ICMIEE20-038

Generation of Electricity from Biogas Source: An Alternative Way to Fulfill the Electricity Demand in Remote Area of Bangladesh

Md Rosaidul Mawla[1*], *Md. Ziaur Rahman Khan*[2],
[1]Department of Electrical, Electronic & Communication Engineering, Military Institute of Science and Technology, Dhaka-1216, BANGLADESH
[2]Department of Electrical & Electronic Engineering, Bangladesh University of Engineering and Technology, Dhaka-1000, BANGLADESH

ABSTRACT
Due to increased population, escalation of GDP and to have universal access of electricity to all with the middle income country by 2021, more generation of electricity is required as per the target. For generation of electricity, Bangladesh greatly relays on domestic natural gas, coal and imported fuel. Natural gas is still leading in generating the power by 48% in Bangladesh. At present, gas production is 889.29 bcf which are expected to be reduced to 63.69 bcf in 2041-42. Again, the domestic coal is likely to finish by next decade. Further, as per Power System Master Plan 2016, Bangladesh has targeted to produce 50% electricity from domestic and imported coal by 2030. As fossil fuel is diminishing day by day, policymakers are questing for alternative fuel to produce electricity. Further, as per the geographical location, Bangladesh has bestowed with enormous renewable energy sources which can be utilized to mitigate the increasing energy demand of the country. As per the policy, Bangladesh has aspired to achieve 10% renewable energy by 2020. So utilization of renewable energy not only helps in curbing environmental degradation but also assist in achieving the energy security and saves from exhaustion of the fossil fuels. The objective of this paper is to explore the feasibility of generation of electricity from a renewable source, biogas in an island. This paper highlighted the design of digester and hydraulic chamber for the produced biogas and calculates the total cost of the system and also accounts the payback period. The cost of energy is only 4.79 taka per kWh which is less than the present cost

Keywords: Biogas, Power System Master Plan 2016, Digester, Hydraulic chamber, Cost of energy

1. Introduction

Bangladesh being the populated country and aspires to be a developed nation by 2041, Bangladesh is in race to generate electricity for economic emancipation. To be a developed country, Bangladesh per capita energy consumption and gross domestic product will rise. According to Bangladesh Bureau of Statistics (BBS), Bangladesh is one of the highly dense populated country having about 165.55 million people in 147,570 square kilometres of land. The population of Bangladesh is expected to increase to 178.99 million, 188.42 and 192.57 in 2030, 2040 and 2050 respectively [1]. Therefore, for increased population and escalation of GDP, more generation of electricity is required as per the target. Bangladesh does not have adequate energy resources to meet its requirement to support the household demand and the rapidly growing industrial and commercial sectors.

For generation of electricity, Bangladesh greatly relies on domestic natural gas, coal and imported fuel. At present, gas production is 889.29 bcf which are expected to be reduced to 63.69 bcf in 2041-42 [2]. All these fossil fuels plants are significant contributors to the greenhouse gases like CO_2 which is responsible for climate change. Owing to climate change, Bangladesh is one of the worse vulnerable for unmanageable and environmental detrimental sources. Again, the domestic coal is likely to finish by next decade. Further, as per Power System Master Plan 2016, Bangladesh has targeted to produce 50% electricity from domestic and imported coal by 2030 [3]. Bangladesh has a vast coal reserve but due to suitable exploration problem, coal-based power plants is still considered not viable. For oil-based power plants, Bangladesh is required to rely on completely on import from other countries which is not only cost effective but also unsecured.

Bangladesh is aims to be middle income country by 2021, a zero poverty level nation by 2030 and a high-income nation by 2041. Bangladesh needs to secure sufficient supply of electricity to derive the desired level of economic growth for the three targeted socioeconomic development of our nation. There are several issues like greenhouse effects, pollution of environment, climate change etc. to safe the mankind which is due to the use of fossil fuel to produce electricity. Further the demand has been accelerated due to increase rate of population, urbanizations and industrializations. To minimize the fossil fuel utilization in power generation and to ensure future energy security, Bangladesh is transforming to energy mix policy where renewable sources like solar panels, biogas, hydroelectricity and wind turbines in the coastal areas are given the due attention. The GoB has correctly recognized the another way to support the Power System Master Plan (PSMP) 2016 by generating 10% of electricity from renewable energy sources by 2021. It is assessed that the renewable energy and energy efficiency are the effective measures to curb the greenhouse emission which are again safe, reliable and cost effective.

Bangladesh is has signed not only the Paris Agreement on Climate Change but also the 2030 Agenda for Sustainable Development Goals (SDGs) by the United

* Corresponding author. Tel.: +88-01769004275
E-mail addresses: mawla71@yahoo.com

Nations with other countries of the globe. As a signatory of the Paris Climate Agreement and a victim of climate change, Bangladesh is committed to contributing on its part by reducing the greenhouse gas emission by decarbonization of energy plants and consumption of fossil fuels to keep the increase of temperature below 1.5°C and thus thwart the pace of global warming. Similarly, the UN Summit on Sustainable Development 2015, has a specific agenda for energy in SDG 7, which is to 'ensure access to affordable, reliable, sustainable and quality energy for all.' Affordable energy not only contributes to the alleviation of poverty, the easing of inequality at the individual consumption level but also promotes the industrial and economic growth of a country. Sustainable and reliable energy is also crucial for the social, economic, environmental, educational, and cultural development of a country. The affordable, durable and reliable energy will ensure energy security which is vital to the national development of a nation. Bangladesh intends to achieve energy security for national development through fuel diversification and the GOB has given the renewable priority.

Renewable energy may be regarded as the future of electricity production as it is replenishable and environment friendly. Renewable energy sources are plenty in nature. Therefore, the GoB has given due attention to promote biogas for production of electricity especially in rural areas where grid connection is not economically feasible.

Bangladesh is blessed with abundant traditional and important source of indigenous energy that is biomass. Being an agricultural country, Bangladesh rural population is highly depend on biomass like tree and crop residues and animal dung etc. to meet their daily cooking need and for other energy related purposes. Though it is plentifully available in Bangladesh, yet it is not only utilized as an energy resource for national economy but also considered as environment friendly and affordable power generation source. Further, Bangladesh possesses a favorable atmosphere for the biogas production also. The ideal temperature for biogas is approximately 35^0 which may ranges from 6^0 to 40^0 in Bangladesh. It is not only produce gas and electricity but also gives organic fertilizer for the farmers [4]. However, this paper portrays the significance of biogas to explore the feasibility of generation of electricity from a renewable source, biogas in a remote area of Bangladesh and also analyses the cost estimation of the biogas plant which will mitigate the electricity scarcity in recent days especially in remote areas.

2. Methods

This paper is articulated based on interview, literature from newspapers and online websites. Research related articles and comments were very useful to compile important data. Besides that, websites of different relevant government and nongovernmental organizations were also rummaged. The quantitative analysis is done by collecting data from the survey area. By prepared unbiased questionnaire, interviews were conducted keeping all norms in consideration. Gathered information was cross-examined for the accuracy by various means. The outcome of the study recommends the feasible economical biogas plant along with the tentative pay back period.

3. Few Energy Statistics of Bangladesh

In Bangladesh, generation of electricity is mostly dependent on non-renewable fuels. Approximately 91.54% of electricity is produced from fossil fuels whereas 5.56% from import and the rest 2.9 % of electricity are generated from the renewable energy sources [5]. Natural gas is the main source of energy supply for the electricity and industrial sectors. However, in subsequent paragraph energy scenario along with status of biogas is highlighted.

3.1 Installed capacity by fuel types

Including Captive Power & Renewable Energy, total Installed Capacity (20,383+2,800+365) =23,548 MW [6] The highest generation was 12,893 MW up to 29 May 2019. The installed capacity of power generation by fuel type and plant types (up to June 2020) are shown in Fig. 1.

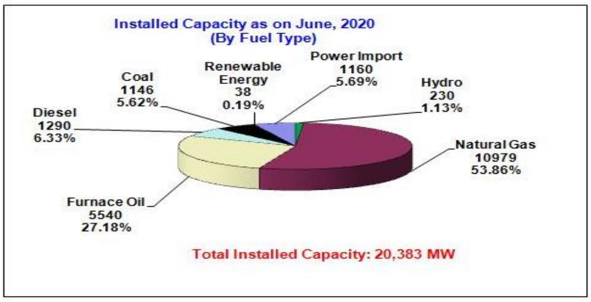

Fig. 1 Installed capacity by fuel type [6]

3.2 Maximum power generation

At present, maximum production of electricity is 12,893 MW in 2019 (as on May 2019) which was less than half (4,606 MW) in 2009. The installed capacity and maximum production since 2009-19 are highlighted in Fig. 2.

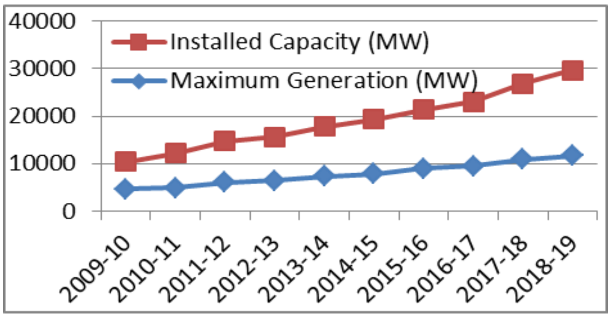

Fig. 2 Installed capacity (MW) and maximum generation (MW) [7]

3.3 Renewable energy emphasis in Bangladesh

Fossil fuels are the key contributors in producing electricity in Bangladesh which contribute approximately 97.16% whereas 2.84% is being shared by RE as on 10 November 2019. Electricity generation mix and renewable share are shown in Fig. 3 and Fig.4 respectively.

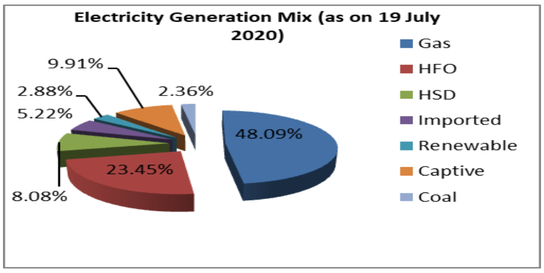

Fig. 3 Electricity generation mix in Bangladesh [8]

From a survey has projected that if the natural gas is being used in present rate and if no further new natural gas field is explored any time soon, the natural gas reserve in Bangladesh is expected to exhaust by 2031. Again, coal is also a key fuel for power generation. But due to different reasons, the coal mining could not be commenced effectively. Therefore, it is important for Bangladesh to quest for alternative energy to mitigate the developmental needs.

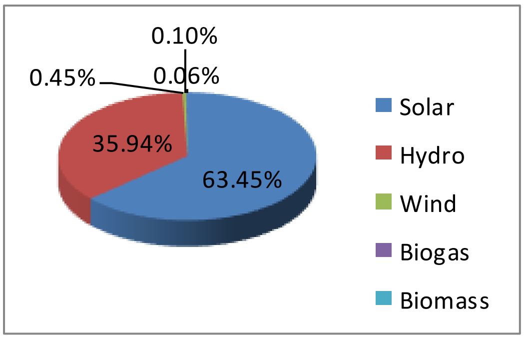

Fig. 4 Renewable energy share in Bangladesh [8]

Total demand of electricity will be increased to 20,000 MW in Bangladesh in the year 2021. Government aims to achieve 10% of total energy production from renewable sources by 2020 respectively and government is looking for various options to achieve it.

3.4 Status of biogas in Bangladesh

The GoB planned to generate 24,000MW by 2021 of which 2896 MW from renewable and 30MW from biomass and 7 MW from biogas. However, the status of biogas in Bangladesh is presented in Table 1[9].

Table 1 Status of biogas in Bangladesh

Organization	Period	Installation
EPCD	1982-84	300
BCSIR	1976-Today	30,000
LGED	1986-Today	5,000
Grameen Shakti	2005-Today	8,000
IDCOL	2006-Today	50,000
M/O Youth	2006-Today	17,000
Others	1972-Today	5,000
Total		1,15,300

3.5 Biomass potential in Bangladesh

Being an agricultural country, Bangladesh has enormous potentials to use biogas. Table 2 shows the biomass potentiality in Bangladesh [9].

Table 2 Biomass potentiality in Bangladesh

Category	Unit
Cattle Dung	22 Million
Poultry Litter	2,20,000 Farms
City Waste	25,000 Tons
Agricultural Waste	Unlimited
Energy Crops	3,00,000 hac
Human Excreta	160 Million
Water Hyacinth	Unlimited

4. Biogas

Biogas is considered as one of the sources of renewable energy. The principal ingredient of biogas is methane (up to 70%). It is generally produced in muddy areas. It is a property of being combustible gas which is considered as a good fuel. Comparing with petrol, about 1.7 m^3 of biogas is equal to one litre petrol. Biogas is a traditional renewable energy source. It has multiple uses such as production of heat, electricity and vehicle fuel. Biogas produced from bacteria by anaerobic (without air) digestion. In other words, biogas is a combination of different types of gases which is generated by the breakdown of raw materials in the absence of oxygen. Methanogens which is considered as methane producing bacteria degrade organic material and return the decomposition products (manure) to the environment. Typical biogas composition are Methane (CH_4): 60 - 70%, Hydrogen (H_2): 2 – 2.5%, Carbon Dioxide (CO_2): 25- 38%, Hydrogen Sulphide (H_2S): 0.1- 0.2%, Oxygen (O_2)-0.3-0.8%, Nitrogen (N_2): 1-1.5% and Carbon monoxide (CO): 0.0% [4]

5. Study Area Swarna Dweep

The name of the selected off-grid remote rural area for this study is Swarna Dweep It lies about 4 km to the south of the Noakhali district mainland and nearly 4.5 km west and about 13.5 km north-east of Hatiya.
Swarna Dweep is located within the extent between 22°37'35.5''North Latitude to 91°23'3.6''East Longitude and 22°25'12.7''North Latitude to 91°11'32.0'' East Longitude. Fig 5 shows the map of survey area Swrna Dweep.

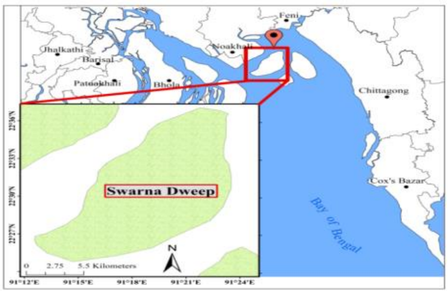

Fig.5 Map of Study Area Swrna Dweep

This island is approximately 3 meter above sea level which is now 28 kilometer long and 14 kilometer wide in area (392 km^2). The island has no grid connected electricity facilities as it is not economically feasible. For this, off-grid electrification is the suitable option here. This island possesses approximately 5000 cattle [10].

6. Total Solid Estimation of Srawna Dweep

In Swana Dweep Island, approximately 5,000 cows with average body weight 200 Kg are available. Let the temperature is 30^{O}C (average) and Hydraulic Retention Time (HRT) is 40 days for temperature 30^{O} C [11]. Total expected discharge = 10 kg X 5,000 = 50,000 Kg/day [11].

Total Solid (TS) of fresh discharge = 50,000 kg X 0.16 [11] = 8,000 Kg.

To make favourable condition, concentration of TS is considered 8% [11]

8 Kg. Solid [11] = 100 Kg influent

1 Kg. Solid = 100 / 8 Kg influent

8000 Kg Solid = 100 x 8000/ 8 = 100000 Kg influent.

Total amount of influent available, Q = 100000 Kg/day.

Water to be added to make the discharge 8% concentration of TS

=100000 Kg - 50000 Kg = 50000 Kg

7. Parameter Estimation

7.1 Volume calculation of digester and hydraulic chamber

Geometrical assumptions for digester design are given in Table 3[11].

Table 3 Geometrical assumptions for digester design [11]

For Volume	For Geometrical Dimensions
V_c<5% V	D = 1.3078 $\times V^{\frac{1}{3}}$
V_s < 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_c = 0.05V
V_{gs} = 0.5(V_{gs}+V_f+V_s)K where K = gas production rate per cubic meter volume per day. For Bangladesh K = 0.4 m^3/day	R_1 = 0.725 D R_2 = 1.0625 D f_1 = $D/5$ f_2 = $D/8$

7.2 Volume calculation of digester

Digester is the principal component of bio-gas plant which is shown in Fig. 6 where,

Volume of chamber for Gas Collecting = V_c

Volume of chamber for Gas storage = V_{gs}

Volume of fermentation chamber = V_f

Volume of hydraulic chamber = V_H

Volume of sludge layer = V_S

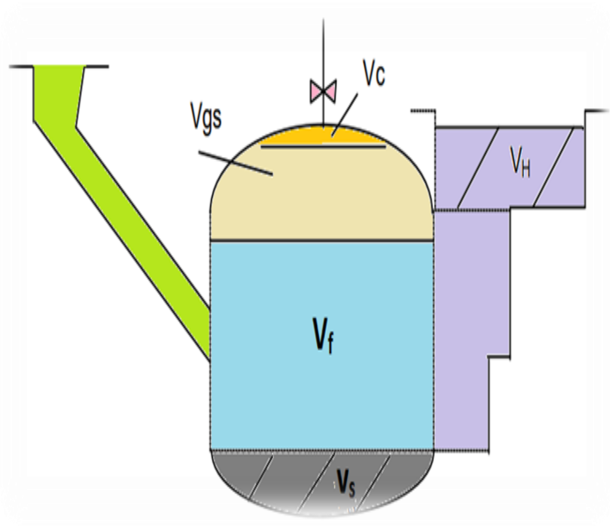

Fig. 6 Cross section of the designed digester

Working volume of digester = Vgs + Vf

Again, Vgs + Vf = Q.HRT
= 100000 Kg/day X 40 days
= 4000000 Kg. (1000 Kg = 1m^3)
=4000m^3.

From geometrical assumptions at table 1[11]:

Vgs + V**f** = 0.80 V

Or V= 4000/0.8 = 5000 m^3. (Putting value Vgs + Vf = 4000 m^3)

& Diameter, D = 1.3078 $V^{\frac{1}{3}}$ =1.307x $(5000)^{⅓}$ = 22.4 m

Again, $V_3 = \frac{3.14 \times D^2 \times H}{4}$[11]

(Putting V_3 = 0.3142D^3)

$H = \frac{4 \times 0.3142 \times D^3}{3.14 \times D^2}$ = 8.96 m

Say, H = 9 m

Now we find from assumption as we know the value of 'D' & 'H'[11]

f_1 = D/5 = 22.4 /5 = 4.48 m

f_2 = D/8 = 2.80 m

R_1 = 0.725 D = 16.24 m

R_2 = 1.0625 D = 23.8 m

V_1 = 0.0827 D^3 = 929.5 m^3

V_2 = 0.3142 D^3 = 3531.4 m^3

V_3 = 0.05011 D^3 = 563.2 m^3

V_c = 0.05V = 250 m^3

Now the design of digester chamber is projected in Fig. 7.

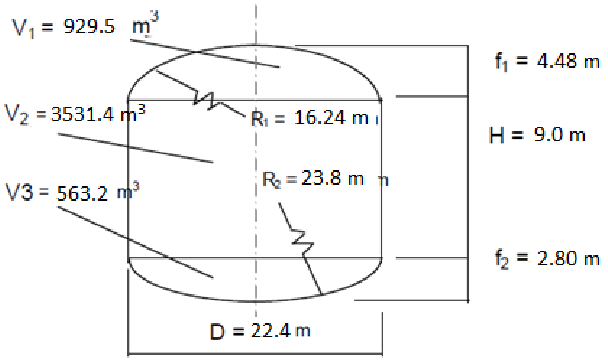

Fig. 7 The dimension of digester chamber

7.3 Volume calculation of hydraulic chamber
From assumptions:
$V_c = 0.05\ V = 250\ m^3$
Again,
Vgs = 50% of daily gas yield
= 0.5 x TS x gas producing rate per Kg TS
= 0.5 x (50000 kg x 0.16) x 0.28 m^3/kg TS
= 1120 m^3
Now,
Vc + Vgs = 250m^3 +1120 m^3 = 1370 m^3

Now, $V_1 = \left[(V_c+V_{gs}) - \frac{\{\pi D^2 H_1\}}{4}\right]$[11]
= [1370 - {3.14 x $(22.4)^2$ x H_1}/4]
Or, H_1 = 1.1183 m

We have fixed h = 8000 mm water volume (I mm = 10 N/ m2)

$h = h_3 + f_1 + H_1$[11]
Or, h_3 = 2.4017 m.

Again we know that
$V_{gs} = V_H$
Or, 1120 m^3= 3.14 x $(D_H)^2$ x h_3/4
Or, D_H = 24.373 m
The final design of hydraulic chamber is depicted in Fig. 8.

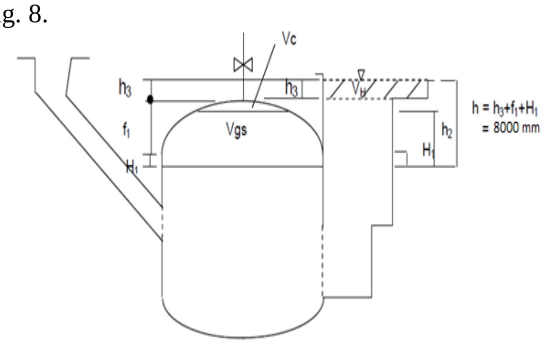

Fig. 8 The dimension of hydraulic chamber

8. **Calculation of Generation of Electricity by Biogas**
The survey information may be summarized as shown in Table 2.

Table 4 Livestock's statistics at survey area

Category	Total Cattle	Tentative Dung Cake (Kg/ Day)	Total Dung Cake (Kg/Day)	Recovery Rate of Dung Cake 20% (Kg/Day)	Total Dung Cake (Ton/Day)
Cow	5000	10	50,000	10,000	10

As per our calculation is below

Available Dung =10 Ton/day
Biogas that can be generated from each Kg of dung = 1.3 cubic feet
Available Gas Production in Cft=10x1000x1.3cft=13,000 cft/day
1 cubic meter=35.314 Cubic feet
Available Gas Production in m^3=13000/35.314m=368.13 m^3≈368 m^3
0.5m^3 gas can produce 1KWh electricity
(One cubic meter biogas can generate 2KWh electricity) [12-13]
So 368 m^3 gas produce=368/0.5=736 kWh of electricity
Considering 20% energy loss as heat and other mechanical losses by electric generator hence net electricity produced = 736x.8=588.33≈588 kWh.
Total Daily required electricity Consumption (KWh/Day) =13 KWh
Remaining (588-13) =575 KWh is remaining for cooking.
To generate 1KWh electricity, 0.5 cubic meter gas is required
So from 575 KWh electricity, 575x0.5=287.5 cubic meter is used
1 cu. M of biogas can be replaced by 0.620 l of Kerosene [14]
Saving in kerosene per day when biogas is used instead=287.5x0.620 =190.325≈190 litre
One family with 4-6 person require 2m^3 or 70 cft gas per day
So (287.5/2=143.75≈) 143 families can use this gas per day for cooking.

9. Total System Cost
The total system cost is given in details below [15]:
Cost of Biogas plant setup with Digester and Hydraulic Chamber = BDT 12,17,500
Cost of generator and related accessories = BDT 3,41,700 , BioGas Generator Set (250 KVA) =BDT 5,28,000.00 , Miscellaneous Cost= BDT 2,08,250
System Cost= BDT 22,95,450
Total Cost (10% maintenance cost/year)= BDT 25,24,994

10. Per Unit Cost of Electricity
Here, calculated load per day 1606 W, considering utilization hours 6 hour per day. Energy Consumed per day (1606 × 6 × 150) = 1445.4 kWh. Here 150 is the number of consumers considered from above calculation.

Total energy supplied = (1445.4 × 365) = 527.571 MWh/year

Per unit energy cost of electricity= $\frac{25,24,994}{527.571\times 10^3}$ = BDT 4.79 /kWh

Designed bio-gas plant, require very less maintenance for digester in its whole life time. Including the maintenance cost of generator, the resulting per unit cost is only BDT 4.79/kWh which is lower than the present determined unit price 6.78 BDT of electricity by the authority of Bangladesh Rural Electrification Board [16].

11. Pay Back Period Calculation

Total amount of organic fertilizer per day=50,000x0.15=750 kg (as total waste is 50,000 kg and organic fertilizer is 15% of the waste)

Total organic fertilizer produced per day-750 kg x2= 1500 BDT= 15000x 30=monthly 45,000 BDT/=45,000x12=yearly 5,40,000 BDT. (rate per kg- 2.00 BDT)

1 cu. M of biogas can be replaced by 0.620 l of Kerosene [8**].**

Saving in kerosene per day when biogas is used instead=287.5x0.620 =190.325≈190 litre

Saving in the cost of Kerosene per day @ Rs. 5 per liter =190x10 = BDT 1900=1900x30=BDT 57,000 monthly=BDT 6,84,000 yearly

Total saving per year= BDT (5,40,000+6,84,000)= 12,24,000

Biogas plant construction cost: BDT 25,24,994

Pay Back Period=$\frac{25,24,994.00}{12,24,000}$=2.06 year≈25 months Therefore, the investment is expected to be recovered by 25 months.

12. **Conclusion**

Electricity generation through bio-gas technology can be considered as a partial but one of the most significant cost effective backup solutions to energy scarcity. With availability of biogas, the cost of installing the biogas plant may be recovered with only 25 months and the cost of energy is only 4.79 taka per kWh which is less than the present cost. However, in recent times availability of backup electricity supply is very much encouraged by the authority where, only a portion of all electrical appliances will have the access to derive its benefit accordingly to ensure sustainable development of a country.

13. Acknowledgement

I am thankful to Military Institute of Science and Technology for providing me with positive environment for conducting this research.

14. References

[1] World Population Review, http://worldpopulationreview.com/countries/bangladesh-population/, accessed on 12 June 2020.

[2] Energy Scenario Bangladesh 2017-18, Hydrocarbon Unit, Energy and Mineral Resources Division Ministry of Power, *Energy and Mineral Resources*, January 2019

[3] Jacobson M., Draxl C., Jimenez T., and O'Neill B., Assessing the Wind Energy Potential in Bangladesh Enabling Wind Energy Development with Data Products, National Renewable Energy Laboratory, September 2018, https://www.nrel.gov/docs/fy18osti/71077.pdf

[4] Gofran M. A., Status of biogas technology in Bangladesh, *The Daily Star*, 05 September 2007. Available at: https://www.thedailystar.net/news-detail-2631, accessed on 17 October 2019.

[5]http://www.sreda.gov.bd/index.php/site/re_present_status , accessed on 10 May 2020

[6] Bangladesh Power Development Board, available at: https://www.bpdb.gov.bd/bpdb_new/index.php/site/page/13e9-2cc0-ce41-9c09-088d-94d5-f546-04a6-b4fa-1d18, accessed on 19 July 2020.

[7] Bangladesh Economic Review 2019, Chapter Ten, Power and Energy, pp 151, Available at: https://mof.portal.gov.bd/sites/default/files/files/mof.portal.gov.bd/page/f2d8fabb_29c1_423a_9d37_cdb500260002/Ch-10%20%28English-2019%29.pdf, accessed on 06 January 2020

[8] Sustainable and Renewable Energy Development Authority SREDA - National Database of Renewable Energy, SREDA, available at http://www.renewableenergy.gov.bd/index.php?id=10, accessed on 04 April 2020.

[9] Gofran M. A., A presentation on 'Policy Issues on Biogas Technology in Bangladesh' National Workshop on Biogas at SREDA, 27 November 2018.

[10] History and resources of Swarna Dweep received from 33 Infantry Division, Bangladesh Army on 20 May 2020.

[11] Bio-gas Project, LGED, ''Design of Biogas Plant'' Booklets & Research materials of Biogas Training Center (BRC), Chendu, Sichuan, Chaina, page 3-7

[12] AQPER, How much energy is there in biogas?, available at: https://www.aqper.com/en/how-much-energy-is-there-in-biogas, accessed on 23 March 2020.

[13] FAQ – Frequently Asked Questions about Biogas, Ecodevelop ecolife, available at: https://ecodevelop.ua/en/faq/, accessed on 20 March 2020.

[14] Biogas, available at: https://vikaspedia.in/energy/energy-production/bio-energy/biogas, accessed on 20 August 2020.

[15] An Interview on Biogas with Rafiqul Islam Shohel, Managing Director, *Seedbangla*, on 15 September 2019.

[16] Trading Economics, available at: https://tradingeconomics.com/bangladesh/access-to-electricity-percent-of-population-wb-data.html, accessed on 05 January 2020