

**Case Study**

# **A Case Study of Green Electricity Generation from Biomass Fuelled Producer Gas Engine in Bangladesh**

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## **Abstract**

This journal represents specific biomass consumption and engine emission in a Biomass Gasification based Power Plant. Rapid rate at which fossil and residual fuels are releasing CO<sub>2</sub> into the atmosphere has raised international and national concern and has spurred intensive efforts to develop alternative, renewable, sources of primary energy. The solar energy stored in chemical form in plant and animal materials is among the most precious and most promising alternative fuels not only for power generation but also for other industrial and domestic applications on earth. Biomass absorbs the same amount of CO<sub>2</sub> in growing that it releases when burned as a fuel in any form. Bangladesh has taken substantial effort to develop power scenario. Policy makers of Bangladesh are giving more emphasizing on renewable energy sector. As a part of improving renewable energy sector, a gas carburetor has been designed for producer gas fuel and forms a part of the power package. The essential requirements of gas conditioning equipment are packaged to meet the engine quality gas as a power plant. Currently there are near about 400KWe gas engines running in this field, of these one is deployed by IDCOL (Infrastructure Development Company Limited). IDCOL has financed a 250 kW biomass gasification based Power Plant at Kapasia, Gazipur, Bangladesh. The power plant is configured with a 300 kW capacity duel-fuel generator. Mainly the gas that has been produced by the gasification of biomass generates electricity. However, in this rice husk based power plant, to run the generator certain amount of diesel is required. Because, the producer gas has relatively lower heating value and needs to be supplemented by diesel to get the necessary power output. That's why the IC engine has been converted into duel fuel mode. The plant has gone for commercial operation from October 2007 and has successfully completed over 6500 hours of operation, generating about 0.3 million units, thus saving a net CO<sub>2</sub> of about 0.6 million Tons against a fossil fuel technology. The plant operates on a continuously to meet the end use requirement over 275 hours non-stop operations hours of operation. The specific biomass consumption is measured to be within  $1.1 \pm 0.1$  kg/kWh with an overall efficiency of 22-24%. The journal also highlights results from other installations using this technology.

**Keywords:** Biomass, Renewable energy, Green electricity etc.

## Introduction

In the recent times, gaseous fuels are gaining prominence as cleaner fuels for power generation via internal combustion engine route; the power generation package including both reciprocating engines and gas turbine machinery. Among the clean sources of fuel for power generation, natural gas has been exploited largely due to significant availability in specific locations. Similarly, there is also an impetus on using gas generated from industrial and municipal wastes, namely diluted natural gas - biogas and land-fill gas. As distinct from gas generation from biological/organic wastes by biological conversion process, which is limited to nonlignaceous matter, the gasification route can process any solid organic matter. The resultant gas known as 'Producer gas' can be used for fuelling an internal combustion (IC) engine in dual-fuel mode. Harnessing of energy from biomass via gasification route is not only proving to be economical but also environmentally benign. In the field of power generation, there has been substantial effort in the development of producer gas engine; systematic experimental and modeling studies followed by long duration field monitoring. As a part of this effort, a gas carburetor has been designed for producer gas fuel and forms a part of the power package. Currently there are several projects are under validation stage which are based on Biomass sources in Bangladesh. Among these projects one that is deployed by Dreams Power Private Limited is reported as a case study in this paper. Also, performances of other gas engine based plants are highlighted.

## Plant Description

The plant referred here is deployed by Dreams Power Private Limited. The plant is expected to supply environment friendly grid quality power to 300 households and commercial entities of that area. The industrial class power plant is configured a rated gas flow 625 Nm<sup>3</sup>/hr is coupled to a producer gas engine of 250 kW nominal capacity. The entire power plant can be categorized into three sub units namely gasifier unit, gas purification unit and internal combustion engine (IC engine).



**Figure 1:** Front face of power plant

The gasifier is essentially a chemical reactor where various complex physical and chemical processes take place i.e. drying of fuel, pyrolysis, combustion and reduction. Downdraft gasifier technology has been used in this project. In this project One kg of biomass can produce 2.5 to 3.0 Nm<sup>3</sup> of producer gas with a calorific value of 1000-1300 Kcal per Nm<sup>3</sup>. One important aspect to be mentioned here is that Biomass feeding process is manual here.



**Figure 2:** Gasifier Unit of the power plant

The gas coming out of the gasifier has a high temperature (450°C or higher). This gas contains tar and fine particles of ash, which need to be cleaned before feeding to the engine. Due to downdraft technology, gas cleaning and cooling system is less complicated and easy to maintain. Several filters have been used in this power plant namely as coarse filter, fine filter and safety filter. At first, rice husk is fed into the gasifier and gas is produced inside the gasifier. Produced gas is then cooled and cleaned in the purification unit and finally clean gas is fed into the engine. A mini grid has been constructed to sell the power to the adjacent area. The plant is able to deliver power to at least 300 households and over 100 commercial entities of that area.

## Process Description

The gasification system comprises of 150 kg/hr capacity down draft re-burn gasifier reactor with gas cleaning and cooling system. The reactor is a cylindrical shell with ceramic lining and an ash extraction system at the bottom. The open top re-burn design has been initially pursued at Indian Institute of Science. Some modification has been done later at different universities of Bangladesh (Islamic University of Technology, Bangladesh University of Engineering & Technology and Dhaka University). This design has a long cylindrical reactor with air entry from the top. The principal feature of the design is related to residence time of the reacting mixture in the reactor so as to generate a combustible gas with low tar content at different throughputs. This is achieved by the combustible gases generated in the combustion zone located around the side air nozzles to be reburnt before passing through a bottom section of hot char. Also, the reacting mixture is allowed to stay in the high temperature environment along with reactive char for such duration that ensures cracking of higher molecular weight molecules. Detailed measurements have shown that the fraction of higher molecular weight compounds in the hot gas from an open top design is lower than a closed top design. The raw producer gas exits the reactor at about 800 to 900 K, and is laden with contaminants in form of particulate matter (1000 mg/Nm<sup>3</sup>) and tar (150 mg/Nm<sup>3</sup>). The hot dust laden gas is further processed in the gas cooling and cleaning system in order to condition the gas to a level that is acceptable for engine operations. The gas cooling and cleaning system processes the hot raw gas to a clean and dry gas with particulate and tar content less than a few ppb. This is possible using Cn patented technology.

Firstly, the hot gas passes through a high efficiency cyclone which separates the dry particulate matter from the raw gas (~ 80%). The next intermediate process of gas cooling and scrubbing is carried in ejector design scrubbers. The wash water for gas scrubbing is used in recycling mode after necessary treatment in the integral effluent treatment plant. The cooled and cleaned gas is further processed in another scrubber such that the resultant gas contains particulate and tar (P & T) matter less than 1 mg/Nm<sup>3</sup>. In this particular scrubber the gas is dehumidified using the principle of condensate nucleation wherein extremely fine particulate matter (~ 5 – 10 microns) is separated from

the gas stream. The gas finally passes through a security fabric filter prior to flowing to the gas engine. The gas engine is provided with a producer gas carburetor system such that the required air-to-fuel ratio of  $1.3 \pm 0.1$  is maintained over the entire range of flow rates, thus permitting variable load operation. The waste heat from the engine exhaust is utilized for drying of the biomass in a tray type biomass drier.

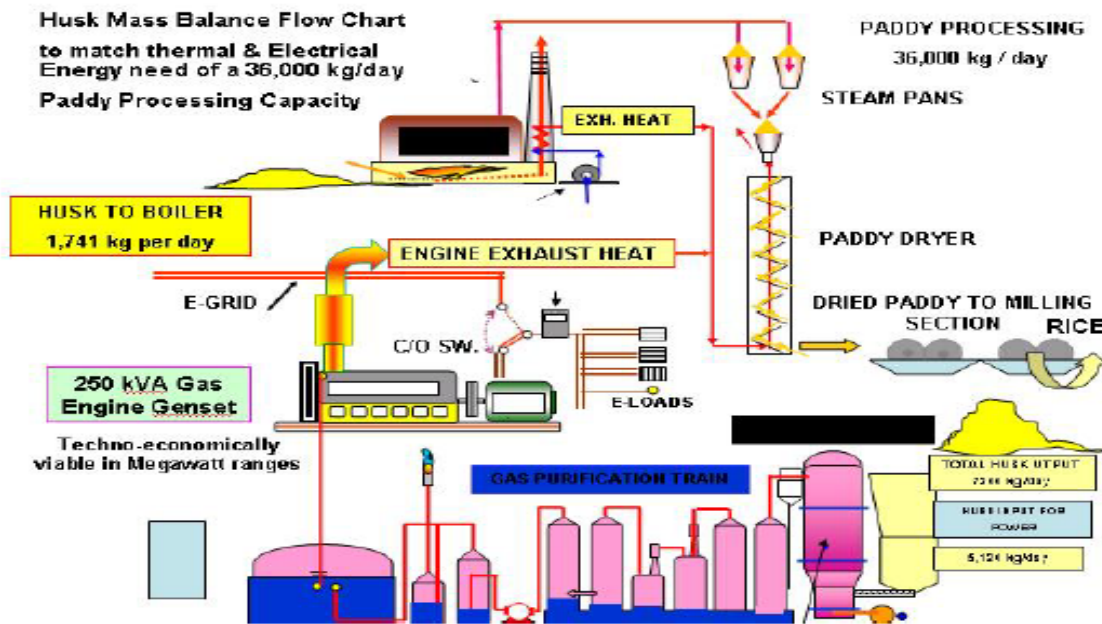


Figure 3: Pictorial diagram of the power plant

### Plant Performance of Gasifier Unit

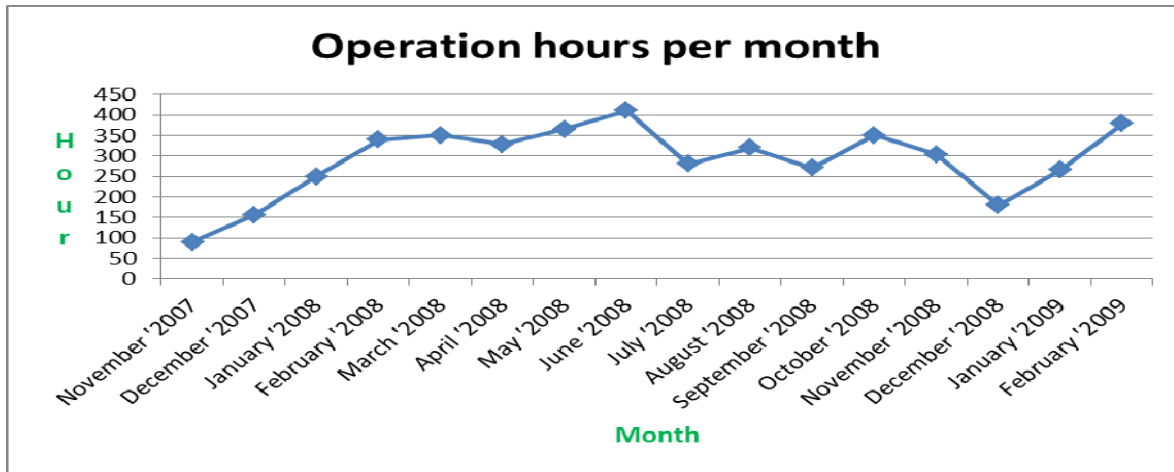
The gasifier reactor has been tested with a feedstock namely rice husk. The biomass is initially sized to about 20 – 30 mm size in processing machine and partly dried by sun drying followed in a biomass drier such that the moisture content is within 15% on dry basis. Depending upon the ash content in the biomass the char/ash is extracted accordingly. The extraction would typically be about 5 - 6% (dry) for a biomass with an ash content of 2 -3%. The performance of the gasifier in terms of gas composition has been monitored at random time intervals, usually when the system is operating close to rated condition.

Table 1: Some information of gasifier unit

Parameter	Description
Rated Gas Flow	625 Nm <sup>3</sup> /hr (up to total 250 kW capacity)
Average Gas calorific value	> 1,050 (Kcal/Nm <sup>3</sup> )
Rated Biomass consumption	Up to 300 kg/hr (for total 250 kW capacity)
Gasification Temperature	1050oC-1100oC
Gasification Efficiency	Up to 75%
Temperature of Gas at Gasifier Outlet	250 to 400oC
Typical Auxiliary Power Consumption	Up to 11 kW
Typical Gas composition	CO-20.62%, H <sub>2</sub> -10.62%, CO <sub>2</sub> -13.61%, CH <sub>4</sub> - Up to 4%, N <sub>2</sub> -52.62%

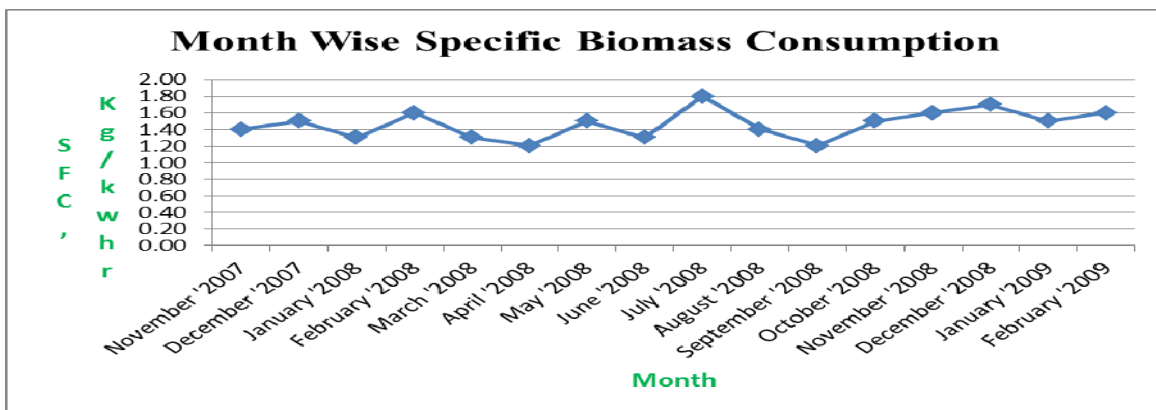
### Performance of Gas Engine

The plant has gone for commercial operation from October 2007 and has successfully completed over 6500 hours of operation, generating about 0.3 million units. It took about 3 – 4 months to stabilize the plant operations; subsequently the plant has been operating 24 hours x 7 days a week.



**Figure 4:** Operating hours per month of the power plant

Fig. 4 shows month-wise operation of the system during November '07 to Feb '09. During the plant stabilization, the duration of operation was lower. The stabilization period was slightly longer because of issues related to load management. The captive load had variations in excess of 60 % of the rated capacity. Even though under no-load condition this variation was acceptable, at the rated condition the engine frequency used to drop. With proper load management this issue was resolved. Subsequent to that the no. of hours of operation was around 50 hours except for few months during the onset of monsoon, wherein procuring dry biomass became a major bottleneck. Once the dryer was installed, dry biomass was available on a continuous basis. The subsequent rise and fall in the no. of hours were more related to non-availability of plant load and has little to do with the availability of the plant for operations. The plant has completed over 6500 hours of operation by this time, 2012.



**Figure 5:** Month wise biomass consumption

Fig. 5 shows the specific biomass consumption (SFC) variation with time. Earlier plant stabilization period, the consumption varied between 150kg/hour to 180kg/hr. During this period the gas engine operated between 40-50%

of the rated load and therefore the cause for SFC to be higher. The gas engine has been jointly monitored by IDCOL and Dreams Power Private Limited and periodically inspected once every 600 hours of operation. These inspections have shown the engine components (throttle valve, compressor of turbo-charger, after-cooler, intake manifold, intake valves and spark plug) to be clean and intact. Similarly the Total Base Number of lube oil quality has been found to satisfactory as per reports of the engine manufacturer. Currently lube oil change is being done once in 500hour of operation. The current operating cost (fuel + manpower + maintenance) per unit electricity generated is about 5 US Cents and moreover the maintenance cost for the gas engine has been found to be comparable to that of a diesel engine.

## Environmental Impacts

The reported power plant is environmental friendly. Normally we get 4 types of effluents that are generated from the gasification process; ash, char, tar, and waste water. Ash is collected in wet condition. Around 20% of rice husk is made up of ash and the ash coming from the gasifier contains 10 to 15% carbon by weight. The ash-laden water can be used as organic fertilizer or land filling purpose. The plant has on site storage facility for ash. Char can be transformed into charcoal which is used as a domestic fuel for cooking and heating. Tar can be either recycled or burnt in the gasifier or used as black paint for the wooden materials like boat, wooden structures and construction of roads. The plant has onsite storage facility to deposit waste water which needs to be changed in every three month.

The below table 2 shows the exhaust emissions of the producer gas engine power plant in terms of CO and NO at rated condition. The engine has no emission regulating device. As evident from the Table, the achieved emission levels are much lower than the existing Europe Stage II (valid up to 2004/5) emission norms for off-road diesel engines. All this has been achieved without any after-treatment for the engine exhaust emissions.

**Table 2:** Gas Engine Emission (g/MJ)

Parameter	Europe Stage	
	II [12]*	PG Engine
CO	0.97	0.7-0.8
NOx	1.67	0.5-0.9
PM	0.083	<< 0.0023

## Other Plants

Bangladesh government has a plan to establish more biomass fueled power plant. Other than the above mentioned power plant another one plant is already in pipe line to generate green electricity using biomass technology. IDCOL is financing this new project, which is located in Chilarong, Thakurgaon sadar, Thakurgaon. This plant will also use locally available rice husk as fuel for power generation. This power plant will be more sophisticated compared to earlier one and has provision for complete automation using PLC. The plant will have also better waste heat utilization, where in the waste heat both from the gasifier and the gas engines will be used for operation of biomass dryers and a vapor adsorption type water chilling system.

## Conclusion

Considering all the aspects of Bangladesh power situation renewable energy seems to be the best solution for long run. The fossil fuels of Bangladesh are going to be finished within next 20years. The fossil fuel price is also hiking.

So biomass fueled power plant can be a good option for our rural areas. The case studies brought out in this journal clearly represents that IDCOL's financed biomass gasification is well established technology. Issues related to gas quality has been successfully addressed and to eliminate issue related to moisture content in biomass (seasonal) an engine/gasifier waste heat drier has been integrated with the package. So, our technologist and policy makers should give more emphasis to generate green electricity from biomass.

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## References

- [1]. Biomass to Bioenergy, The Science and Technology of the IISc bio-energy systems, ABETS, IISc, Bangalore, 2003, pp 154.
- [2]. S. Dasappa, P. J. Paul, N. K. S. Rajan, H. S. Mukunda, G. Sridhar, H.V. Sridhar, 'Biomass gasification technology – a route to meet energy needs', Current Science, Vol. 87, No. 7, 2004, pp – 908-916.
- [3]. S. Dasappa, G. Sridhar, H.V. Sridhar, P. J. Paul, H. S. Mukunda, 'On the advances in thermo chemical conversion technology', 2nd world conference on biomass for energy, industry and climate change, held at Rome, Italy, 10-14 May 2004.
- [4]. <http://www.dieselnet.com/standards/eu/offroad.html#s3>
- [5]. G. Sridhar, S. Dasappa, H.V. Sridhar, P.J. Paul and N.K.S. Rajan, 'Gaseous Emissions Using Producer Gas Fuel in Reciprocating Engines', paper no. 2005-01-1732, the SAE centenary conference held at Detroit in April 2005.
- [6]. M. Jayamurthy, S. Dasappa, P. J. Paul, G. Sridhar, H. V. Sridhar, H. S. Mukunda, N. K. S. Rajan, C Barge, T Lilledahl, K. Sjostrom., 'Tar characterisation in new generation agro-residue gasifiers--cyclone and downdraft open top twin air entry systems, Biomass Gasification and Pyrolysis, State of the art and future prospects', pp. 235--248, CPL Press, 1997.
- [8]. [http://www.bpdb.gov.bd/bpdb/index.php?option=com\\_content&view=article&id=26&Itemid=24](http://www.bpdb.gov.bd/bpdb/index.php?option=com_content&view=article&id=26&Itemid=24)
- [9]. G Sridhar, H V Sridhar, S Dasappa, P J Paul, D N Subbukrishna and N K S Rajan, 'Green Electricity from biomass fuelled producer gas engine' accepted paper at ninth international conference on Electronic commerce (ICEC '07). ACM, New York, NY, USA, pp. 65-74, 2007.
- [10]. Report No. EP/RAS/106/GEF, Local Government Engineering Department (LGED), Bangladesh Government, 'Reducing Greenhouse Gas Emissions by Promoting Bioenergy Technologies for Heat Applications'.
- [11]. Peter McKendry, 'Energy production from biomass (part 1): overview of biomass', accepted paper in international conference of Bio-source Technology, 2002.
- [12]. Warren, T.J., Poulter, R., Parfitt, R., 1995. 'Converting biomass to electricity on a farm-sized scale using downdraft gasification and a spark-ignition engine'. Bioresource Technology 52, 95–98.