydrocarbons, water, nitrogen (if air is used as gasifying agent). Gasification also produces tar and solid particles like ash and char. Gasification is different from pyrolysis in the sense that gasification is performed to produce gaseous components, whereas pyrolysis is the production of liquid residues and charcoal. The latter normally occurs in the total absence of oxygen, while most gasification reactions take place in an oxygen deficient or starved environment [4m] [5m].

Gasification occurs in a gasifier in which the biomass particle is exposed to high temperatures. As the particle is heated, the moisture is driven off and the weight of biomass fuel reduces to even more than 50%. Further heating of the particle begins to drive off the volatile gases. Discharge of these volatiles will generate CO and a wide spectrum of hydrocarbons ranging from methane to long chain hydrocarbons comprising tars, creosotes and heavy oils. After about 900°C-1000°C, the biomass particle is reduced to ash and char. Typically the char is contacted with air, or oxygen and steam to generate CO, introduced below the grate and diffuse up through the CO_2 and heat. The total gasification procedure is performed in three stages [6m]:

- Stage 1: Gasification process starts as autothermal heating of the reaction mixture. The necessary heat for this process is covered by the initial oxidation exothermic reactions by combustion of a part of the fuel
- Stage 2: Combustion gases are pyrolyzed by being passed through a bed of fuel at high temperature. Heavier biomass molecules distillate into medium weight organic molecule and CO_2, through following reaction

$$C_6H_{10}O_5 \longrightarrow C_XH_Y + CO_2 \qquad (1)$$

- Stage 3: Initial products of combustion, CO_2 and H_2O are converted by reduction reaction to CO, H_2 and CH_4:

$$C + H_2O \longrightarrow CO + H_2 \qquad (2)$$

$$CO_2 + H_2 \longrightarrow CO + H_2O \qquad (3)$$

$$C + 2H_2 \longrightarrow CH_4 \qquad (4)$$

The combustible gases produced by this technology can be used in power or heat generation shown in Fig.1 [8].

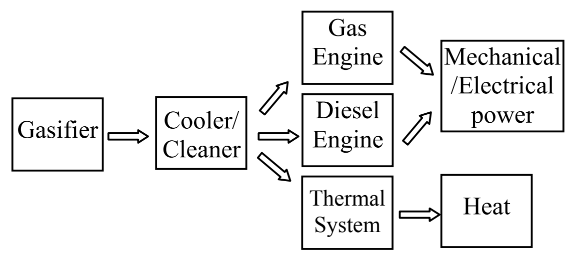
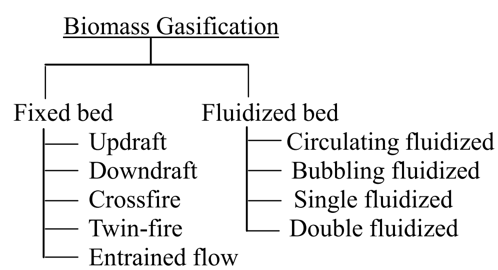


Fig 1. Usage of produced gas in different purposes.

3. GASIFICATION TECHNOLOGIES

Several types of gasification methods have been used in the last few decades depending mainly on the type of gasifier. These methods can be summarized in a flow chart:



Besides these basic classes, gasification technologies are also classified based on the type of feeding (automatic or manual), amount of pressure applied (atmospheric or pressurized), type of opening (open top or closed), etc. A few of them is discussed in the following sections.

3.1 Updraft Gasifier [9m]

The oldest and the simplest form of gasifier is updraft. It has clearly defined zones for partial combustion, reduction and pyrolysis. Biomass is introduced at the top of the reactor and a grate at the bottom of the reactor supports the reacting bed. Air or oxygen or steam is bed of biomass and char. Complete combustion of char takes place at the bottom of the bed, liberating CO_2 and H_2O. These hot gases (~1000°C) pass through the bed upward, where they are reduced to H_2 and CO and cooled to about 750°C. Containing up the reactor, the reducing gases (H_2 and CO) pyrolyze the descending dry biomass and finally dry the incoming wet biomass, leaving the reactor at a low temperature (~500°C). Therefore it has four clearly definer reaction zones and these are oxidation, reduction, pyrolysis and drying zone. The reactions in each zone are:

Oxidation:

$$H + O_2 \rightarrow H_2O + Heat \quad (5)$$

$$C + O_2 \rightarrow CO_2 + Heat \quad (6)$$

Reduction:

$$CO_2 + C + Heat \rightarrow 2CO \quad (7)$$

$$H_2O + C + Heat \rightarrow H_2 + CO \quad (8)$$

Pyrolysis:

$$C_6H_{10}O_5 + Heat \rightarrow C_XH_Y + CO \quad (9)$$

$$C_6H_{10}O_5 + Heat \rightarrow C_nH_mO_y \quad (10)$$

Drying:

$$\text{Wet biomass} + Heat \rightarrow \text{Dry biomass} + H_2O \quad (11)$$

3.2 Downdraft Gasifier

Downdraft gasifier is so called as the fuel and gas flow downward direction of the gasifier. It is also known as concurrent-flow gasification. The downdraft gasifier has the same mechanical configuration as the updraft gasifier except that the oxidant and product gases flow down the reactor in the same direction as the biomass [9m]. In the updraft gasifier, gas leaves the gasifier with high tar vapor which may seriously interfere the operation of internal combustion engine. This problem is minimized in downdraft gasifier. This process can combust up to 99.9% of the tars formed. Primarily biomass and air or oxygen is ignited in the hearth zone [10m]. The produced flame generates pyrolysis gas or vapor, which burns leaving 5% to 15% char and provide hot combustion gas.

These gases flow downward and react with the char at 800 to 1200°C, generating more CO and H_2. Finally, unconverted char and ash pass through the bottom of the grate and are sent to disposal.

3.3 Circulating Fluidized Bed Technology

The bed material along with heated biomass particles circulates in the gasifier and hence called circulation fluidized bed [9m]. Gasification temperature ranges from 800 to 950°C. The gas velocity inside the gasifier is higher than that of bubbling bed technology. The approach velocity in the gasifier lies in the order of magnitude of the terminal velocity; as a consequence, the bed material is carried into the freeboard thus forming a gas/solids flow in the entire reactor. With the help of a cyclone, the carried away bed material is separated from the gas stream and recirculated into the reactor [11, 12m].

3.4 Bubbling Fluidized Bed Gasification

A bubbling fluidized bed consists of fine, inert particles of sand or alumina as bed material [9m]. As oxidant (oxygen, air or steam) is forced through the inert particles, a point is reached when the frictional force between the particles and the gas counterbalances the weight of the solids. At this gas velocity (minimum fluidization) bubbling and channeling of gas through the media occur such that the particles remain in the reactor. The fluidized particles break up the biomass feedstock effectively and ensure good heat transfer throughout the reactor [11m]. This is the gasification mode of operation. Typical desired operating temperatures ranges from 900°C to 1000°C.

3.5 Comparison among different gasifier systems

Table 1 presents a comparison between the fixed bed and fluidized bed gasification technologies and Table 2 compares the merits and demerits of different fixed bed technologies.

However high rate of tar production in updraft gasifier makes them very impractical for high volatile fuels. On the other hand, downdraft gasifier has been developed for the conversion of high volatile fuels to low tar gas and therefore has proven to be the most successful design for power generation. It is also recommended where a clean gas is required. Downdraft gasifier is very suitable for small-scale power plant as well as preferred for the application in internal combustion engines.

3.6 Selection of Gasification System for Bangladesh

Either updraft or downdraft gasifier system can be chosen for Bangladesh's perspective due to their simplicity in construction and low maintenance requirements. Also, the technologies of these systems are quite matured in the world. Based on the above comparative discussions, however, a downdraft gasifier is better than an updraft gasifier system in many aspects. Therefore, "an open top downdraft gasification system" can be chosen as the most suitable one for Bangladesh. This gasifier has some unique advantages like suitability to small scale production (50-150kW), minimum operating labor required, exhaust type (particularly % of tar content), and easy as well as less maintenance required.

4. AVAILABILITY OF BIOMASS IN BANGLADESH

Bangladesh is an agriculture-based country and the available biomass is mainly of agricultural wastes. In addition to the agricultural wastes, the other biomass sources are industrial wastes such as saw dust, rice husk, bagasse from sugar industries. The approximate annual biomass production is summarized in Table 3.

4.1. Pulse's Rind (A New Option)

The rind of pulses ("dal") can be used as biomass fuel for gasification as it has better uniformity in size and good calorific value. The most common rinds of pulses are Gram, Mug, Masur, Khesari, Mashkalai, Peas etc. The annual pulse production is tabulated below in M.tons in Table 4 [17]. This enormous amount of pulses is capable of producing substantial amount of rind, which can be used as biomass feedstock.

Table 1: Comparison between fixed bed and fluidized bed technologies [13, 14]:

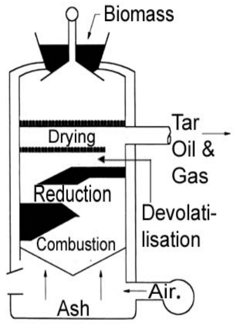
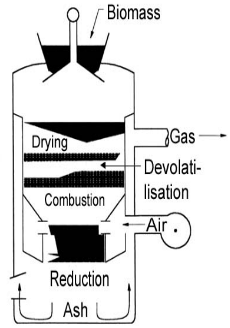
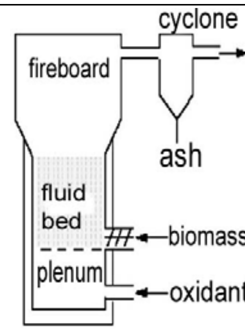
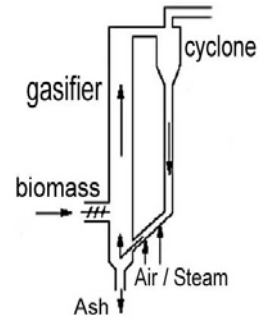
Fixed bed technology		Fluidized bed technology	
Updraft	Downdraft	Bubbling	Circulating
			
Advantages - Simplicity in design and construction and suitable for small scale production - Easy and less maintenance and thus more economical - Good maturity		**Advantages:** - Excellent gas and solid mixing - Uniform temperature and high heating rates - Large variety of biomass can be used as feedstock - Greater tolerance to particle size range - Safer operation and good control	
Disadvantages - Limited type of biomass fuel can be used - Requires smaller feed size - Allowable moisture content is <20% - Calorific value of gas is low - More tar content - Different scrubber and cleaner are to be employed.		**Disadvantages:** - Complex construction and greater maintenance and hence expensive - Fused ash and tar condensation provokes defluidization	

Table 2: Comparison among fixed bed technologies [9, 13, 14, 15]:

Gasifier type	Advantages	Disadvantages
Updraft	- good maturity and have a good thermal efficiency - small pressure drop - little tendency towards slag formation - simpler construction and less installation cost	- great sensitivity to tar and moisture - poor reaction capability with heavy gas load - suitable for small size fuel only
Downdraft	- flexible adaptation of gas production to load - low sensitivity to charcoal dust and tar content of fuel - better quality of gas - simple and low cost process and minimum maintenance required	- design tends to be tall - little complex construction than updraft - suitable only for small scale plant - feed needs to have a fairly uniform particle size - limited access to the type of fuel
Cross draft	- short design height - very fast response time to load - flexible gas production - economy in gasifier size	- very high sensitivity to slag formation - high pressure drop - complex construction
Twin-fire	- clean gas production and no need of extra purification devices - simple in design as well low cost - suitable output gas temperature - economy in gasifier size	- it needs an additional oxygen production plant - limited type of fuel can be used - higher amount of oxidant required - complex construction
Entrained flow	- produced gas is about completely tar free - simple design - clean gas production excluding the need of purification apparatus.	- fuel is ground to very small sizes - it needs an additional oxygen production plant - operates at high temperature. - needs large volume of carrier gas

Table 3: Yearly biomass (Million in m. ton) from various unorganized sectors [16]

Year	Jute stick	Rice straw	Rice husk	Bagasse	Fire wood	Twigs leaves	Other wastes	Total million in m.ton
1995-96	1.5	18.75	6.2	1.3	1.3	3.60	2.70	44.45
1996-97	1.8	18.95	6.3	1.4	1.4	3.90	2.80	45.45
1997-98	2.1	18.18	6.3	1.4	1.4	5.00	2.90	46.18
1998-99	1.9	18.12	6.3	1.2	1.2	5.60	3.00	46.52
1999-00	2.1	18.04	6.4	1.2	1.2	6.00	3.00	47.54
2000-01	2.2	18.75	6.4	1.3	1.3	6.20	3.10	48.95
2001-02	2.3	18.49	6.5	1.4	1.4	6.40	3.10	49.29
2002-03	2.2	18.60	6.6	1.4	1.4	6.60	3.20	49.80
2003-04	2.1	18.60	6.5	1.5	1.5	7.20	3.20	50.50
2004-05	2.2	18.50	6.5	1.5	1.5	7.80	3.30	51.20
2005-06	2.3	18.65	6.5	1.5	1.6	7.90	3.35	

5. CASE STUDY (DREAMS POWER PRIVATE LTD.)

5.1. Background

The biomass gasifier-based decentralized power generation system is implemented in Gaspur village in Kapasia of Gazipur district. Gaspur is a non-electrified village. Asaduzzaman Manik, a poultry farmer of this village, experienced difficulties in keeping his business running without electricity. He then decided to generate electricity required his farm by himself. He visited India and learned about small-scale husk-fired power plant. Following his visit, he planned to build such a about the availability of the biomass feedstock as Bangladesh produces plenty of rice-husk throughout the country. He then managed to install a rice-husk based decentralized small-scale power plant with the technical an financial supports of IDCOL (Infrastructure Development Company Limited) and World Bank in 2007. The details of the plant are summarized in Table 5.

5.2 Investment

The total investment for creating the entire infrastructure, including installing power generation (gasifier, dual-fuel engine, generator, and other apparatus), distribution cost and end-use (lighting, flour mill, etc.) was about Tk. 25 millions. IDCOL provided concessionary loans and grants about 20%; the World Bank provided 60% of the project cost as grant while the owner himself provided 20% of the total investment.

5.3. Plant Capacity

The total capacity of the power pant is 250 kW. It has two units having equal capacity to supply 125 kW. The plant was originally proposed to supply electricity to the villagers covering more than 50% of its total population (approximately 200 households) and 100 commercial entities of that area, after meeting the demand of the farm.

Table 4: Yearly produced pulses (M.tons) in Bangladesh [17].

year	2004-05	2005-06	2006-07
Gram	9630	9760	9810
Mung	17935	16870	18675
Masur	121065	115370	116810
Khesari	136085	107250	82735
Mashkalai	17190	17400	18190
Peas	9410	7780	6645
Arharl	1005	1015	1445

5.4 Type of Biomass Used and Its Availability

The plant is using rice husk as the feed material. It is cheap and easily available. As mentioned above, being, an agricultural based country Bangladesh produces varieties of agricultural residues. Until now they are consuming mainly as domestic cooking purposes in rural areas and industrial (rice parboiling) energy source. Among the various agricultural residues rice husk is ranked the top in terms of its availability, as paddy is the main crop of Bangladesh. Rice husk is a good quality biomass fuel as it has good calorific value, small in particle size having an excellent uniformity.

5.5 Economic Analysis

The total project is a profitable one provided that the plant is running with its full capacity and the generated electricity is fully utilized. The estimation is quite simple:

If the project runs in its full capacity it is capable of earning Tk. 900,000 per month (250kW * 24hr * 30days * Tk. 5.0) = Tk. 900,000). Its running costs are about Tk. 600,000 (includes biomass procuring, diesel, mobile, filtering, and others (= 400,000 + 150,000 + 10,000 + 10,000 + others)). Thus it provides a net income of about Tk. 300,000 per month. Based on this simple analysis, the turn over period can be determined as about 7 years.

However, the present situation is quite different. The plant is not running with its full capacity and currently, only from one unit, fractional power is supplied about 336 kWh/day (56 kW * 6hrs = 336 kWh/day). So it earns only about Tk. 50,000 per month. Whereas the operating costs are about Tk. 90,000 per month. Thus the project is now in running under loss.

According to the management, if there is a rice mill beside the plant, the loss could be minimized. As the rice mill would act as both supplier of biomass and a consumer of the generated electricity.

5.6 Problems Encountered During Operation

Being a pioneer entrepreneur in terms of biomass

Table 5: Plant description at a glance [18]

Parameter	Description
Gasifier type	downdraft
Capacity	max. 250 kw
Rated gas flow	625 Nm^3/hr
Max. gasification efficiency	up to 75 %
Gasification temperature	1050-1100°C
Biomass feeding	manual
Outlet gas temp	250-400°C

Average gas calorific value	>1.05 Kcal /Nm^3
Rated biomass consumption	up to 300 kg/hr
Typical gas composition	CO-20.6%,H_2-10.6%,CO_2-13.6%,CH_4-4%,N_2-52.6%

gasification power plant in Bangladesh, this project is now facing different types of problems. Being located in a rural area the project often faces a number of problems: lack of skilled operators, improper guidelines, poor management, technical and financial problems, lack of government patronization, unavailability of biomass, tendency of the customers not to pay the bill in due time etc. Study also identifies that there are some sort of social and political problems that are discouraging this effort.

6. CONCLUSIONS

Based on the above discussions the following conclusions can be drawn:

- Biomass gasification can offer an attractive alternative renewable energy system especially in rural areas where biomass fuel is available. Thus can provide community based small-scale independent power plants.
- Between the updraft and downdraft gasifier systems, an open top downdraft gasifier with manual feeding downdraft gasifier is preferred as it provides cleaner gases. This type of system has been identified for Bangladesh's perspective.
- The biggest challenge in these gasification systems lies in developing reliable and economically cheap cooling and cleaning systems.
- For the fuels with high ash content, fluidized bed system may offer a better solution, but they are more complex in design.
- Rice husk can be ranked the top of the available biomass types in Bangladesh. However, other types of biomass such as rind of pulses, saw dust should also be considered for gasification.
- If rice husk is used for gasification, rice mills should be installed beside the power plant to make it feasible.

7. RECOMMENDATIONS

Rural electrification is a great challenge for the Government of Bangladesh. Installation of biomass based, small-scale independent power plants around the country could be a feasible solution. Biomass gasification is treated as an emerging technology that can be employed for the purpose. However, there are problems or barriers, which need to be solved or removed for the sustainability of such projects. The following recommendations are made out of the above discussions:

- Provision of government subsidies for the installation of such gasification power plants. Government can seek funds from different foreign aids. Also carbon trade can be an option.
- NGOs and other government organizations that work for the well being and development to the society should be motivated and involved in such projects.
- Rural unemployed people should be educated and trained to the standard that would make them eligible to take part in such projects.
- It is essential to have an access to the database of the available biomass quality and quantity.
- A market should be development so that local and foreign entrepreneurs would convince to invest in such projects.
- Government of Bangladesh would need to amend energy policy so that the gasification plants can run to their full capacity and can sell the surplus electricity to the grid.

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