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ASSESSMENT OF BIOGAS GENERATION FROM CATTLE DUNG IN BANGLADESH

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Abstract. *Biogas Production from cattle dung exposes massive interest in south Asian countries. Biogas production system offers various sorts of benefits over other forms of bio-energy as it provides different forms of energy and reduces huge amount of environmental impact. As Bangladesh is an agricultural country, it has blessed with plenty of biomass, which can be used as a source of biogas production. In rural areas of Bangladesh, where more than 63% of the population live, only 78% have access to electricity on percentage of rural population in FY 2017. There are about 93.07 million tons cow dung from 25.6 million cows and buffaloes and 12.337 million tons poultry litter from 338 million chickens and ducks, 14.77 million tons manure from 26.10 million goat FY 2017-18 in Bangladesh. Such a large amount of these waste has great fuel value which can be utilized to produce biogas for cooking and electricity generation. Bangladesh has the potential to generate 5361.562 Mm^3 of biogas which could add around 7.50 GWh electricity to the national grid. The design for a 5 m^3 biogas plant is proposed for cooking & electricity supply for 4 houses in remote rural areas in Bangladesh. The energy starved Bangladesh needs to promote biogas technology to reduce the dependence on conventional energy system as well to ensure energy security for the future.*

Keyword. Biomass waste (cattle dung), Biogas, Renewable energy, Electricity.

1. INTRODUCTION

Biomass is well known as a renewable fuel energy resource and ranks fourth providing about 14% of the world's energy need [1]. Biogas production from animal manure has received a significant attention as an alternative energy source in recent years. Depletion of fossil fuel and climate change due to excessive CO_2 emission in the environment, increased economic growth & energy demand are the main drivers for the transformation of the present energy system from fossil to renewable sources. Biomass can play an important role in this alteration to a low carbon economy. Bangladesh is a large and heavily densely populated country in South Asia with a population of about 168.07 million living in an area of 147,570 sq. km and has been struggling to keep up with the energy demand of its large population. More than 90 percent of Bangladesh rural households are still using traditional biomass for cooking; biomass accounts for 50 percent of Bangladesh's total energy supply [2]. The commonly used fuels are rice husks, jute sticks, cow dung and wood. In rural areas, where more than 63% of the population lives, only 78% have access to electricity on percentage of rural population in FY 2017. Only 3% of the total people have the access of natural gas coming to their households through national grid pipe lines and most of them live in the cities [3]. Meantime, most of the rural people depends on biomass, crop residues, leafs and twigs, dung cake and forest wood for cooking that carry out adverse effect in environment. Most of the energy needed for rural people comes from traditional biomass fuels comprising of agricultural residues (45%), wood and wood wastes (35%), and animal dung (20%) [4]. generally, biomass are provided over half (~62%) of the country's total energy consumption. The technology practices in rural areas for burning agriculture, animal waste and fuel wood are inefficient (less than 10 %) [5]. Burning of these fuels is harmful to both environment and health due to emission of deadly CO_2 and rising of smoke cause air pollution. So, it is necessary to encourage alternative sources to generate energy in Bangladesh. Several research works are accomplished to assess the biomass resources to generate electricity through gasification in Bangladesh. Besides, biogas plant is one of the potential renewable energy sources since it can produce gas for cooking and lighting, electricity for power generation, and slurry for developing organic fertilizers. Statistics show that about 2.9% of

national GDP is covered by the livestock sector, and its annual rate of growth is 5.5%. About 20% of the population of Bangladesh earn their livelihood through work associated with raising cattle and poultry. From the source of banglapedia.org, Livestock population in Bangladesh is currently estimated to comprise 25.6 million cattle, 1.49 million buffaloes, 26.10 million goats, 3.47 million sheep in FY 2017.

2. BIOGAS POTENTIAL IN BANGLADESH

Biogas is a combustible mixture of different gases produced through anaerobic digestion of biological materials including livestock manure. It consists mainly of methane (CH_4) and carbon dioxide (CO_2) and is formed from the anaerobic bacterial decomposition of organic compounds in absence of oxygen. It amalgamated with methane (50-75%), carbon dioxide (25-50%), nitrogen (< 1 - 2%), hydrogen (0-1%), hydrogen sulfide (0-2%) and Oxygen content (<1%). The gases are produced from the waste products of the respiration of these decomposer microorganisms at temperatures between 30°C-40°C or 50°C-60°C [6]. The composition of the gases depends on the substances that are being decomposed. The constituents of biogas are shown in Table 1.

Table 1: Percentage of constituent for biogas [7].

Sl No.	Constituent	Chemical formula	Percentage (%)
1	Methane	CH_4	50-70
2	Carbon Dioxide	CO_2	30-40
3	Hydrogen	H_2	5-10
4	Nitrogen	N_2	1-2
5	Water vapor	H_2O	0.3

Bangladesh has favorable climate for most of the renewable including biogas technology. The ideal temperature for biogas in the mesophilic range is around 30 to 40 degree Celsius (℃), and in the psychrophilic range from 15 to 25 (℃). The average air temperature in Bangladesh usually varies from 15 to 40 ℃ But the inside temperature of a biogas digester remains 22 ℃ to 33 ℃ which completes for both requirements [8]. Raw materials for biogas are available across the country. All organic materials that easy decompose and pollutes environment, spreads bad smell and diseases, are the potential raw materials in a biogas plant.

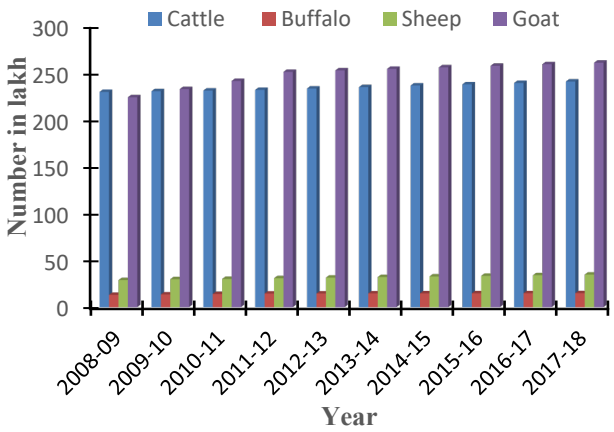


Fig.1: Number of livestock's in Bangladesh (in lakh number)

Figure 1 from livestock economy et al., 2017 [9] presents the number of livestock and poultry in Bangladesh from FY 2008–2009 to FY 2017–2018. From Figure 2, it is observed that the amount of livestock and poultry are increasing day by day, which in turns increase the extent of manure. At present, there are about 100,000 small sized biogas plants in the country, most of them are household farm biogas plants. The break-up of the usage of dung in the country is: fuel 34 %, manure 46 %, building materials 5 %, and waste15 %. The share used as fuel and fertilizer may be combined and made available for use in biogas plants to provide gas and fertilizer. About 80 % of the total dung from over 24 million head of cattle can therefore be made available for biogas production. An estimate of the total biogas potential in the country is presented below.

Table 2: Gas production potential of some animal dungs [8].

Animals	Amount of biogas (L/Kg wet dung)
Dairy cattle	30
Beef cattle	42
Swine	53
Poultry	116

Table 3: Potential for biogas generation from animal waste in 2017 -2018

Sl No.	Sources	Total Amount (in millions)	Manure generation (kg/day)	Biogas obtained ($\mathbf{m^3}$/ **kg** of manure)	Total biogas production (M$\mathbf{m^3}$/ **year**)	Amount of electricity generation (kwh/$\mathbf{m^3}$ of biogas)	Total electricity potential (GWh)
1	Cattle [4]	24.08	10	0.037	3252.004		
2	Buffalo	1.49	10	0.037	201.225	1.4	7.50
3	Goat	26.10	1.55	0.06	885.965		
4	Sheep	3.47	1.44	0.06	109.43		
5	Poultry [11]	338	0.1	0.074	912.938		
			Total		5361.562		

Table 3 shows the projected biogas generation and electricity potential of animal and poultry waste in Bangladesh in FY 2017-2018. It is possible to total electricity potential 7.50 GWh by using these animal manure, which can solve energy demand situation and load-shedding problem of Bangladesh. One ton of dung can produce 37 m^3 of biogas. Available cattle dung can produce 2.97 x $10^9 m^3$ of gas which is equivalent to 1.52 x 10^6 tons of kerosene or 3.04 x 10^6 tons of coal

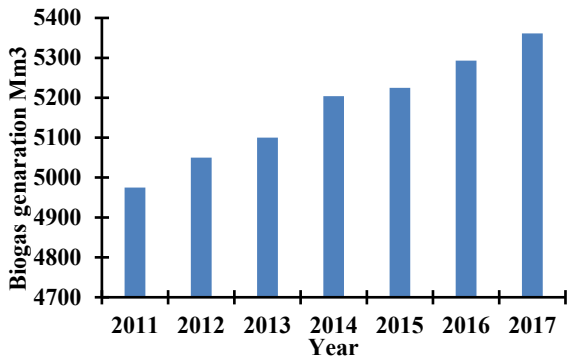


Fig. 2: Total expected biogas generation in different years of Bangladesh

Figure 2 shows the total amount of biogas generation in different fiscal years. The generation of biogas depends on various factors such temperature, pH value, quality of waste. In the year 2017, Bangladesh has the total potential to generate 5361.562 Mm^3 of biogas. It is observed that cow dung has the highest potential of generating biogas.

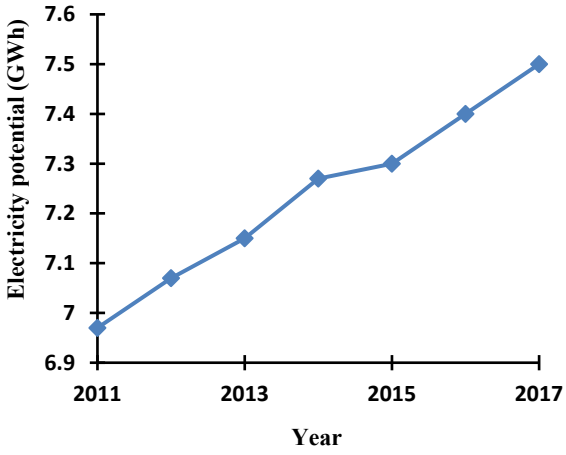
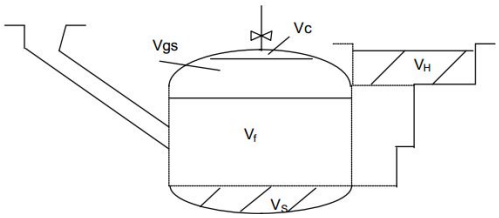


Fig. 3: Electricity potential through biogas in different years of Bangladesh.

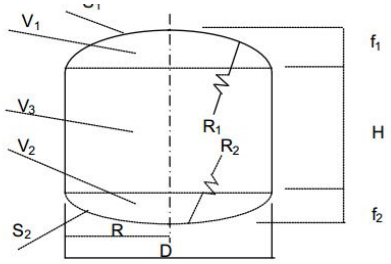
Figure 3 shows electricity potential of Bangladesh corresponding the total amount of biogas generation in different fiscal years. If the available resources could be recovered, it is possible to generate 7.50 GWh of electricity to electrify rural population.

3. MODELING OF A 5 m^3 BIOGAS PLANT

The design for a 5 m^3 biogas plant is proposed for cooking & electricity supply of 4 houses in remote rural areas in Bangladesh where will be used 14 cows of body weight 200 kg each and temperature 30 ℃ (average). Each cow yields 10 kg dung/day.



(a)



(b)

Fig. 4**:** (a**)** Cross-section of a digester (b) Geometrical dimensions of the cylindrical shaped biogas digester Body

a) Volume of gas collecting chamber = V_c
b) Volume of gas storage chamber = V_{gs}
c) Volume of fermentation chamber = V_f
d) Volume of hydraulic chamber = V_H
e) Volume of sludge layer = V_s

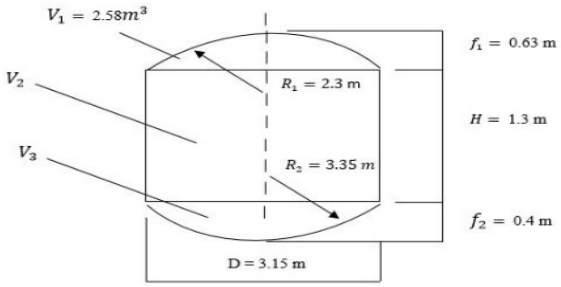
Total volume of digester V= $V_c + V_{gs} + V_f + V_s$

Table 4: The Assumptions for design of 5 m^3 biogas digester [10].

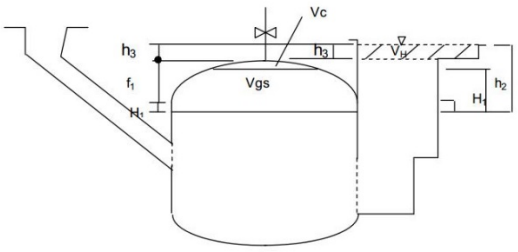
For volume	For geometrical dimensions
$V_c \leq 5\%$ V	D =1.3078 × $V^{\frac{1}{3}}$
$V_s \leq 15\%$ V	$V_1 = 0.0827\ D^3$
$V_{gs} + V_f = 80\%$ V	$V_2 = 0.05011\ D^3$
$V_{gs} = V_H$	$V_3 = 0.3142\ D^3$
$V_{gs} = 0.5\ (V_{gs} + V_f + V_s)$ K	$R_1 = 0.725$ D
Where K = Gas production rate per m^3 digester volume per day. For Bangladesh K = 0.4 m^3/m^3 d.	$R_2 = 1.0625$ D
	$f_1 =$ D/5
	$f_2 =$ D/8
	$S_1 = 0.911\ D^2$
	$S_2 = 0.8345\ D^2$

Table 5: Volume Calculation of Digester Chamber

Equations (From geometrical assumptions)	Calculation
Let, HRT = 40 days (for temperature 30℃)	140 Kg/day
Total discharge	
TS of fresh discharge	22.4 Kg
In 8% c (b)	280 Kg
TS (To make favorable condition) .Total influent required	
Water to be added to make the discharge 8% concentration of TS	140 Kg
Working volume of digester = $V_{gs} + V_f$	$11.2m^3$
$V_{gs} + V_f$ = Q. HRT	
$V_{gs} + V_f = 0.80$ V	V= 14 m^3
(Putting value $V_{gs} + V_f = 11.2\ m^3$)	
D =1.3078 × $V^{\frac{1}{3}}$	D =3.15 m
$V_3 = \frac{3.14 \times D^2 \times H}{4}$	H = 1.3 m
(Putting $V_3 = 0.3142\ D^3$)	
$f_1 =$ D/5	$f_1 =$ 0.63m
$f_2 =$ D/8	$f_2 = 0.4m$
$R_1 = 0.725$ D	R_1 =2.3m
$R_2 = 1.0625$ D	R_2 =3.35m
$V_1 = 0.0827\ D^3$	V_1 =2.58m^3
$V_c = 0.05$V	V_c =0.7m^3



(a)



(b)

Fig. 5: (a) Dimension of proposed digester chamber (b) Geometrical dimensions of the Hydraulic Chamber

Table 6: Volume Calculation of Hydraulic Chamber

Equations (From geometrical assumptions)	Calculation
$V_c = 0.05V$	$V_c = 0.7m^3$
V_{gs}= 0.5 ($V_{gs} + V_f + V_s$) K Where K = Gas production rate per m^3 digester volume per day	$V_{gs} = 2.7m^3$
V_{gs} = 50% of daily gas yield	$V_{gs} = 3.136\ m^3$
Animal barnyard manure Yield of Biogas = 0.260 ~ 0.280 m^3 /kg TS. Let $V_{gs} =$ 3.136 m^3.	$V_c + V_{gs} = 3.84m^3$
$V_1 = [(V_c + V_{gs}) - \{\pi D^2 H_1\}/4]$	$H_1 = 0.16\ m$
We have fixed h= 800 mm water volume	$h_3 = 0.01\ m$
$h = h_3 + f_1 + H_1$=800 mm	
$V_{gs} = V_H$	$D_H = 20$ m

Now we know the dimension of hydraulic chamber. Moreover, keeping h =800 mm, we can choose or re -arrange the dimension considering availability of site and construction suitability.

4. POWER GENERATION POTENTIAL FROM 5 m^3 BIOGAS PLANT

The estimation of biogas production comprised three sets of calculations: manure generation, biogas generation and baseline methane emissions prior to biogas. The proposed design for a 5 m^3 biogas plant where 14 cows of body weight 200 kg each. 1 kg of dung yields 0.037 m^3 gas and each cow yields 10 kg dung/day, so dung available is 140 kg/day and gas that may be obtained is $5m^3$. As $1m^3 = 19\ MJ$ So, Potential energy generation = $5\times 19 = 95\ MJ$. To convert it to kWh, 95/3.6 = 26.4 kWh. When we convert it to electrical energy 65% of energy lost as Heat & other mechanical losses as utilized by electrical generator. So $26.4\times \frac{35}{100} = 9.24$ kWh is available as electrical from 140 kg of cow dung. We can run (25 watts - 4 LED bulbs + 4 fans of 70 watts) for 24 hours easily on 9.24 kWh (el) energy. Medium stove uses 9 MJ of energy /hr. manure of 14 cows is fuel for stove to run for $\frac{95MJ}{9} = 10.6\ hours$

5. CONCLUSION

Bangladesh is an agricultural country and more than 70 % of its total population involve directly or indirectly on agriculture. Energy generation from these available animal waste (cattle dung) through biogas production can be a strong alternative option to lessen rural energy demand. Besides, it will reduce greenhouse gas emissions and dependence on fossil fuels. Biogas is a clean, efficient, and sustainable source of energy to protect the environment from various adverse effects. Bangladesh has the potential to generate 5361.562 Mm^3 of biogas in the year 2017 which could enhance around 7.50 GWh electricity to the national grid. The proposed design for a 5 m^3 biogas plant where 14 cows of body weight 200 kg each, dung available 140 kg/day and Power generation from biogas plant is 26.4 kWh on which 9.24 kWh is available as electrical energy. By using this electrical energy, we can run (60 watts of 6 bulbs + 5 fans of 80 watts) for 11 hours easily. But there are some limiting factors such as declining number of cattle per household, Monsoon flooding, high plant cost, impede the development of biogas-based power generation in Bangladesh. Also, the Uncertainty of feedstock availability, Variability in biomass types and compositions are the challenges for biogas-based power generation in Bangladesh. An organized effort of the corresponding authorities and stakeholders and effective management of biogas policy will improve the adaptation approach to mitigate the challenges of energy crisis in Bangladesh.

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