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DESIGN AND IMPLEMENTATION OF AN ENERGY NEUTRAL HOME SYSTEM FOR RURAL AREAS OF BANGLADESH

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Abstract—*Bangladesh is suffering from acute power crisis for a quite long time without any respite. Most of the power stations of Bangladesh are based on non-renewable energy resources. Natural resources or non-renewable energy sources such as: fossil fuels, oil, natural gas etc are completely used or economically depleted. So this is the time to search such a system where the residential areas of Bangladesh become Energy Neutral. This paper demonstrates such a system in which an Energy Neutral Home (ENH) is designed and implemented for rural areas of Bangladesh. The designed system is able to meet the energy requirement with renewable energy resources without taking any electricity from grid. In this research, biogas is used as primary renewable energy source for the generation of electricity.*

Keywords**:** Biogas, Digester, Energy Neutral Home (ENH), HRT.

1. INTRODUCTION

Nowadays, Power crisis is one of the greatest problems of Bangladesh. Present electricity coverage in Bangladesh is only 43% and per capita electricity consumption is about 176 KWh [1]. Currently, against a demand of around 5,200MW, the country is generating around 3,700MW to 4,000 MW power while the demands for power have been rising by 10% every year [2]. About 86% power stations in Bangladesh are based on gas, 5% are hydro, 5% are fuel oil and 4% are coal based [3]. These are by no means a pleasant scenario as we are rapidly exhausting our non-renewable resources. By including the renewable energy sources, the energy sector green house gas emission reduces and energy security increases. As for example, an agriculture based country like Bangladesh has huge potentials for utilizing biogas technologies. According to IFRD - there is potential of about million biogas plants in our country[4]. So, it can be a potential renewable energy source by which a home may be completely energy neutral. An Energy Neutral Home produces as much energy as it consumes over the course of a year [5]. Energy Neutral is using established methods of energy production such as solar panels, solar water heater and small wind turbines for windy areas and combining them with energy-saving construction practices to provide an affordable house that achieves energy neutrality [6]. The house may draw energy from the grid as needed, such as during evening hours, but send energy back into the grid on sunny days. In all, the house is expected to be a net producer of electricity and carry a zero energy bill over its life [7].

2. MATERIALS AND METHOD

2.1 SELECTION OF RENEWABLE ENERGY SOURCE

Biogas is a renewable source of energy which is used as fuel for cooking, lighting, running vehicles and generators, etc. On the other hand, solar energy is also an excellent natural resource for the electricity generation. Due to the high cost of solar panel and battery, this design considered an energy neutral home system with biogas as primary source for a home or a residential/commercial area where the energy requirement is met without taking any electricity from grid. The availability of waste is an important factor of the design for biogas generation. If the wastes are available in a specific area, then the proposed system can run only with biogas for the reduction of installation cost. Thus the main objective of this research is to design a system to produce electricity by using biogas. To facilitate the availability of waste for biogas generation, the system should have poultry farms, cow farms or other sources of waste.

2.2 SYSTEM OVERVIEW

The system to be designed is similar to a small power plant. To design a completely energy neutral system, the renewable energy sources will be taken as the input of the plant. The system may be designed with single source only or more than one source together as hybrid but the focus is given to cost reduction. Considering the cost, the biogas source is selected as primary source for the proposed system. Poultry farms facilitate the waste for biogas generation in this system. The total load of the system is calculated and based on the calculated load the digester is designed. With this system all the necessary household energy requirements such as electricity generation, cooking etc. can be easily fulfilled. The system block diagram is shown in figure 1.

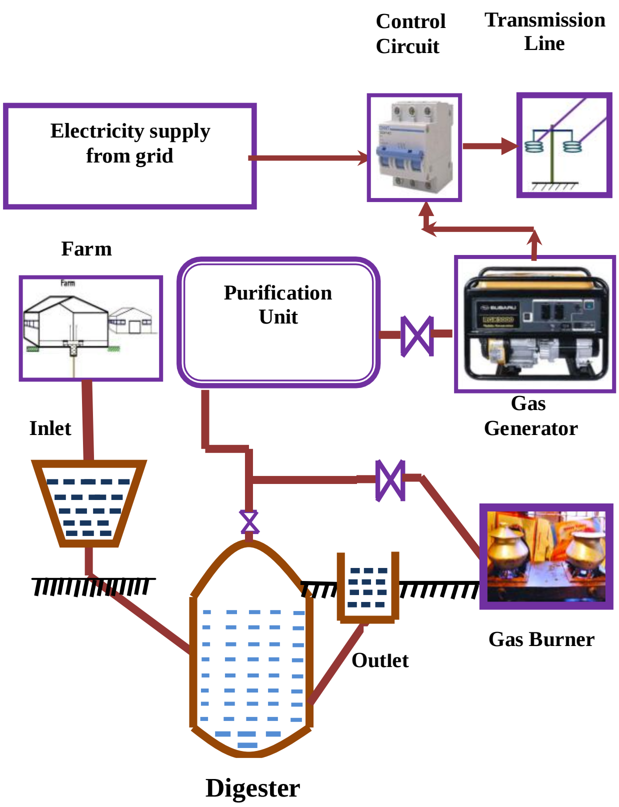

Fig 1: The Block Diagram of the designed system.

2.3 DESIGN FACTORS OF THE PROPOSED SYSTEM

The design factors of the system are selection of site, the availability of waste, the nature of waste, the size of the digester, the amount of load and the capacity of the generator. By considering these design factors the location of the system is selected. The address of the selected location is Village: Pomora, Talukder Para, P.S.: Rangunia, District: Chittagong, Bangladesh. The Owner of the selected home is Mr. Anil Kanti Das. Depending on the climate condition of Bangladesh, the taken Hydraulic Retention Time (HRT) for the system is 40 days [8]. The rate of Total Solid (TS) value and the water to be added is maintained according to the table 1 [9-10].

Table 1: List of TS value and the water to be added with fresh discharge.

Kinds	Body weight (Kg)	Discharge per day (Kg)	TS value of fresh discharge (% by wt.)	Water to be added with fresh discharge to make the TS value 8% (Kg)
Human	50	0.5	20	0.75
Cow	200	10	16	10
Chicken	1.5	0.1	20	0.15
Pig	50	5	20	7.5

3. SYSTEM DEVELOPMENT

3.1 THE ENERGY DEMAND OF A STANDARD HOME

The gas containing capacity of the digester in our designed system is 6 m^3 which is a standard value to neutralize a home. To meet the energy requirement the proportion of the produced gas is depicted in figure 2. The energy demand of the designed system is shown in table 2. According to the energy demand the amount of load is calculated as shown in table 3. The load curve is shown in figure 3.

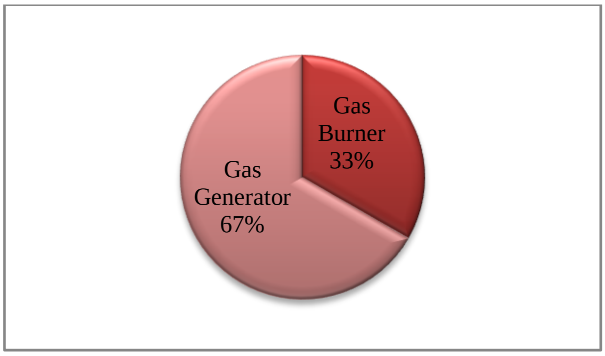

Fig.2: the proportion of gas for electricity and cooking.

Table 2: The energy demand of the proposed system.

Load	Rating (Watts)	Number	Total Power (Watts)
Energy Bulb	15	3	45
Energy Bulb	25	2	50
Energy Bulb	11	2	22
Ceiling Fan	75	4	300
Color TV	100	1	100
Refrigerator	150	1	150
		Total	667

Table 3: Load Calculation according to the demand

Time	**6-8 am**	**8-10 am**	**10-12 am**	**12-2 pm**	**2-4 pm**	**4-6 pm**
Load(W)	0	0	0	250	300	0
Time	**6-8 pm**	**8-10 pm**	**10-12 pm**	**12-2 am**	**2-4 am**	**4-6 am**
Load(W)	400	400	300	300	300	300

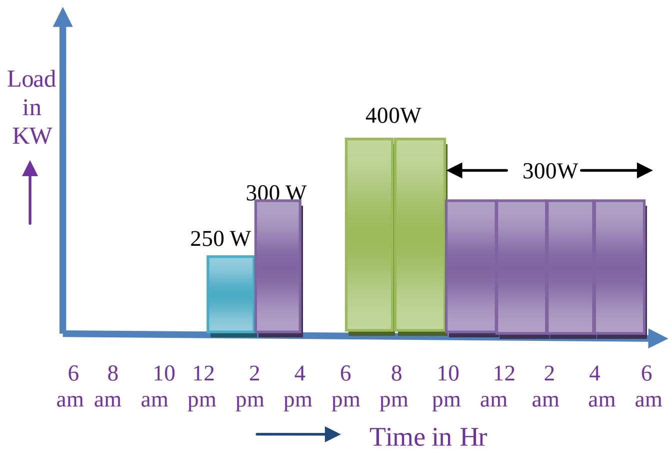

Fig. 3:- Load Curve for electricity supply

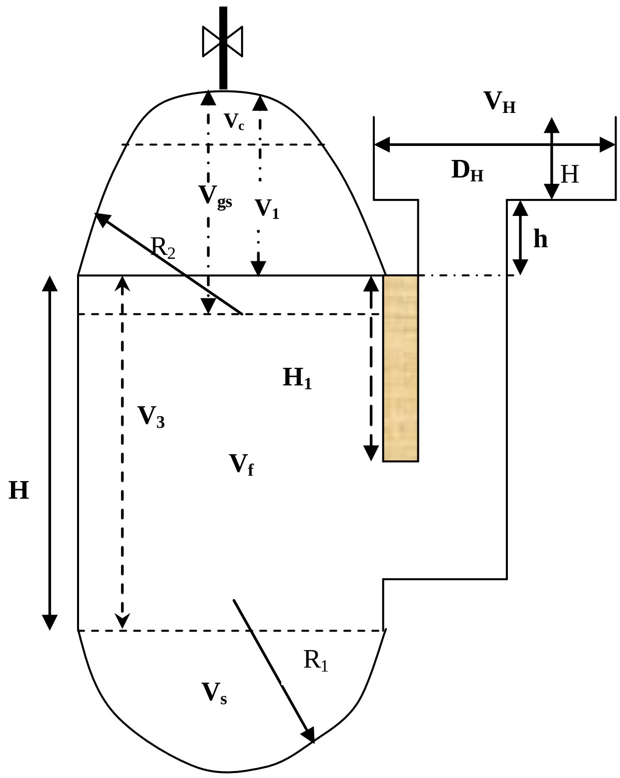

Fig 4: Design Parameter of Digester

3.2 SYSTEM DESIGN

3.2.1 DESIGN OF DIGESTER

As the digester is the main part of the system, it is designed at first by considering some geometrical assumptions [9] as shown in table 4.

The design parameters are shown in figure 4.
Let HRT =40 days (for temperature 30°C)
We know from every layer 100gm manure is obtained per day [9]. So, total discharge=800× $0.1\ kg = 80kg$
TS of fresh discharge=0.2 × $80kg = 16kg$

8 kg solid equivalent 100 kg of influent

$$\therefore\ 16 \text{ kg solid equivalent} = \frac{100 \times 16}{8} = 200\ kg$$

So, total influent required, Q= 200 kg.

Table 4: Geometrical assumptions for Digester Design

For Volume	**For geometrical dimensions**
$V_c \leq 5\%V$ $V_s \leq 15\%V$ $V_{gs} + V_f = 80\%V$ $V_{gs} = V_H$ $V_{gs} = 0.5(V_{gs} + V_f + V_s)K$ where K=gas production rate per cubic meter volume per day. For Bangladesh K=0.4 m^3/day	$D = 1.3078 \times V^{1/3}$ $V_1 = 0.0827D^3$ $V_2 = 0.05011D^3$ $V_3 = 0.3142D^3$ $R_1 = 0.725D$ $R_2 = 1.0625D$ $f_1 = D/5$ $f_2 = D/8$ $S_1 = 0.911D^2$ $S_2 = 0.0.8345D^2$

Required water to be added to make TS value 8% $=200 - 80kg = 120\ kg$
Working volume of digester= $V_{gs} + V_f$

$$V_{gs} + V_f = Q \times HRT = 200\frac{kg}{day} \times 40\ days$$
$$= 8000\ kg = 8m^3$$

From geometrical assumption:
$V_{gs} + V_f = 80\%V$
Or, 8=0.8V [Putting the value of $(V_{gs} + V_f)$]
Or,$V = 10m^3$
And $D = 1.3078V^{1/3} = 2.817m \approx 2.82\ m$
Again,

$$V_3 = \frac{3.14 \times D^2 \times H}{4} \quad Or, H = 1.13m$$

Now we find from assumption as we know the value of 'D' and 'H'
f_1= D/5=0.564m, f_2=D/8=0.3525m, R_1=0.725D=2.04m
R_2=1.0625D= 3m, V_1=0.0827D^3=1.85 m^3
V_c= 0.05V= 0.5 m^3

3.2.1 DESIGN OF HYDRAULIC CHAMBER

From assumptions,
$V_c = 0.05V = 0.5\ m^3$
$V_s = V - \left(V_{gs} + V_f + V_c\right) = 1.5\ m^3$.
So, $V_{gs} = TS \times gas\ production\ rate\ per\ Kg\ TS$
$= 16 \times 0.35 = 5.6\ m^3$
So, out let discharge, $V_{dis} = \frac{200}{1000} = 0.2\ m^3$
Let the normal pressure of the digester is $P_i = 4\ kPa$.
and final pressure after gas being stored = P_f

So, according to Boyle's law,

$$P_i \times (total\ gas\ produced + 2.55) = P_f \times 2.55$$

$$Or, P_f = 12.78kPa$$

Let, height of the hydraulic chamber is h.

$$P_f + H\rho g = H\rho g + h_1\rho g + h\rho g$$

$$Or, h + H_1 = \frac{P_f}{\rho g} = \frac{12.78 \times 1000}{1000 \times 9.81} = 1.3\ m$$

$$\text{Let, } H_H = 1m, Thus, \pi\left(\frac{D_H}{2}\right)^2 H_H = 0.2$$

$$or, D_H = 0.167\ m$$

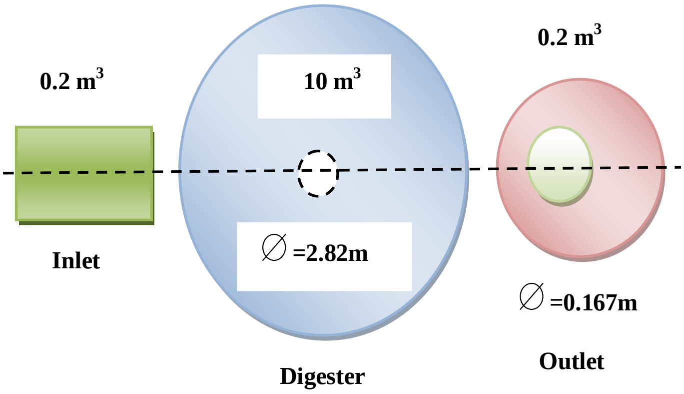

Fig 5: Top view of Digester for a standard home

4. SYSTEM IMPLEMENTATION

Some photographs of the system implementation are revealed in figure 6, 7, 8, 9 and 10. After completing the whole structure of the designed system, the digester is filled up with the required quantity of waste materials. The waste materials are kept airtight inside the digester till the HRT period for the production of necessary amount of gas. After the HRT period, the pressure of gas inside the digester is sufficient enough to be used for cooking purpose and running the generator.

Fig. 6:- The base construction of the digester and hydraulic chamber

Fig. 7:- The construction of outer structure of the digester and hydraulic chamber

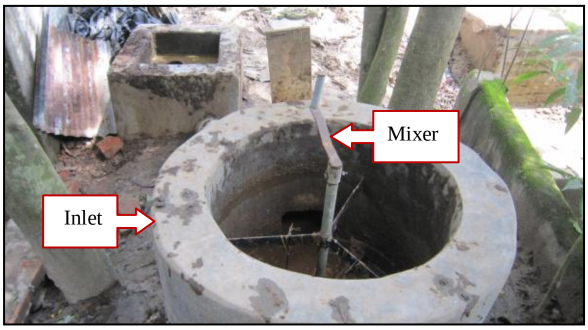

Fig. 8:- The Inlet of the system with mixer

Fig. 9:- The complete structure of the digester and hydraulic chamber

Fig.10:- The stove burns and food is cooked using the gas produced by the system.

5. COST ANALYSIS

5.1 COST CALCULATION

The cost of the implemented system is divided into two parts as shown in table 5 and table 6.

Table 5: Cost of Digester, Inlet and Outlet

Description	Quantity	Rate (BDT)	Amount (BDT)
Bricks	2000 pcs	6.00	12,000.00
Cement	22 bags	350.00	7,700.00
Mass Rod	80 kg	50.00	4,000.00
Sand	170 CFT	20.00	3,400.00
Bricks chips	80 CFT	70.00	5,600.00
Paints	2 Liter	200.00	400.00
Appliances			1,500.00
Soil digging			4,000.00
Mason for construction			6,000.00
Total=			44,600.00

Table 6: The cost of other components of the system.

Description	Amount (BDT)
Cost of generator 1 (1.2kW)	26,890.00
Cost of generator 2 (1.2kW)	26,890.00
Purification Unit Cost	10,000.00
Manometer, Range 0-3000,water column	3000.00
Pipe Line, Special SS Ball Valves	3000.00
Electrical Change-over Switch (From grid to biogas power and vice-versa)	1400.00
Electrical Energy (kWh) Meter (Digital)	1200.00
Miniature Circuit Breakers	800.00
Electrical wiring	1000.00
Installation Cost	5,000.00
Total	52,290.00
Total Cost of Digester, Inlet and Outlet from table 5	44,600.00
The overall cost	1,23,780.00

Operating time of generator in 20 years
=8X365X20=58,500 hour

The overhauling cost of generator is 15% of total cost [11].

Top overhauling (3 times) Cost
= 3 X (15% of 26890) BDT
=12,100.50 BDT

Major Overhauling (3 times) Cost = 3 X (50% of 26890)
= 40,335.00 BDT

Maintenance Cost (Gen 1) = 12,100.50+40,335.00
= 52,435.50 BDT

Maintenance Cost (Gen 2) = 52,435.50 BDT

Total Maintenance Cost of Generator= 1, 04,871 BDT

Cost of system in 20 years = Installation cost + maintenance Cost = (1, 23,780 + 1, 04,871) BDT
=2, 28,651 BDT

5.2 PER UNIT COST

Electricity used in 20 years = 5.1X365X20
= 37230 KWH

Savings in Cooking = 500X12X20 = 120,000 BDT
Remaining Cost = (2, 28,651 - 1, 20,000) BDT
= 108,651 BDT
Per unit cost = 108,651 / 37230 = 2.92 BDT

The total life time of the biogas plant is 20 years. With this time no maintenance is required for digester. Considering the evaluated maintenance cost of generator, we have got the per unit cost is only 2.92 BDT which is lower than the present determined unit price of electricity by the government of Bangladesh.

6. ENERGY NEUTRAL SYSTEM FOR AN AREA

The implemented system is for neutralizing only a home. The result shows that the unit price of electricity is only 2.92 BDT for a home. If the system is designed for an area of 200 homes (capacity 85 KW) as shown in figure 11 then by similar analysis we get the unit price of electricity is only 1.74 BDT. So, it can be said that the unit cost of electricity decreases with the increase of number of homes.

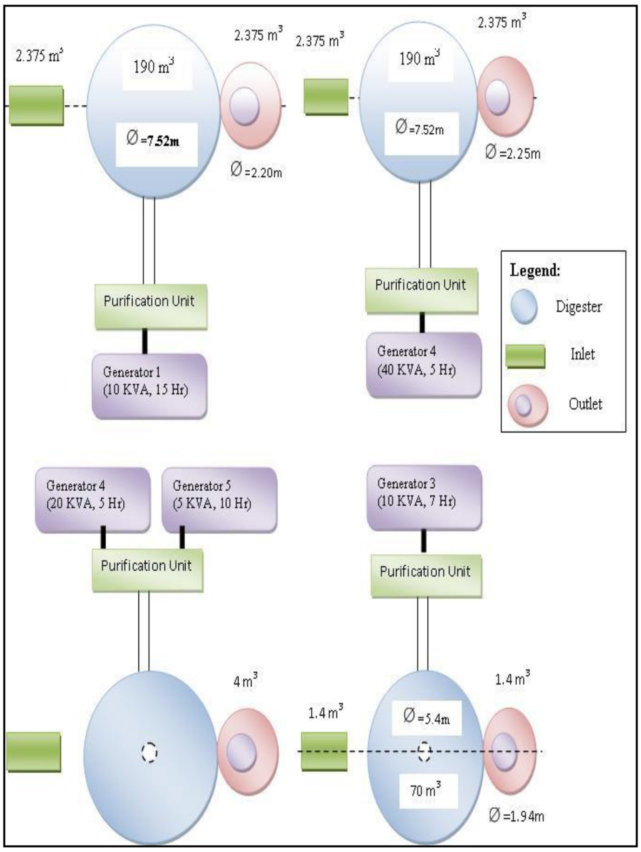

Fig. 11: The energy neutral system for an area of 200 houses

7. SCOPE OF ENERGY NEUTRAL TECHNOLOGY IN BANGLADESH.

The designed energy neutral system is very much important for the developing countries like Bangladesh for the following reasons:

(1) To meet the energy requirements at the present extreme power crisis of Bangladesh.
(2) To preserve the non-renewable energy sources by the reduction of their household expenditures for energy services.
(3) To create part-time job in each community for the operator of the plant by that way it reduce poverty.
(4) To create and improve of small business policy.
(5) To give the rural students a better condition with house lighting and more time for studying.
(6) To reduce the greenhouse effect by creating a complete smoke free system.
(7) To produce slurry that can be utilized as fertilizer for the land and fish.

8. CONCLUSION

In the designed system, the energy neutrality is proved by fulfilling the energy requirement without taking any electricity from grid. The implemented system can produce net 1.1kW (100w is considered as system loss) of electricity which is sufficient for a home if the full proportion of gas is used for the generation of electricity only. The system also supplies necessary gas for a home. The slurry of the system can be used in land as fertilizer. Thus the designed system is very fruitful for fulfilling the energy requirement with renewable energy source. Other natural resources like oil, gas etc. are limited and will be exhausted in course of time. So, the developed and developing countries consider their natural resources very precious and are cautious about extracting those. For this reason, this research is very much important for a country like Bangladesh where the people are facing great power crisis at present.

9. REFERENCE

[1]: Badrud Doza's profile in Bangladesh, Budget, Economy, and Governance "power crisis and Bangladesh Budget 2008-2009''August 3, 2008.

[2]: BPDB-Bangladesh power Development Board, "key Statistics", 2006.

[3]: Kanama D. and Kawamoto H., "Research and development trends of solar cell for highly efficiency" from Nanotechnology and Material Research Unit, July, 2008.

[4]: A. K. M. S. Islam and M. Islam "Status of renewable energy technology in Bangladesh" ISESCO Science and Technology Vision, Vol-1, May 2005, pp. 51-60.

[5]: The Energy-Neutral Home, by K. A. Dolan. Available online, March 12, 2011, at: http://www.forbes.com/2009/11/06/net-zero-energy-technology-breakthroughs-house.html

[6]: Zero-energy building, Available online, March 12, 2011, at: http://en.wikipedia.org/wiki/Zero-energy_building

[7]: An Example of Net Zero-energy Home System, Available online, March 12, 2011, at: http://www.popsci.com/environment/article/2009-07/ge-wants-our-smart-grid-equipped-homes-consuming-zero-net-energy-2015.

[8]: K. U. Islam, Senior Advisor, Sustainable Energy for Development (SED), GTZ (Deutsche Gesellschaft fur Technische Zusammenarbeit)

[9]: Training material of LGED, available online, March 05, 2011, at: http://www.paksc.org/psc-renewable-research/bio-energy/biogas.pdf

[10]: Biogas composition, Biogas Digest, Vol-1, Available online, March 01, 2011 at: http://www.gtz.de/de/dokumente/en-biogas-volume1.pdf

[11]: A. A. Sorkaar, Service Engineer, Bangla Power Company Ltd., Bangladesh.