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Research article

Climate Change Mitigation by Biomass Gasification Combined with CO_2 Capture & Storage for Biomass Power Plant in Kapasia, Bangladesh

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Abstract

This journal represents climate change mitigation by biomass gasification combined with CO2 Capture & storage for first biomass power plant in Bangladesh. 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. 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. The specific biomass consumption is measured to be within 1.1 ± 0.1 kg/kWh with an overall efficiency of 22-24%. Gasification technology combined with CO2 capture is being seriously considered in several countries for reducing CO2 emissions from power generation. It could also be applied to power generation from biomass; the net result would be to generate electricity with a net "negative emission" of CO2. In this paper, the potential effectiveness of this approach is assessed in terms of cost, quantity of emissions avoided, and feasibility. Purpose-grown and by-product biomass feeds are considered. The conclusion is that, despite the negative emissions of CO2, biomass gasification combined with CO2 capture and storage is likely to be less attractive than more established fossil fuel and biomass-based mitigation options. BIGCC combined with CO2 capture and storage is not a cheap option. This applies to both the cost of electricity generated, and the cost per tonne of CO2 emission avoided. It is more expensive than a coal IGCC with CO2 capture, and more expensive than biomass use in BIGCC without CO2 capture. The extent of technology development required is significant, e.g. to clean raw synthesis gas sufficiently to use in a shift-conversion catalyst, but it is possible that the technology could be used in a country that had a highly developed biomass energy industry and cheap biomass feedstock.

Keywords: Biomass, Renewable energy, Green electricity, CO_2 capture & storage etc.

Introduction

We have considered the application of CO_2 capture and permanent storage to the production of electricity by biomass gasification in this paper. It has been reported that combining CO_2 capture and permanent storage with biomass conversion to energy would result in the net removal of CO_2 from the atmosphere. Figure 1 illustrates the concept. Atmospheric CO_2 is adsorbed by growing biomass which is then used to produce electricity. If the CO_2 produced is returned to atmosphere, the process is essentially carbon-neutral. However, if the CO_2 produced by burning biomass is captured and permanently stored, e.g. in an underground geological formation, the overall process would result in a net removal of CO_2 from the atmosphere.

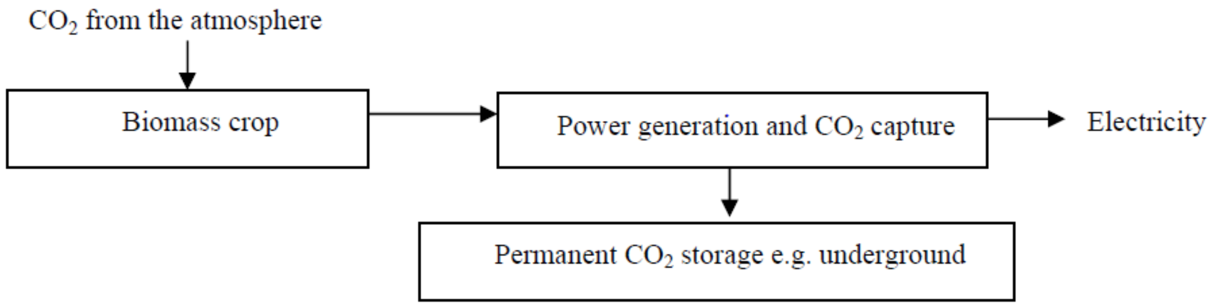

Figure 1: Power generation from biomass combined with CO_2 capture and storage

CO_2 reduction has been assessed for a processing scheme based on the production of electricity from rice husk in a sustainable manner. The rice husk is converted into electricity in an integrated gasification combined cycle. Such BIGCC schemes have been assessed previously by IEAGHG, and reported to be feasible, although not yet widely used, and a relatively expensive way to produce electricity.

The application of BIGCC combined with CO_2 capture and storage is considered in 3 potential contexts:

• A 'Stand-alone' development in which the source of fuel, power plant, and CO_2 storage are all local and not integrated into larger schemes. Land suitable for energy crops is located near a potential CO_2 store. Sufficient such developments are assumed to have taken place that the technology is commercially mature. Water is available, and a convenient connection can be made locally into the electricity grid, but there is no other opportunity for integration with CO_2 emission reduction schemes.

• A 'CO_2 intensive' development which is one of many CO_2 capture and storage schemes, some of which are fossil fuel based and much larger than the BIGCC plant. It is assumed that CO_2 transportation and storage facilities can be shared with others. Hence, the store can be large and need not be near the power plant and biomass source.

• One of many biomass developments in a 'Resource-rich' country with a growing energy demand. Development of a large-scale biomass infrastructure is a major objective. Sufficient biomass is available to meet local heat demands and to provide a surplus which could be used for production of transport fuels, hydrogen, etc. In this context the ability to produce a net reduction in CO_2 emissions whilst increasing electricity production may have commercial value. For example, if the reduction in emissions can be traded for carbon credits. The initial focus of the paper is on the use of a purpose-grown biomass crop in the 'Stand-alone' context. This enables the costs and benefits of combining BIGCC and CO_2 capture and storage to be presented on a clear basis. We then consider how these costs and benefits would be modified by introducing the BIGCC with CO_2 capture and storage into the 'CO_2 intensive' and 'resource-rich' contexts.

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 Nm3/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 2: 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 Nm3 of producer gas with a calorific value of 1000-1300 Kcal per Nm3. One important aspect to be mentioned here is that Biomass feeding process is manual here. The gas coming out of the gasifier has a high temperature (450oC 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.

Fig. 3 shows the specific biomass consumption (SFC) variation with time. Earlier plant stabilization period, the consumption varied between 150kg/hour to 180kh/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.

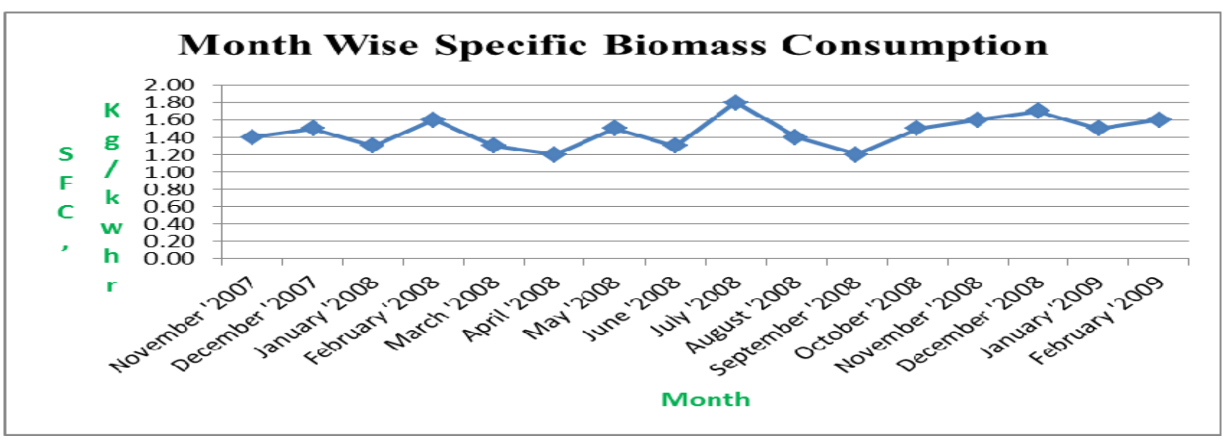

Figure 3: Month wise biomass consumption

Future Modification Plan 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. Some important information are given below of gasifier unit-

Table 1: Some information of gasifier unit (Present scenario)

Parameter	Description
Rated Gas Flow	625 Nm3 /hr (up to total 250 kW capacity)
Average Gas calorific value	> 1,050 (Kcal/Nm3)
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

A view needs to be taken on the size of future commercially mature BIGCC installations. In particular, how big they should be made to optimize potential scale advantages.

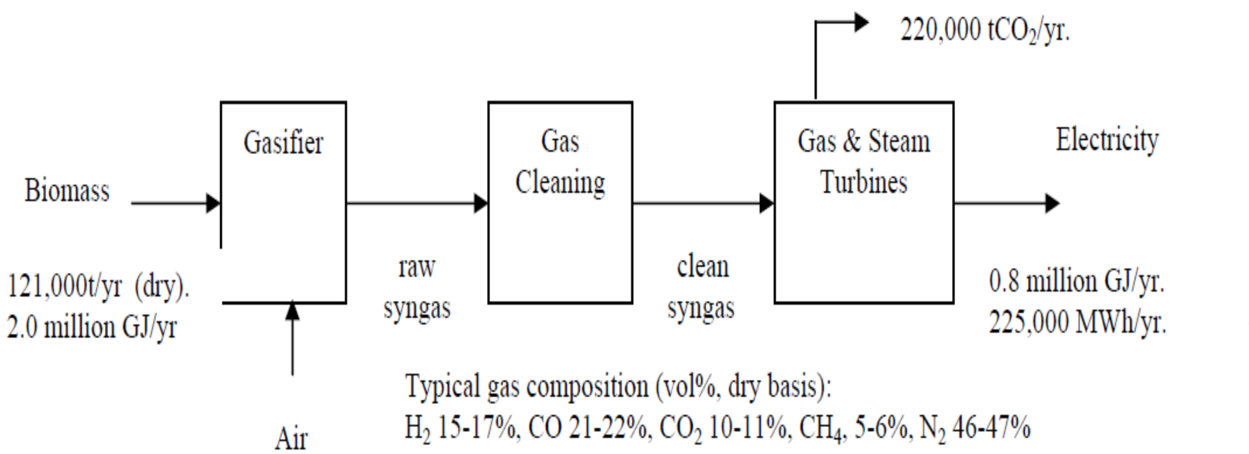

Figure 4: Biomass integrated combined cycle (without CO2 capture)

A gas-cleaning step is required before raw syngas can be used in an efficient gas turbine. Successful development of gas-cleaning is now recognized as a key requirement for BIGCC technology. Raw syngas can contain many contaminants, see Table 1; the extent of treatment required depends on its use. Low levels of all contaminants must be achieved to avoid fouling and corrosion problems in gas turbines.

Table 2: Raw syngas contaminants

Contaminant	Nature	Problem
Particulate matter	ash, char, any fluid bed material	Erosion, deposition
Alkali metals	Na and K compounds	Corrosion, catalyst poison
Nitrogenous compounds	NH3, HCN	Emissions
Tars	Polyaromatic and oxygenated hydrocarbons	Deposition, fouling, handling, and disposal problems
Sulphur and Chlorine	HCl, H2S	Corrosion, catalyst poisoning

Additional Processing for CO_2 Capture in Biomass Gasification

As can be seen in Figure 4, the CO2 content of the BIGCC syngas is only about 10% by volume (the CO2 contains about 18% of the carbon in the syngas). The balance is still in the form of fuel (CO, CH4). Different gasifiers and process conditions alter syngas composition but the FW unit can be taken as typical. The low CO2 concentration in gas turbine exhausts makes the option of post-combustion CO2 capture not very attractive. Pre-combustion capture of CO2 is therefore assumed. A shift-conversion step is added to the process (CO + H2O ↔ H2 + CO2) to increase the quantity of CO2 available for capture. Almost total conversion of the CO can be achieved. In addition to the cost penalty for the shift reactor unit there is an energy penalty mainly due to the large quantities of steam required. Various commercially available solvents can be used to capture the CO2. The presence of nitrogen as nearly 50% of the syngas is a major processing disadvantage because in effect it is a diluent doubling the amount of gas to be processed. However, air is the most widely used oxidant in biomass gasification because it avoids the cost and energy penalties associated with producing oxygen. The main disadvantage is the low calorific value of the syngas of about 4-7MJ/Nm3. If oxygen were to be used in the gasifier a medium heat value gas can be produced, with a calorific value of 11-13MJ/Nm3. The relative merits of air and oxygen gasification were much debated for coal gasification but have now clearly been decided in favour of oxygen. It is possible that commercial BIGCC units may also favour oxygen. Given the above, an oxygen-blown gasifier was selected for use with the CO2 capture BIGCC. It was assumed that an air separation unit would be used, although a pressure-swing adsorption unit is a possibility. Syngas produced in the BIGCC without CO2 capture contains an appreciable amount of methane. This normally has the useful attribute of raising the calorific value of the gas. About 26% of the carbon present is contained in the methane. Methane in the syngas is not desirable in the case of CO2 capture as it would pass through the shift reforming process and reduce the quantity of carbon available for capture. Steam reforming (CH4+2H2O ↔ CO2+4H2) is a possibility but would add to the complexity and cost of the process. We assume that a gasifier minimizing CH4 production can be selected; the higher temperatures achieved with oxygen blowing should make this possible. The problem of syngas cleaning for use as a turbine fuel becomes more acute if a shift-conversion unit is installed as the catalyst needs to be protected from tars, particulates, and potential catalyst poisons such as volatile alkali metals. This is also the case for the CO2 capture solvent.

The cost of transporting CO2 by pipeline (or other means) is highly dependent on the quantity and distance. This is illustrated in Table 4 which has been produced using information available from IEA GHG. In the context of a 'Stand-alone' development we assume the power plant is adjacent to the CO2 store and the transmission costs are negligible (in comparison, the average crop transport distance is 25km.). In the 'CO2 intensive' context we assume that the captured CO2 is stored in a large store and the costs shared with others. The captured CO2 is transported about 25km to a CO2 pipeline network (at a cost of 2$/tCO2) and then transported 500km in a pipeline conveying 5 million tCO2/year (at a cost of 5$/tCO2) giving a total transmission cost of 7$/tCO2.

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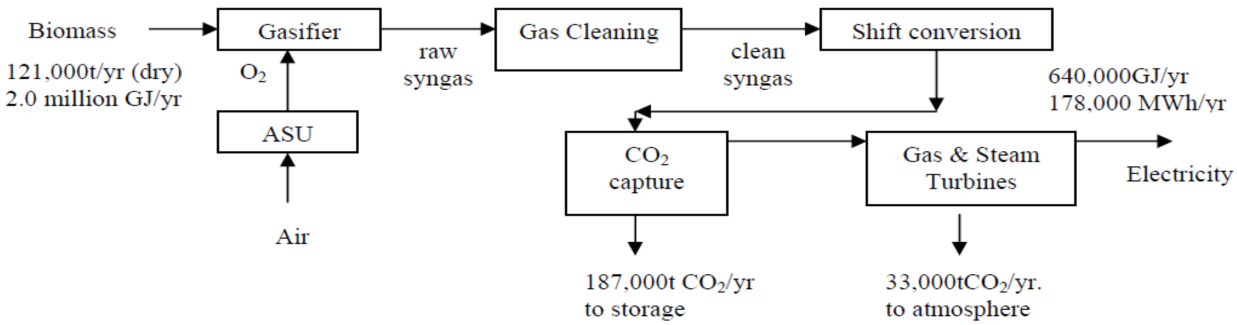

Figure 5: Biomass integrated combined cycle with CO_2 capture

Table 3: Cost of CO2 transport by pipeline (US$/tCO2)

Rate (t/yr)	Length of pipeline (km)		
	25	100	500
200000	2	7	32
500000	1	3.8	17.6
1 million	0.7	2.5	10.4
5 million	0.64	1.4	4.7

Conclusion

BIGCC combined with CO2 capture and storage is likely to be less financially attractive than many of the more established fossil fuel and biomass-based emission reduction options. We should, however, consider whether the ability to generate electricity with negative emissions of CO2 might be attractive for other reasons: One is the ability to remove emissions from the atmosphere is not unique to this technology; for example, CO2 can be removed from air by scrubbing it with sea-water. Another reason is the possibility of ‘cleaning-up afterwards’ using this technology should not be seen as a justification for delaying the introduction of emission reduction measures. Last but not the least reason is that it is possible that the technology could be used in a country that had a highly developed biomass energy industry and cheap biomass.

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