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Biogas Utilization from Biomass and Kitchen Waste and its Impact on Energy Cost on a University Campus

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ABSTRACT: *Electricity problem is one of the main trammels of our economic growth. There are many ways to solve this problem. We can increase our dependency on renewable energy. Bangladesh is endowed with plentiful supply of renewable source of energy. Out of various renewable sources solar, wind, biomass can be effectively used in Bangladesh. In this paper, we try to give a clear discussion about biogas and how to implement a biogas plant on a small populated area such as university campus.*

Keywords: *Biomass, Micro organism, Municipal solid waste, HRT, Fixed dome, Digester.*

I. INTRODUCTION

Biogas is one of the promising renewable energy sources in Bangladesh. As an agricultural country Bangladesh has embedded with plenty of biomass which has been used for extracting energy by burning directly or making biogas. The first biogas plant was introduced by one professor of Bangladesh Agricultural University (BAU) Dr. M. A. Karim in 1972. Prakash C. Ghimire (2005) study and several studies explained that the interest in Biogas technology in Bangladesh is growing due to the increasing awareness of the importance of the renewable energy sources and their potential role in decentralized energy generation in rural areas. Implementation plan 2010-2012 of National Domestic Biogas and Manure Program of IDCOL mentioned that total technical potential of domestic biogas plants is 3 million. “Mobilizing market for the biogas technology” of GIZ study and other studies explained that the large potential market for the biogas digester in 100,000 poultry farms could benefit from the technology through the savings of traditional cooking fuel as well as prevention of disease and pathogen free fertilizer and also meet the energy crisis.

II. LITERATURE REVIEW OF BIOGAS:

In this section, several important terms are discussed which appeared to us after the review of recent Literature of Biogas based power plant: Biogas originates from bacteria in the process of biodegradation of organic material under anaerobic (without air) conditions. The natural generation of biogas is an important part of the biogeochemical carbon cycle. Methanogens (methane producing bacteria) are the last link in a chain of micro-organisms which degrade organic Material and return the decomposition products to the environment. In this process biogas is generated, a source of renewable energy. The anaerobic digestion process undergoes three distinct processes of micro organism activities.

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- The fermentative bacteria fermented and hydrolyzed the complex organic materials, carbohydrates protein and lipid into fatty acid, alcohol, carbon dioxide, hydrogen, ammonia and sulfides.
- The acetogenic bacteria consume the primary products and produce hydrogen, carbon dioxide and acetic acid.
- In this stage, two types of methanogenic bacteria work. The first reduces carbon dioxide to methane and the second decarboxylates acetic acid to methane and carbon dioxide.

Bangladesh has a wonderful climate for biogas production. The ideal temperature for biogas is around 35°. The temperature in Bangladesh usually varies from 6°C to 40°C.But the inside temperature of a biogas digester remains at 22°C-30°C, which is very near to the optimum requirement. In Bangladesh animal dung, poultry waste, and agricultural residues have long been used to produce biogas in the plant. The highly production rate of animal dung has given it more attraction to be used as the chief biomass element. But in urban areas due to the unavailability of space animal farm is not available. So the concerned have turned into alternative sources of biogas. The municipal waste management could be a potential source of biogas production in the urban areas. Most of the developed countries are having adopted these municipal waste materials as their main bio gas production element. Bangladesh is yet to implement this municipal waste management system which could facilitate the major increase of biogas production to meet the demand of household cooking and transport fuel largely. The following table shows the increasing rate of municipal waste in the urban areas of Bangladesh. Two basic processes are being used to recover the energy from municipal solid waste. Such as:

- **Thermo chemical conversion**: In this process the wastes get de-composed to produce heat or fuel gas.
- **Bio-chemical conversion:** In this process the waste become decomposed by the enzymatic action of some bacteria.

For the waste containing high percentage of non-biodegradable materials thermo chemical conversion is more suitable. The main technologies involved in this process are Incineration and gasification. For the waste having high percentage of Biodegradable organic materials and more moisture content thermo chemical conversion is preferable.

- **Hydraulic Retention Time (HRT):** The retention time is the theoretical time that a particle or volume of liquid added to a digester would remain in the digester. It is calculated as the volume of the digester divided by the volume of slurry added per day and it is expressed as days. The solids retention time (SRT) represents the average time that the solids remain in the system. The solids retention time can be determined by dividing the weight of volatile solids in the system by the weight per unit time of volatile solids leaving the system. The hydraulic retention time (HRT) is equal to the solids retention time in completely mixed non-recycled digester systems.
- **Total Solid (TS):** The amount of solid material without considering the liquid part is termed as Total Solid (TS). Total solid is the material unit that indicates the production rate of Biogas. The favorable total solid value for smooth fermentation is 8% .
- **Fresh Discharge:** Fresh discharge is the total amount of manure including moisture content directly obtained from the com, chicken, human etc.
- **Liquid Part:** Liquid part is the amount of water to be added with fresh discharge to make the TS value is 8%.

III. METHODOLOGY

We are designing a biogas plant with respect to human and kitchen waste of four hostels and a dormitory at a university campus which act as a ideal model for reducing load shedding and at the absence of load shedding it will provide electricity at power grid.

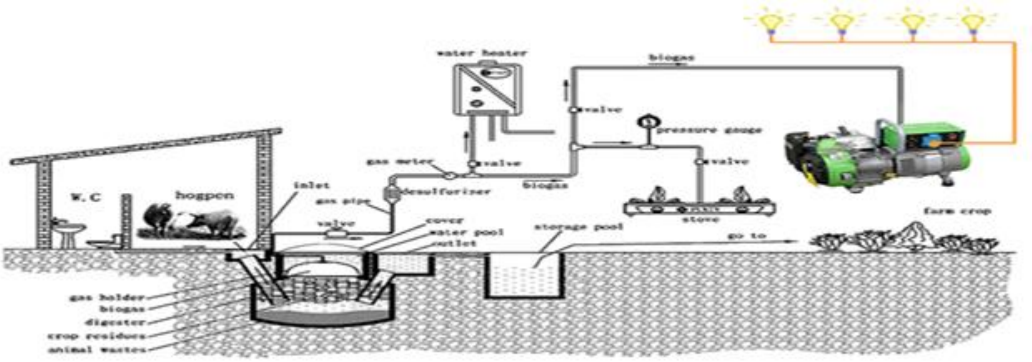

Figure: *Biogas plant for generating electrical power*

- **Potential Of Biogas Energy:**

Every university has sufficient renewable energy which can act as rising part to reduce the load shedding problem of that university. By considering these, we are presenting a biogas plant with respect to human waste and kitchen waste of hostel 1,2,3,4 dormitory building of a campus where these wastes are used as raw materials.

Position of floor	Types	Quantity	Population
1st Floor	Dining, Kitchen & Student Common Room	3	–
2nd Floor	St. Room	31	124
3rd Floor	St. Room	31	124
4th Floor	St. Room	31	124
5th Floor	St. Room	31	124
			500

Table: *For hostel from Human waste*

Total number of people = 500 (Assuming Populations). On an average each person's human waste is = 0.5Kg.
So, Total Human waste = (0.5×500) = 250Kg.
An ordinary temperature (30° C) biogas obtained from human waste = 0.365 m^3 / Kg TS (estimated).
Again TS value of human = .2
So, the total biogas from 500 peoples = (0.5×500×0.2×0.365) = 18.25$m^{3.}$
When the population is 1000 = (0.5×1000×0.2×0.365) =36.5m3
When the population is 300 =(0.5×300×0.2×0.365) =10.95m3
From Kitchen :
Total Population= 3300
We have, 1 person= 0.10 Kg Kitchen waste
So, 3300 persons= 3300×0.10= 330 Kg
Total kitchen waste= 330Kg
An ordinary temperature (30° C) biogas obtained from kitchen waste 0.949 m^3/Kg TS (estimated).
TS value of kitchen waste is = 52%.
Since, 20% = 0.365 m^3/kg.
Or, 1% = $\frac{0.365}{0.2}$$m^3$/kg .
Or, 52% = $\frac{0.365 \times 0.52}{0.2}$ m^3/kg = 0.949 m^3/kg.
So, the total biogas from kitchen waste= (330×0.52×0.949) = 162.85m^3.

Position of floor	Types	Quantity	Population
1st Floor	Teacher's room & Kitchen room	25	50
2nd Floor	Teacher's room & Kitchen room	25	50
3rd Floor	Teacher's room & Kitchen room	25	50
4th Floor	Teacher's room & Kitchen room	25	50
Total			200

***Table:** For Dormitory (from human waste)*

Electricity generation from available gas (Assuming 500 peoples):
From Human waste:
We know that, each cubic meter biogas, we get 1.4 kw /h electricity.
So, the electricity = 18.25× 1.4 = 25.56 kw /h. (500 peoples)
If we use electricity = 3hr/day then capacity of the system for electricity generation can be obtained by the following equation capacity = (25.56 ÷3) = 8.5 kw /h.
From Kitchen waste :(Assuming 3300 peoples)
We know that, each cubic meter biogas we get 1,4 kw/h electricity.

So the electricity =162.85×1.4 = 228 kw/h.

If we use electricity 3 hr/day, then capacity system for electricity generation can be obtained by the following equation capacity = 76 kw/h.
For dormitory (from human waste):
We know that, each cubic meter biogas, we get 1.4 kw /h electricity.
So, the electricity = 7.30 × 1.4 = 10.22 kw /h.
If we use electricity = 3 hr/day then capacity of the system for electricity generation can be obtained by the following equation capacity = (10.22 ÷3) = 3.41 kw /h.

- **Design Of Biogas Plant**
  Biogas plant technology has three basic designs:
- The fixed dome.
- Floating cover dome.
- Plastic dome.

Fixed dome: A fixed dome biogas plant is an airtight underground tank in which organic materials mixed with water are digested/ or fermented through anaerobic bacteria action in the purpose of generating biogas fuel. The treated waste is nutrient-rich fertilizer while the biogas is a flammable gas composed of methane (component with burns), Carbon dioxide, Hydrogen, Nitrogen and Hydrogen sulfide. The main components are methane and carbon dioxide other gases are in form of traces.
The fixed dome design is very popular in Bangladesh. We are designing a biogas plant with respect to fixed dome.

Materials	Dry Matter (%)	Water Matter (%)
Human waste	20	80
Kitchen waste	52	48

***Table:** Contents of Human & Kitchen waste material*

Components of Biogas based plant:

a. **Receiving Tank / Inlet pipe:** The slurry is moved into the digester through the inlet pipe/tank.
b. **Digester:** The slurry is fermented inside the digester. Biogas is produced through bacterial action.
c. **Outlet pipe:** The slurry is designed into the outlet tank. This is done through the outlet pipe or the opening in the digester.
d. **Gas purification unit:** Biogas contains about 55-75% methane& also contains moisture, hydrogen sulphide and some other impurities. The main purpose of the gas purification unit is to remove these impurities.
e. **Gas generators:** Gas generators are internal combustion (IC) gas engines, which is internally burn the biogas & convert the prospective energy of the biogas to mechanical rotation which next converted into electrical energy. The electrical energy is used to operate the electrical energy.
f. **Gas holder or gas storage dome:** The biogas thus formed gets collected in the gas holder. It holds the gas till the time it is transported for transmission.
g. **Gas pipeline:** The gas pipeline carries the gas to the utilization point like a stove or lamp.

- **Composition of Biogas based plant:**

The composition of biogas varies depending upon the origin of the anaerobic digestion process. Landfill gas typically CH_4 concentrations around 50%. Advanced waste treatment technologies can produce biogas with 55-75% CH_4 or higher using in situ purification techniques. Biogas also contains water vapor, with the fractional water vapor volume a function of biogas temperature. In some cases biogas contains siloxanes. These siloxanes are formed from the anaerobic decomposition of materials commonly found in soaps and detergents. During combustion of biogas containing siloxanes, silicon is released and can combine with free oxygen or various other elements in the combustion gas. Deposits are formed containing mostly silica (SiO_2) or silicates (Si_xO_y) and can also contain calcium, sulfur, zinc, phosphorus. Such white mineral deposits accumulate to surface thickness of several millimeters and must be removes by chemical or mechanical means. Practical & cost effective technologies to remove siloxanes and other biogas contaminants are currently available.
The average composition of biogas is shown in table with respect to percentage 55%to75% biogas is methane gas.

Matter	Percentage (%)
Methane (CH_4)	55-75
Carbon-dioxide (CO_2)	25-45
Carbon mono-oxide (CO)	0-0.3
Nitrogen (N_2)	1-5
Hydrogen (H_2)	0-3
Hydrogen sulphide (H_2S)	0.1-0.5
Oxygen (O_2)	0.1-0.8

***Table:** Composition of Biogas*

- **Human Waste & Kitchen Waste:**

1. **Human waste:**
2. Human waste is a kind of waste of bio-waste generally used to transfer to byproducts of digestion such as faces & urine.
3. **Kitchen waste:**
4. Kitchen waste is that waste which is not suitable to eat & which is thrown away from the food after used.

IV. CALCULATION OF DIGESTER VOLUME:

A. Calculation of digester volume for hostel from human waste:

Digester volume for 500 peoples
Let, HRT= 40 day (for temperature 30° C).
We know, from every person 0.5 Kg waste is obtained per day.
Total discharge for human waste = (500×0.5) Kg = 250Kg.
TS of fresh discharge = (250×0.2) = 50 Kg.
To make the TS value of 8% for favorable condition we have to mix some additional water with fresh discharge. The required water added can be calculated by the following way.
8 Kg solid equivalent of influent.
50Kg solid equivalent = 100*50/8Kg = 625 Kg.
Working volume of digester = Q × HRT =625×40=25 m^3.
From geometrical assumption,
$V_{gs}+V_f$= 80% of V

or, 25 = 0.8 $\times$ V

or, V = 25/.8 = 31.25 m^3

When the populations 300;
The volume of digester is=18.75m3
When the populations 1000;
The volume of digester is=62.5m3

B. Calculation of digester volume for kitchen(Assuming 3300 peoples)

Digester volume for student hostel-1:
Let, HRT= 40 day (for temperature =30° C).
We know, from every household 0.10 Kg waste is obtained per day.
Total discharge for kitchen waste = 3300×0.10Kg =330Kg.
TS of fresh discharge = (330×0.52) = 171.6 Kg.
To make the TS value of 8% for favorable condition, we have to mix some additional water with fresh discharge. The required water to add can be calculated by the following way. 8 Kg solid equivalent of influent.
26.624 Kg solid equivalent = 100*1716/8Kg = 2145Kg .
Working volume of digester = Q × HRT =2145 ×40=85.80m^3.
From geometrical assumption,
V_{gs}+ V_f= 80% of V

or, 85.80= 0.8 $\times$ V

or, V =85.80/.8 = 107.25m3

C. Calculation of digester volume of Teacher's Dormitory:

Digester volume for teacher's Dormitory.
Let, HRT= 40 day (for temperature 30° C) .
We know , From every person 0.5 Kg waste is obtained per day .
Total discharge for human waste = (200×0.5) Kg = 100 Kg .
TS of fresh discharge = (100×0.2) = 20 Kg.
To make the TS value of 8% for favorable condition we have to mix some additional water with fresh discharge. The required water to added can be calculated by the following way.
8 Kg solid equivalent of influent.
6 Kg solid equivalent = (100*20)/8 Kg = 250 Kg.
Working volume of digester = Q × HRT =250×40=10.00 m^3.
From geometrical assumption,
V_{gs}+ V_f= 80% of V

or, 10.00 = 0.80 $\times$ V

or, V = $\frac{10.00}{0.80}$ = 12.50 m^3 .

- **Total Generation Capacity From Human Waste, Kitchen Waste:**

Position	Type	Waste Type	Power (KW)
Student hostel 1,2,3,4	AC	Human	8.54*4 = 34.16
Teachers Dormitory	AC	Human	3.41
Student hostel 1,2,3,4 & Teacher's Dormitory	AC	Kitchen	50.29
Total			87.86

- **Study of Existing University Load Curve:**

According to the demand of power we have separated the total generation on the basis of renewable energy. The demand of electricity is varying with respect to time. When we required a huge amount of power then connects the required energy with respect to some units (Renewable energy). We are maintaining the total generation and BPDB supply by using control unit and substation. With respect to renewable energy source and BPDB we can fulfill the total demand of university campus.

Building Name	Load (Emergency) KW	Quantity of Light	Rating per light (Watt)	Quantity of Fan	Rating of Fan (Watt)
Student hostel 1,2,3,4	22.82	992	23	_	_
Teacher Dormitory	11.60	200	23	100	70
Academic Building	7.615	115	23	71	70
Server	15				

Table: *Identifying important loads.*

Distribution Of Loads:

- Load A: Teacher's room (60) = 60×(23(Light)+70(Fan)) = 5.58 KW
- Load B: Chairman room (11) = 11×(23(Light)+70(Fan)) = 1.00KW (Approximately)
- Load C: Server= 15 KW
- Load D: Classroom (22) = 22×(2×23(Light)) = 1KW
- Load E: Student Hostel 1,2,3,4 and teacher's dormitory :

For student hostel 1,2,3,4 = 992*23(light) = 22.80 KW
For Teachers dormitory = (200*23(light) + 100*70(fan)) = 11.60 KW
Teachers Dormitory+ Hostel = 11.60+22.80 = 34.40 KW

Based on priority:

Time of day	00:00 – 06:00	06:00 – 08:00	08:00 – 14:00	14:00 – 18:00	18:00 – 24:00
Running Load			Load A	Load A	Load A
				Load B	Load B
	Load C	Load C	Load B	Load C	Load C
			Load C		
	Load E		Load D	Load D	Load E
Total Load(KW)	49.40 KW	15 KW	22.58 KW	22.58 KW	55.98 KW

Table: *Time duration table.*

- **Distribution Of Renewable Energy:**

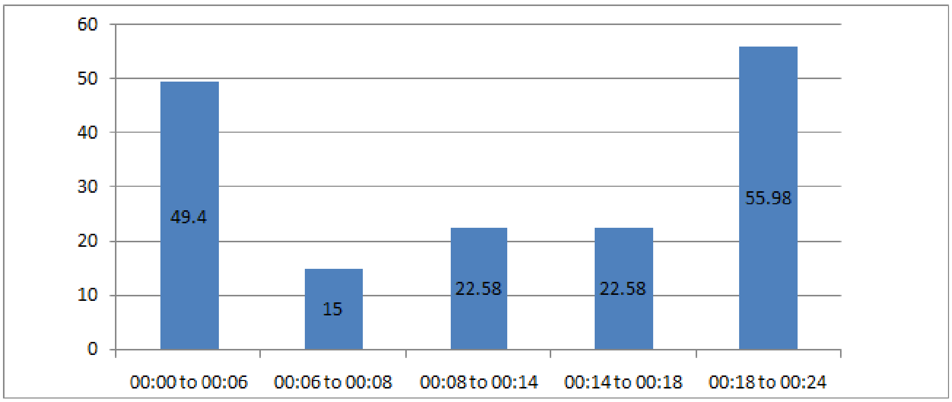

Figure: *Distribution of renewable energy*

Cost Analysis:
From the time duration table:
In time (00:00-06:00), the total load= 49.40 KW
Total time=6 hours
Total KW= 49.4×6=296.4 KWh
1KWh= 1 Unit
1 Unit = 5 Taka
=>296.40 KWh = 296.40 × 5 = 1482 Taka
For 1 day= 1482 Taka
=>30 day = 1482×30= 44,460Taka
From the time duration table:
In time (06:00-08:00), the total load= 15 KW
Total time=2 hours
Total KW= 15×2=30 KWh
1KWh= 1 Unit
1 Unit = 5 Taka
=>30 KWh = 30 × 5 = 150 Taka
For 1 day= 150 Taka
=>30 day = 150×30= 4500 Taka
From the time duration table:
In time (08:00-14:00), the total load= 22.58 KW
Total time=6 hours
Total KW= 22.58 ×6= 135.48 KWh

1KWh= 1 Unit
1 Unit = 5 Taka
=>135.48KWh = 5 × 135.48 = 677.40 Taka
For 1 day= 677.40 Taka
=>30 day = 677.40 ×30= 20,322 Taka
From the time duration table:
In time (14:00-18:00), the total load= 22.58 KW
Total time = 4 hours
Total KW= 22.58 ×4= 90.32 KWh
1KWh= 1 Unit
1 Unit = 5 Taka
=>90.32KWh = 90.32 × 5 = 451.60 Taka
For 1 day= 451.60 Taka
=>30 day = 451.60 ×30= 13,548 Taka
From the time duration table:
In time (18:00-24:00), the total load= 55.98 KW
Total time = 6 hours
Total KW= 55.98 ×6 = 335.88 KWh
1KWh= 1 Unit
1 Unit = 5 Taka
=>335.88KWh = 335.88 × 5 = 1679.40 Taka
For 1 day= 1679.40 Taka
=>30 day = 1679.40 ×30= 50,382 Taka
Total per month savings = 44,460+4500+20322+13548+50382 = 1, 33,212 Taka.

V. CONCLUSION

Bangladesh has a great opportunity to generate biogas and solar with the help of human waste, kitchen waste and sun shine. This renewable energy sources can be used for generating electricity and removing load shedding problems in Bangladesh. As the load shedding problems may not be removed in near future, this is the best alternative source to generate electricity. Our thesis paper represents the back-up source during load shedding at a University Campus according to biogas and solar based where human waste, kitchen waste and sun-shine is used as new materials. Complete design including system specification has been worked out. To remove load shedding problem, our represented thesis paper can be used as an ideal model for every University Campus in Bangladesh.

VI. FUTURE WORK

We will investigate about more detail regarding interconnected grid system, reliability and system failure and management of load. We will plan and design for this new concepts to our university not only to save cost but also reliable electric supply. So our thesis objectives not only focus for one campus but also community based power generation as well as development of our country through green energy.

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