PROSPECTS OF IMPLEMENTING UNION BASED BIOGAS PLANT MODEL AT CHATTOGRAM DIVISION IN BANGLADESH

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Abstract - The growingdisposition of livestock resources as well as the poultry sector with the corroborating weather conditions in Bangladesh encourages an auspicious future of bioenergy. In this paper, existing energy situation of Bangladesh and noteworthy activities associated with renewable energy has been mentioned. After presenting the potential of livestock resources of Bangladesh, the Union based biogas plant model has been explained. The model has been employed to study the potential of generating biogas as well as electricity in Chattogram division of Bangladesh. Under this model, each union can contribute 552 m^3 of gas or 0.75 MW of electricity daily and in total 3.2×10^5 m^3 of gas or 435 MW of electricity can be generated in Chattogram division. Union based biogas plants will be beneficial for the rural development but difficult in implementation. Therefore, several issues that required reconciling before installations have been indicated.

Keywords: Biogas; Electricity; Union; Bangladesh; efficiency.

1. INTRODUCTION

Energy crisis is one of the biggest hurdles to the progress of Bangladesh. According to the government's assessment, 58% of total households are under the grid connection and with the contribution from renewable energy; about 70% of the population has access to electricity. The government is planning to link 98% of the households mainly through the grid extension within 2021 (Das, C. K., et al. 2016; Rahman, K. M., et al. 2014). In recent years, there is an improvement in the power generation, and the capacity of the generation which comprises the captive power and renewable energy has reached 20,000 Megawatt (MW). The present peak power demand in Bangladesh ranges between 10000 MW to 14000 MW per day, and the typical generation is over 9000 MW per day, and the highest generation was 12738 megawatt (MW) (on 05/08/2019) (The Bangladesh Power Development Board (BPDB, 2019)). The Bangladesh Power Development Board (BPDB) has taken up an extensive capacity expansion plan to adjoin about 11,600 MW over the next five years, aiming to generate 24,000 MW of electricity by 2021. Besides, the work of establishing the first-ever nuclear power plant is also in progress. It has been anticipated that the demand will be over 33000 MW by 2030 (Kabir, H., Palash, M. S., & Bauer, S. 2012).

The power plants run on several fossil fuels, and most of them are natural gas based, which will ultimately finish within a few decades (Kabir, H., Palash, M. S., & Bauer, S. 2012). Till now 26 gas fields (24 in the onshore and 2 in the off-shore) have been discovered in the country and among them 19 gas fields are in production, the current average production of natural gas is about 2633 million cubic feet per day (MMcfd). A total 961 billion cubic feet (BCF) of natural gas was produced in 2017-18 which was used by power- 40%, fertilizer-5%, captive power-16%, industry-17%, domestic-16%, CNG - 5% and others very minute quantity. Natural gas accounts for the 66% grid electricity generation while all the 7 urea fertilizer industries are reliant on natural gas for feedstock. Natural gas has contributed remarkably towards industrial expansion in the country as fuel for heating and captive power generation at a very favorable price. While the entire nation has been benefitted by this resource, only about 7% of the populations have been served directly by utilizing piped natural gas for household purposes. So, they have to operate alternative fuels like kerosene or wood for cooking (Hydrocarbon Unit, 2019).

There have been several efforts undertaken in exploiting the renewable energy sources in Bangladesh. According to the Sustainable and Renewable Energy Development Authority (SREDA) renewable energy has the potential to contribute 534 MW of electricity, which is 2.84% of the total generation (SREDA, 2019). Among the renewable energy activities, solar energy is the most eminent in Bangladesh, adding about 300 MW of electricity. Several solar parks are under planning which will yield 100 MW each. Hydropower is next to solar energy, contributing 230 MW of electricity (SREDA, 2019). There are a few prospects for wind energy in the coastal territories in Bangladesh, and the plants located in Kutubdia and Feni are producing 2.30 MW of electricity (Nandi, S. K., &Ghosh, H. R. 2010).

Biogas is a renewable, as well as a fresh source of energy. Gas spawned through bio digestion is non-polluting and shrinks greenhouse emissions or effect. No combustion takes place during the process ensuring zero emission of greenhouse gasses to the atmosphere. Consequently, using gas from waste as a form of energy is essentially a great way to battle global warming.

Biogas is considered a promising technology for Bangladesh (Rahman, K. M., et al. 2014; Kabir, H., Palash, M. S., & Bauer, S. 2012; SREDA, 2019). The production temperature of biogas through the anaerobic digestion is also favorable in Bangladesh. In agrarian areas, many of the households are using domestic biogas plants for cookery. Biogas plants also yield high-quality fertilizer. But the generation of electricity through biogas is nevertheless insufficient in Bangladesh. Across the country biogas plants contribute no more than 0.68 MW of electricity (SREDA, 2019). The quantity of the Biogas-Electricity plants is also very little compared with the total number of plants.

In section-II, the potential of livestock resources and biogas plants in Bangladesh are discussed. After briefly discussing the "Union Based Biogas Plant Model" (Al Zaman, MDA, et al. 2019), we will apply it to the Chattogram division (in section-III), based on the existing data. In the remaining sections- the calculated results, benefits and challenges and conclusion have been conferred.

2. LIVESTOCK RESOURCES AND BIOGAS PLANTS IN BANGLADESH

Livestock has been one of the fundamental components of the composite agricultural practices in Bangladesh. About 70% of the total population of Bangladesh inhabits pastoral areas. As the contemporary machineries are not available in many of the localities, this resource is serving both as a source of meat protein and farm power services. In the preceding few decades, it's also popular as an approach to self-employment. This particular sector delivers full-time employment for 20% of the total population and part-time employment for almost 40-50% of the entire population (Begum, I. A., et al. 2011). Livestock products include particularly leather and leather made products which are also strengthening to the country's economy. Even though the grazing facilities are inadequate and declining rapidly, yet the livestock production has been showing the moderately rising tendency (shown in Fig. 1).

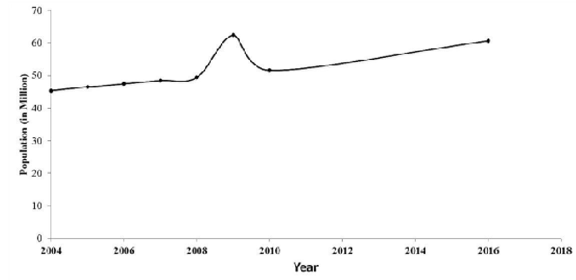

Fig. 1. Livestock resource of Bangladesh over the years [10, 24]

According to the assessments obtained from the Bangladesh Ministry of Fisheries and Livestock (2011), Bangladesh Bureau of Statistics (BBS Report, 2011) and Food and Agriculture Organization Statistical Databases (FAOSTAT), we can say there are over 60 million domestic animals which includes cows, buffaloes, goat, and sheep in Bangladesh. According to FAOSTAT (2016), there are 23.8 million cattle and 1.5 million buffaloes in Bangladesh, and the amount is rising every year. The average production of manure for each cow or buffalo is roughly 10- 11.5kg per day (Alam, M. S., Huq, A. M. Z., &Bala, B. K. 1990; Rashid, M. M., et al. 2007). According to The Institute of Fuel Research & Development (IFRD) under the good condition, the quantity of gas manufactured by each Kg of manure is around 1.3 cubic feet (Iqbal, S. A., Rahaman, S., &Yousuf, A. 2014).

The first ever biogas plant in Bangladesh was installed for research purpose in 1972. Since then the number has increased gradually. Government also provided subsidies in the early epochs. Later in the 90's many government organizations like Environment Pollution Control Department (EPCD), Bangladesh Council of Scientific and Industrial Research (BCSIR), Department of Livestock (DLS), Local Government Engineering Department (LGED) started several initiatives to install biogas plants. Later many Non-Government organizations like Building Resource across Communities (BRAC), Grameen Bank, Danish International Development Agency (DANIDA) etc. started funding to install biogas plants in numerous zones in Bangladesh (Al Zaman, MDA, et al. 2019). However, the number of Biogas plants across the country actually elevated after the inauguration of Infrastructure Development Company Limited (IDCOL) in Bangladesh. IDCOL with the support from World Bank, KreditanstaltfürWiederaufbau (KFW) development Bank and Netherland Development Cooperation (SNV), has set up over 48 thousand biogas plants in different zones of Bangladesh (Chy, S. M. 2016).

There are six different capacities of plants for each design is found in Bangladesh. The daily gas production capacities of these plants are ranged between 1.2 m3 to 25.0 m3 which meet the demand of both domestic households and mid-sized dairy or poultry farms. German Technical Cooperation (GTZ), under the program 'Sustainable Energy Development', has come up with an opportunity to support setting up and financing of large biogas plants with a capacity of above 4.8 m3, established mostly in commercial poultry, dairies, and slaughterhouses (Iqbal, S. A., Rahaman, S., &Yousuf, A. 2014). According to the Sustainable and Renewable Energy Development Authority (SREDA), some 76,771 biogas plants are currently installed in Bangladeshi villages, and the Fixed Dome biogas plants are most common (Mahdi, T. H., et al. 2012). The regular investment cost of a biogas plant in Bangladesh is about USD 400 which is less than other Asian countries like Pakistan, Nepal, Vietnam, China etc. (Kabir, H., Palash, M. S., & Bauer, S. 2012).

According to IFRD, 105 billion cubic feet of biogas could be produced per year which can be served to around 20% of the entire population (Khanam, J.S., et al.2019). Yet the amount of electricity generated from biogas plants is comparatively low. Electricity generation from biogas in Bangladesh was initiated right after 2000. Again here IDCOL is the prominent organization in installing these plants, and till 2016, they have set up 7 such plants that are capable of producing 0.69 MW of electricity which is only 0.1% of the total electricity that comes from the renewable energy sources (SREDA, 2019). The largest one of those is located in Gazipur that has the capability of generating 0.40 MW of electricity. Bangladesh Power Development Board published a plan to set up a one MW grid-connected biogas plant nearby Dhaka within 2020. Besides these, many domestic biogas plants around the country are making electricity from biogas (Alam, M. S., Huq, A. M. Z., &Bala, B. K. 1990).

3. UNION BASED BIOGAS PLANT MODEL

Being an agronomic country there are over 86 thousand villages in Bangladesh. Here Union councils or typically recognized as Unions are the lowest rural administrative and local government units. It is generally composed of nine Wards. Here a single village is labeled as a ward. At present, there are 4,554 unions in Bangladesh. A Union Council comprises of a chairperson and twelve members plus three members exclusively reserved for women. The area of a typical union is around 20 square kilometers, and more or less 25 thousand people live in a union on an average (Haque, C. E., 2012).

Union based biogas plant model (Al Zaman, MDA, et al. 2019), is a similar form of “Community biogas plants” in the countries like Germany, Finland, India, Nepal, Myanmar etc. We considered unions of several divisions with a particular number of cows and buffaloes with a minimum amount of dung to collect. The dung will be collected from the mass people who are the owners of the animals of that locality and will be carried by the vehicles. Then it will be accumulated in the traditional way to yield the biogas. We have shown (Al Zaman, MDA, et al. 2019), how this type of model can be utilized for generating the electricity in rural areas. Fig. 2 is representing the block diagram of the model.

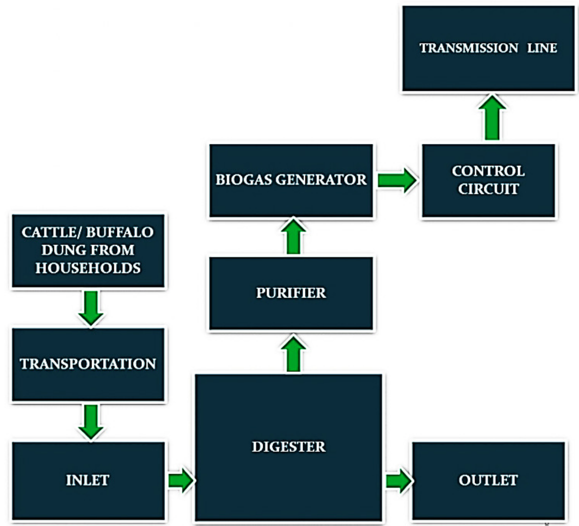

Fig. 2. Block diagram of union based biogas plant.

We applied this model for calculating the output in three different divisions of Bangladesh. In this paper, we will apply it only for the Chattogram division for observing the gas output as well as electricity (study area is shown in Fig. 3).

Fig.3. Map of Bangladesh, the shaded region is showing Chattogram division

Chattogram, formerly known as Chittagong is one of the biggest divisions in Bangladesh. It is located at the southeastern zone of the country. Chattogram plays a vital role in the Bangladeshi economy. The Port of Chattogram is the prime maritime gateway to the country. The port is the busiest international seaport on the Bay of Bengal and the third busiest in South Asia.

According to SREDA database, currently there are 81 completed and running renewable energy projects in Chattogram. Most of them are in fact solar energy projects. A 60MW Solar Park is under planning in a region called Rangunia inside Chattogram. Also the only

Hydro power plant (Kaptai Hydro Power Plant) in Bangladesh is situated at Chattogram, contributing about 230 MW of electricity (Nandi, S. K., &Ghosh, H. R. 2010).

4. RESULTS

The amount of gas that will be generated under this model can be obtained from the equation,

$$M_{BIO} = N_{UC} \times E_M \times C \text{ --------- } (i)$$

Where,
M_{BIO} = Maximum amount of gas that can be produced under proper condition
N_{UC}= Number of cows and buffalos under consideration
E_M= Expected amount of manure to be collected per cow or buffalo
C = Amount of gas that can be produced per Kg (1Kg manure = 1.3 Cubic feet) (Iqbal, S. A., Rahaman, S., &Yousuf, A. 2014).

The electrical energy from biogas can be calculated (Cuellar, A.D. & Webber, M.E. 2008; Surroop, D. &Mohee, R.2012; FNR, 2019) by the following equation,

$$Electrical\ energy = \frac{M_{BIO} \times M_F \times L_{HV} \times \rho \times \eta}{3.6} \text{ -------------- } (ii)$$

Where,
M_{BIO} = Maximum amount of gas that can be produced under proper condition,
M_F = Methane fraction,
L_{HV} = Lower Heating Value of biogas,
ρ = Density of Methane,
η = Conversion efficiency of gas engine/ Generator

The data of livestock (Cows and Buffaloes) is collected from District Statistics-Bangladesh Bureau of Statistics (BBS) (Table -1). As we will utilize the manure from 2500 cows and buffaloes for this model, for that reason we will only consider only those unions where the number of cows and buffaloes is greater than 3000.

Table 1. Data for Chattogram Division [18]

District Name	No. of Upazila	No. of Unions	Total number of cows/buffalo	Cows/Buffalos per Union (Average)
Brahmanbaria	9	98	268220	2736
Bandarban	7	30	97076	3235
Chandpur	8	86	307171	3571
Chittagong	15	206	595181	2889
Comilla	16	169	662900	3922
Cox's Bazar	8	71	259348	3652
Feni	6	43	134604	3130
Khagrachori	8	37	141504	3824
Laxmipur	5	53	180561	3406
Noakhali	9	91	376394	4136
Rangamati	10	49	122758	2505

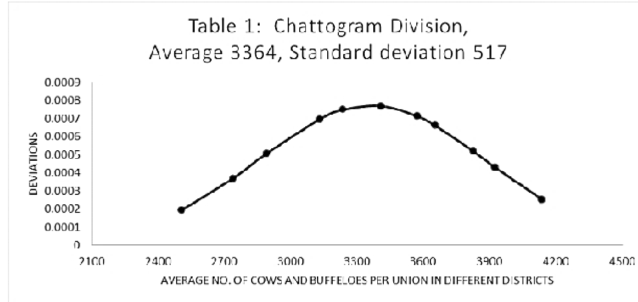

Fig.4. Normal distribution for Table 1 (Chattogram)

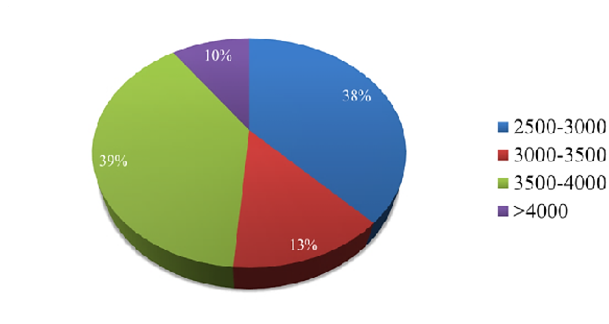

Fig.5. Population distribution of Cows and buffaloes in the Unions of Chattogram Division under study.

Table 2: Union overview

Total No. of Unions in Chattogram	933
Unions that has more than 3000 Cows and Buffaloes	580

Table 3: Gas production from a union (per day)

No. of cows and buffaloes under consideration, (N_{UC})	2500
Expected amount of dung to be collected per cow or buffalo (E_M)	6 kg
Total amount of dung	15000 kg or 15 Tons.
Maximum amount of gas that can be produced under proper condition (M_{BIO}) (Per Union, using equation (i))	**19500 cubic feet or 552m^3**

Table 4: Electricity generation from biogas (per Union, per day)

Maximum amount of gas that can be produced under proper condition (M_{BIO}) (Table 3)	552m^3
Considering Methane fraction (M_F)*	50%
Lower Heating Value of biogas (L_{HV}) [20]	50 MJ/kg
Density of methane (ρ)	0.656 kg/m³
Considering efficiency of gas engine or generator (η)*	30%
Electricity generation from biogas (Per Union, using equation (ii))	754.4 KW-h (= 0.75 MW-h)

Table 5: Overall gas or electricity generation estimation

Biogas generation from one union	552 m^3
Total biogas generation from Chittagong division	3.2×10^5 m^3
Electricity generation from one Union	754.4 KW (= 0.75 MW)
Total Electricity generation from Chattogram division	435 MW

For collecting the main ingredients (manure) for the plants here we have considered 2500 cows and buffaloes, and then the unions should or expected to have more than three thousand cows and buffaloes. The data (Table 1 and Fig. 4 and 5) shows us that on an average the unions of Chattogram divisions have at least 2500 cows and buffalos. About 73% of those unions have more than 3000 cows or buffaloes. 580 unions satisfy the benchmark under the study area (table 2).

Using the Equation (i) we have estimated the amount of gas that can be produced under proper condition from a biogas plant in a Union (Table 3). If the produced gas is used in generating electricity, then 0.09 MW of Electricity can be yielded from each union (Using Equation (ii)). In total, about 3.2×10^5 m^3 gas can be produced from Chattogram division each day and if all the gas is used to generate electricity, then about 52 MW of electricity can be generated each day.

Also Biogas can be compressed to fill the conventional cylinders (Nallamothu, R.B., Teferra, A. &Rao, B.A. 2013) which are used across the country for cooking. If we manage to compress the gas in a regular sized cylinder (28 cubic meters of biogas is equivalent to one domestic LPG cylinder) (Nallamothu, R.B., Teferra, A. &Rao, B.A. 2013), everyday about 49 thousand cylinders can be filled and 1.4 million gas cylinders can be filled in a month. This will be enough for more than a million families for a month and more than 5 million people will be directly benefitted. More importantly, cooking on a gas stove, instead of over an open fire, inhibits the family from being exposed to smoke in the kitchen. This helps to prevent deadly respirational diseases.

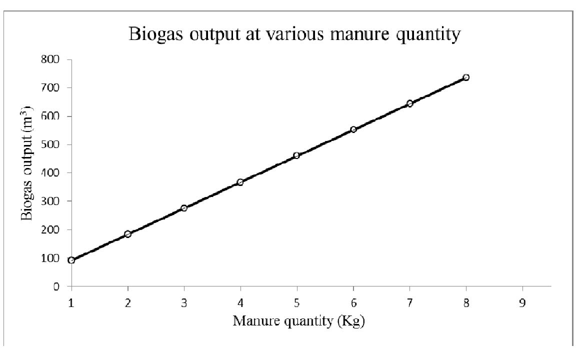

Fig.6. Biogas output for different manure quantities (Per union under the study area)

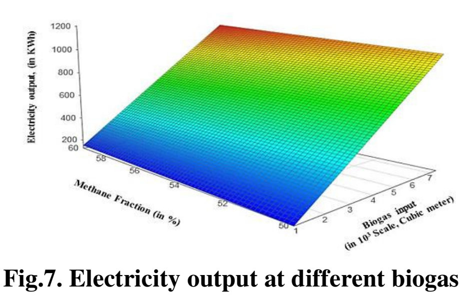

Fig.7. Electricity output at different biogas input and methane fraction

(Per union under the study area at 30% generator efficiency)

Results are shown for biogas output in accordance with different manure quantities (Fig. 6). The value of methane fraction usually ranges between 50-60% (Cuellar, A.D. & Webber, M.E. 2008). The surface plot is showing (Fig. 7) the electricity output at different methane fractions and biogas input to the generator with 30% efficiency. Any point within this surface can be defined by the expression,

$E_{electricity} = M_{BIO} \times M_F \times 2.73$-------------- (iii)

Where,

$E_{electricity}$= Electricity output (in KWh)

M_{BIO} = Amount of gas that can be produced under proper condition (in cubic meter unit),

M_F = Methane fraction (%),

5. BENEFITS AND CHALLENGES

In this study, we have considered only Chattogram divisions. The output of Union bases biogas plant model could have been much greater if we had considered all the divisions. By executing this sort of Biogas plants, the distant places where electricity transmission is problematic or hasn’t extended yet, can be greatly aided. Many people will enjoy the profits of electricity. It will lessen the consumption of fuels like kerosene or diesel used for lightning or other purposes. Apart from the electricity generation, biogas plant also delivers high-quality fertilizers which can be very beneficial for agriculture. If the fertilizers distributed properly, it will unquestionably assist the farmers. This type of biogas plant will also reduce the pollution in a smaller scale and will manage to constitute a healthier environment. The construction procedure and the maintenance of those biogas plants will ensure full time or part time employment for many people and will help to progress the economic condition in some extent. The produced electricity can also be diverted or supplied only to the industries or factories near the plants at reasonable price and the money can be distributed among the farmers who will contribute raw materials for the plants which will also encourage them for further enhancement of their farms or livestock production. The government will also be able to receive some sort of revenue from that.

However, the construction of this type of biogas plants will not be easy. Though the small scale biogas plant installations are easy and inexpensive, the dimension of the biogas digester and the transportation of raw material can be really challenging in this model. Also if we want to dedicate solely to generating electricity, with components like the generators or controlling circuits, the installation cost will be enormous. That’s why, before the installation, several surveys are required in order to ensure the economic feasibility or viability. The assistance of the citizens of the unions is also significant. Without their assistance, it will be much tougher. There are also little concerns about the temperature as in the winter although it does not drop to very low, still it will hurt the anaerobic digestion in the biogas plant and the production will not be the same as expected. Biogas plants required water and that's why these plants should be installed with proper water supply which can be difficult in some places to ensure. As Bangladesh is often stumble upon by natural hazards (Al Zaman, MDA. & Monira, N.J., 2017) like cyclones, earthquakes, floods etc. and Chattogram is also one of the most affected territories, the plants should be set up in those sites with proper safeguard in order to maintain continuous production. For the appropriate maintenance, qualified manpower is also a challenge.

6. CONCLUSION

After the evaluation of the assembled data, we have observed the capability of the union-based biogas plants. Installation of these plants has many benefits as well as challenges already discussed in the previous section. We have dealt with an average quantity of cow/ buffaloes for our investigation and so the substantial output may diverge from our assessment in some cases. Though we have dealt with a distinct amount of manure and the number of cow/buffaloes was too specific but the distribution of the population of cows and buffaloes shows that, on an average many of the unions have greater than 3500 cows/buffaloes. It suggests possibilities of gaining greater amount of raw ingredients for biogas production and bigger biogas production facility. Again, we have considered only 50% of methane from the produced gas and 30% percent generator efficiency for our calculations; both of them can also vary.

However, the suitable location, temperature variation, big primary cost etc. are the impediments to the setting up of these plants. But if the initiatives are taken in a strategic way, it will unquestionably benefit the rural people and will speed up the development process in this region (Chattogram). Although we have worked only with the manure from cows and buffaloes, some other ingredients or wastes can be utilized for biogas production. Particularly Poultry wastes are excellent for biogas production. Employing diverse wastes in the biogas plants in larger quantity will certainly raise the biogas as well as electricity production. This will also reduce the wastes as well as waste management cost. Studies can be done for the transportation system and the expenditures required for the installation of this type of massive biogas plants.

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