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Prospect of rural electrification through biogas in Bangladesh-design & feasibility study of biogas based electricity facility of a poultry farm

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Abstract

Production of biogas from organic waste exposes massive interest in many parts of the world. Biogas production system offers various sorts of benefits over other forms of bioenergy 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 70% of the population live, only 62.4% have access to electricity. There are about 102.6 million tonnes cow dung from 25.5 million cows and buffaloes and 12.9 million tonnes poultry litter from 291.5 million chickens and ducks until 2016 in Bangladesh. Such a large amount of these wastes have great fuel value which can be utilised to produce biogas for cooking, heating and electricity generation. From the feasibility study, it has been found that Payback period is 3 year, IRR is 35%, NPV is positive & Cost of per unit electricity is 3 BDT. The main objectives of this article are to evaluate the prospect of rural electrification through biogas in Bangladesh and design & feasibility study of biogas based electricity facility of a poultry farm.

Keywords: Poultry Waste, Biogas, Renewable Energy, Electricity, Environment

1. Introduction

Enhanced energy security, economic development, depletion of conventional fuel and climate change mitigation are the main drivers for the transformation of the energy system from fossil to renewable sources. Biomass has to play a key role in this transformation to a low carbon economy. Bangladesh is a developing country with a population of about 160 million living in an area of 147,000 sq. km and has been struggling to keep up with the energy demand for its large population. In rural areas, where more than 70% of the population lives, only 62.4 % have access to electricity [1]. Rural people meet up the energy needs mostly from traditional biomass fuels comprising of agricultural residues (45%), wood and wood wastes (35%), and animal dung (20%). Generally, biomass is estimated to account for over half (~62%) of the country's energy consumption [2]. In Bangladesh, about 7 million tonnes of fuel woods are consumed annually. As a result, the country has reduced the forest area to a low of 9% of its total area. Till April 2016, IDCOL has financed construction of over 42,800 biogas plants all over the country through its 43 partner organizations. Infrastructure Development Company Limited (IDCOL) has a plan to install 60,000 biogas plants in Bangladesh by 2018 [3]. Grameen Shakti has constructed over 26298 biogas plants up to 31 august,2013.Grameen Shakti future plan is to install 6000 biogas plants in 2013,8000 in 2014 & 12000 in 2016 [4]. Bangladesh govt. has taken future plan to set upto 150000 plants in rural areas by 2016 [3]. Biogas is one of the auspicious renewable energy sources which refers to a mixture of different gases generated by the decomposition of organic matter like agricultural waste, municipal waste, and animal manures in the absence of oxygen this article mainly focusses to identify potential of biogas for rural electrification in Bangladesh and provide an optimum design of biogas based electricity facility of a poultry farm.

2. Material and Method

A. Biogas Potential in Bangladesh:

The existing biomass resources on our planet can give us an idea of the global potential of biogas production. This potential was estimated by different experts and scientists, on the base of various scenarios and

assumptions. Regardless the results of these estimations, only a very small part of this potential is utilized today, thus there is a real possibility to increase the actual production of biogas significantly. In 2013, Bangladesh had approximately 245 million chickens and 46 million ducks respectively that produced 12.9 million tonnes of waste [5]. In 2013, the country had approximately 24 million cows and 1.5 million buffaloes respectively that produced 102.6 million tonnes of waste [5]. The daily per capita per person solid waste produced in Bangladesh is about (300400) gram and approximately 8.65 million tonnes municipal waste was generated in 2013 [6]. If we carefully analyze this waste, we will realize that most of these are biodegradable.

Table 1. Energy calculation chart [7]

Animal Type	*Waste per Day (Kg)*	*Amount of biogas produced from 1 Kg of waste (m^3)*	*Amount of biogas for 1 KW electricity generation(m^3)*
Poultry bird	0.1	0.074	0.71

Table 2. Energy from organic waste (Daily in 2014)

Source	*Number of Chicken & Duck*	*Total amount of waste (Kg)*	*Amount of produced biogas in cubic meter*	*Amount of generated electricity in MW*
Poultry litter	304172000	30417200	2250872	3170

B. Design & Feasibility study of Biogas based electricity plant for 5000 poultry birds:

Bangladesh is a promising place for the poultry industry. As a result, the number of poultry farms have continually increased over the past years. The main objective of the poultry industry was to assist to the food supply against the backdrop of an ever-growing demand from a highly dense population. The approximate number of farms and the distribution among different farms size according to data presented in a Brac Bank study is shown in Table 1.

Table 3. Distribution of Poultry Industry in Bangladesh. [8]

Poultry Farm Size (No of birds)	*Approximate farms*
100-249	15000
250-499	35000
500-999	45000
1000-4999	12000
5000-9999	8000
10,000-50,000	1200
More than 50,000	50
Total	**1,16,520**

Table 3 shows that there is a significant number of poultry industries that host 1000+ birds. Biogas from poultry waste can be used as fuel in generator to generate electricity.

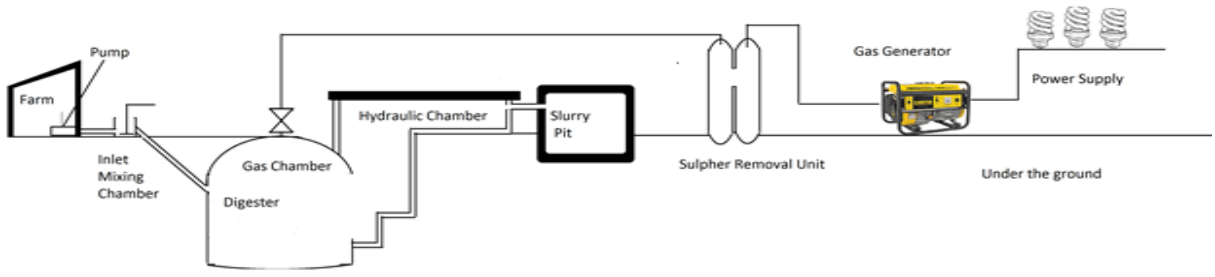

Fig. 1: Layout: Biogas Based Electricity Plant

Design of Digester:

A Digester Design for 5000 poultry bird:

Digester Type: Fixed Dome [For low cost]

Waste: Water = 1:2[9]

Waste=0.1Kg/bird/day

Total Waste= 5000×.01=500Kg/day

Digester Design According to LGED:

Vol. of Gas collector chamber = V_c

Vol. of Gas storage chamber = V_{gs}

Vol. of Gas fermentation chamber = V_f

Vol. of Gas sludge layer = V_s

Vol. of the hydraulic chamber = V_h

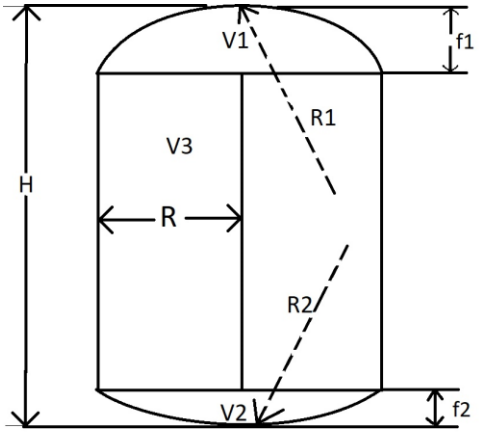

Fig.2. Various parameters of a digester

Relations between the Parameters [7]:

Diameter of Digester, $D = 1.3078 \times \sqrt[3]{V}$

$V_{gs} = V_h$

Height of the upper parabolic shape $f_1 = D/5$

Height of the lower parabolic shape $f_2 = D/8$

Volume of upper parabolic portion, $V_1 = 0.0827 \times D^3$

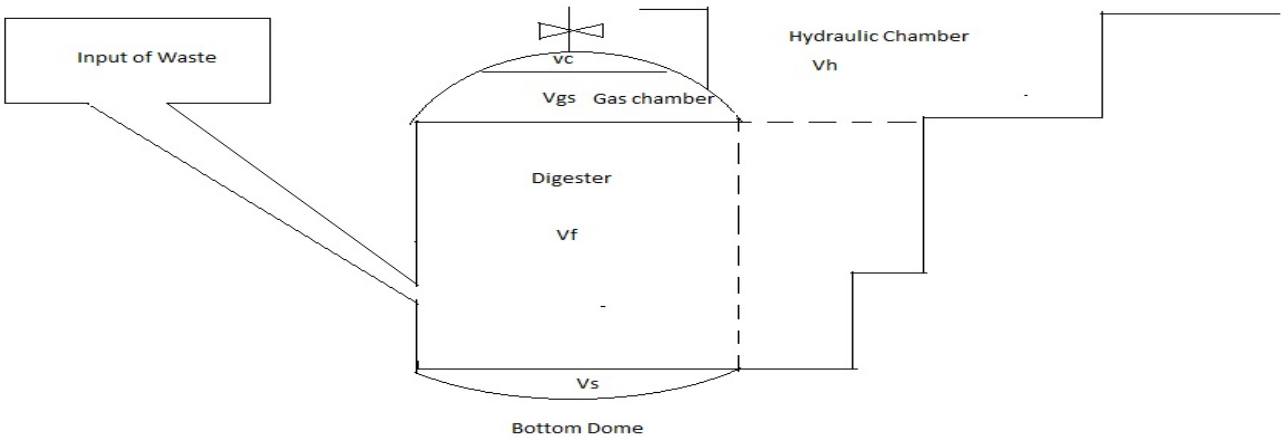

Fig. 3. Layout of Digester

Volume of lower parabolic Portion, $V_2 = 0.05011 \times D^3$

Volume of the cylindrical portion, $V_3 = 0.3142 \times D^3$

Total volume, $V = (V_c+V_{gs}+V_f+V_s)$

$V_{gs}+V_f = 80\%\ V$

Hydraulic Retention Time for Poultry litter 30 Days [10]

Discharge = 500 Kg/day

Total solid (TS) for Poultry = 20% [7]

TS of fresh discharge = 500×0.2 = 100 Kg/day

Working Vol. of Digester = $V_{gs}+V_f$

$V_{gs}+V_f$ = Q.HRT [7]

= (1000+500) Kg ×30

= 45000Kg

= 45cubic meter

In 10% of concentration [7]
For 100Kg of waste liquid to be Added = 1000Kg
(TS=500Kg, Liquid=1000Kg)

$V_{gs} + V_f = 0.8V$

From previous calculation $V_{gs}+ V_f = 45m^3$

45=0.8×V
So, V=56.25m^3
Then, D = 1.3078×$\sqrt[3]{V}$
So, D = 5 m
V_3, for the cylindrical shape,
V_3 = 3.1416×D^2×H)/4 & V_3 = 0.3142 × D^3 where D = 5.
So, by SOLVING two equation for V_3, H= 2m
So, the Diameter of the Digester = 5m
Height of the Digester = 2m

Hydraulic Chamber Design:

D_h= Diameter of the hydraulic chamber
f_1 = D/5, f_1 = 1m
f2 = D/8, f_2 = 0.625m
V_1 = 0.0827D_3= 10.3m
V_c= 0.05V = 2.8m
V_{gs}= 50% of Daily gas Yield [7]
=0.5×TS×Gas producing rate per Kg of TS
=0.5×100×0.28
=14 m^3
V_{gs}+V_c = 14+2.8=16.8
From figure 2, V_1= {(V_c+V_{gs})-(πD^2H_1/4)}
From the above equation we can get, H_1=0.33m
Depth of the soil, h_3 = f_1/2 = 1 /2 = 0.5m,
Since V_{gs} = V_h
So, 14 = (3.1416×D_h^2 ×h_3)/4
So, Diameter of the hydraulic chamber, D_h= 5.9m = 6m

Feasibility study of plant:

A feasibility study is done in terms of payback period, IRR & NPV to justify that the project is economically feasible or not.A farm named as "Rahmat Poultry farm", located at Atgharia, pubna with 5000 birds was visited.

Table 4. Energy demand of the visited farm [11]

Load	*Rating (Watt)*	*Number*	*Total power*	*Working Hour*	*Unit (kw-hr)*
Bulb for lighting	26	30	780	5	3.9
Bulb for lighting	30	12	360	4	1.44
Ceiling Fan	75	3	225	11	2.5
Table Fan	25	3	75	5	0.38

Table 5. Gas Production Calculation

Number of Bird	5000
Waste (Kg)	5000× 0.1=500
Daily Gas Production (cubic meter)	500×0.074=37 [7]

Table 6. Demand and Generator Selection

Max Demand (kw)	1.44
Generator Capacity (kw)	2
Daily Unit Energy consumption	8 kw-hr
Daily Energy Generation	37×1.4=51kw-hr
Existing Energy for sell	51-9= 42 kw-hr

Table 7. Total Investment for the Proposed Model

Sl No	*Capital Cost Item*	*Price (BDT)*	*Price (USD)*
01	Hydraulic Chamber+ Inlet	50,000	637
02	Slurry Pit	79,000	1006
03	Pump	11,770	150
04	Desulphurization Unit	40000	509
05	Pipeline & Others	37,000	471
06	Generator cost	27636	352
07	Sub-Total Cost (STC)	245406	3127
08	Transmission & protective circuit (5% of STC)	12270	156
09	Digester	1,58,000	2013
10	Total investment	4,15676	5297

Table 8. Replacement & maintenance cost

Cost factor	**BDT/Year**
Digester Cleaning	5,000
Pipe Replacement	5,550 (15% of Piping cost) [12]
Generator overhauling and repair	9,437
Variable operating cost	5,000
Technician cost	10,000
Total	34,987
	USD= 445

Table 9. Yearly Income

Income	*BDT/Month*	*BDT/Year*	*USD/Year*
Electric Bill	51×30×9.81=15,009	1,80,111	2295

3. Result and Discussion

Biogas has great potential to cover a variety of markets, including electricity, heat, transportation fuels and also to use the gas for direct combustion in household stoves and gas lamps. Bangladesh has installed power plants having electricity generating capacity of 11877 MW where maximum generation is 8177 MW and peak demand is 10283 MW until 2015 [13]. From table 2, total electricity generated from poultry waste is 3170 MW. In 2014 if we could utilise at least 10% of total amount of organic waste, 370 MW electricity would be produced which was able to fulfil 4.4% power of demand out of 8339 MW in Bangladesh [13].

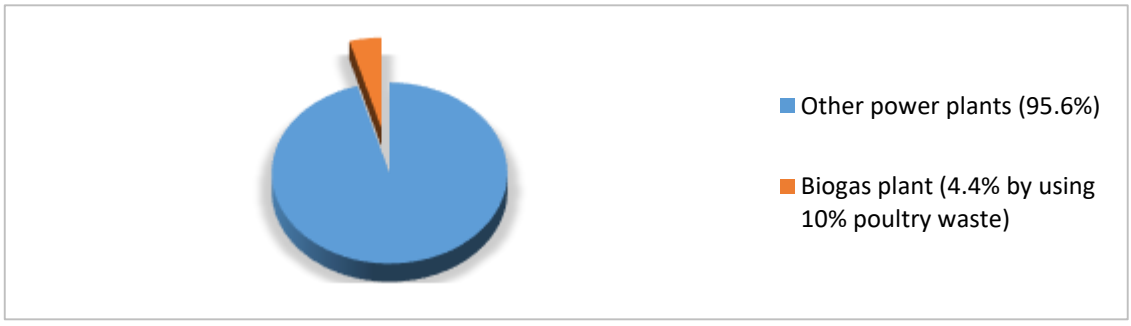

Fig. 3. Possibility of electricity generation in Bangladesh (2014)

Fig. 3. Shows how biogas could play a vital role to fulfil 4.4% of peak demand if 10% of total amount of poultry waste was utilized in 2014 [14].

Financial Evaluation:

Payback Period:
Payback period, IRR & NPV Is calculated by considering 6% interest on investment is assumed [15].Life time of project is 20 years.
Net annual cash inflow=1, 80,111- 34,987=1, 45,124 BDT.
Payback period=investment required/Net annual cash flow

Payback Period	3 Year
Net Present Value (NPV)	BDT= 1,230,614 USD= 15684
Internal return rate (IRR)	35%
Cost per unit electricity	3 BDT

Hence Payback period is 3 year. So investment will be returned in the 3rd year. IRR is 35%, NPV is positive & Cost of per unit electricity is 3 BDT. From above discussion, we can conclude that the project is economically feasible.

4. Conclusion

Production of biogas from organic waste exposes massive interest in many parts of the world. Biogas production system offers vital environmental benefits over other forms of bioenergy because it provides different final products: a renewable energy source, convertible to electricity and heat or to fuel for the automotive sector, and a good organic fertilizer. The outcome of this paper indicates that the biogas is a great source to fulfil the future power demand of Bangladesh and to improvise the rural electrification policy. Feasibility study confirms that the presented project is economically feasible.

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