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Designing Solar and Biogas based Renewable Energy System on University Campus and its Impacts on Energy Cost after Renewable Energy Interconnection on University Campus Grid Network

By Ummay Habiba, Sujan Kumar Talukdar & Md. Rabiul Islam
Pabna University of Science & Technology, Bangladesh

Abstract - In Bangladesh power crisis is one of the great problems. The whole of the probable sector is affected by it. The effects of power crisis is destroyed our economic growth. The total development of a country's depends on the power generation. On the other hand when the load shedding is occurred, then the students of the university are basically affected, then they do not attain their lesson attentively and study their lesson attentively. Even they do not able to complete their laboratory works, complete their thesis and their class notes and so on. But, there is a huge opportunity to back up the load shedding using Solar and Biogas energy. This paper presents a design and analysis of Solar based power plant using sunlight and Biogas based plant using Human and Kitchen waste of the University for Load shedding Backup and the cost analysis results that, the system is economically feasible for University campus.

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Ummay Habiba [α], Sujan Kumar Talukdar [σ] & Md. Rabiul Islam [ρ]

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I. Introduction

Bangladesh is endowed with plentiful supply of renewable source of energy [1]. Out of various renewable sources solar, wind, biomass can be effectively used in Bangladesh. Renewable energy practices in Bangladesh are [2]-

- Solar energy
- Biomass energy
- Wind energy
- Hydro power energy

Wind & Hydro power have a limited scope of success in Bangladesh, but could solar & biogas provides a viable solution to our existing energy problems [3].

Authors α σ : Department of Electrical & Electronic Engineering (EEE), Pabna University of Science & Technology (PUST), Pabna.
E-mails : engr.suma.eee@gmail.com, sujan.talukdar090240@gmail.com
Author ρ : Lecturer, Department of Electrical & Electronic Engineering (EEE), Pabna University of Science & Technology (PUST), Pabna.
E-mail : mrabiul_eee_eng@hotmail.com

Solar power is not new in Bangladesh. Since, 1996 different companies have tried to market solar energy systems to the public [4]. Yet in a technologically backward country like Bangladesh the ides took a fair while to gestate. Solar and biogas energy is a renewable energy without causing pollution to the environment. Grameen Shakti and few other companies are working to provide solar biogas energy to the villages in Bangladesh. The Government of Bangladesh is working to provide more energy to its people to accelerate economic growth, social development and reduce poverty [5]. On one hand, government is working to promote the use of renewable energy technologies. On the other hand, the government works with industry public sector power utilities and private households to increase the use of energy efficient appliance and production processes and promote energy generation. Renewable energy and energy efficiency is a priority area of Bangladeshi–German development co-operation [6].

II. Literature Review

Sun is the richest source of energies like light and heat. Huge amount of energies are available for us to take and make big impact on our electricity requirements [7]. Our sun throws as much amount of energy on earth in one day which is equivalent to the energy requirement for the entire year. Sun surface is about 109 times bigger than surface of the earth [8]. It takes millions of years for energy generated from the center of the sun to reach to the surface of the sun [9]. Our mother earth is about 149.63 * 106 kilometers away from the sun, and light takes about 8 minutes and 31 seconds to reach to the surface of the earth. Light from the sun travels 186,262 miles per second to reach to earth [10] [11]. Energy emitted from the sun which reaches earth is in massive amount and can be extremely dangerous for mankind on earth if direct exposure is made.

a) Solar Energy

Solar electricity is the energy which is extracted by Sun using solar power plants.

i. *Photovoltaic or Solar Cell*

It is possible to convert solar energy directly into electrical energy by means of silicon wafer photovoltaic cells, also called solar cells, without any intermediate thermodynamic cycle [12]. The solar cell operates operate on the principle of photovoltaic effect, which is a process of generating an EMF as a result of the absorption of ionizing radiation. Thus a solar cell is a transducer, which converts the sun's radiant energy directly into electrical energy.

ii. *Storage Device*

The electricity produced by the PV modules is stored in batteries for later use when there is no sun [13]. Charge controllers regulate the rate of flow of electricity from the modules to the battery or the loads or to both simultaneously. It keeps the battery from overcharging or overloading thus prolonging its life.

iii. *Inverters*

The inverter converts the DC electricity produced by the solar modules into alternating current (AC) since most electrical appliances and equipment run on AC electricity [14].

b) Biogas Energy

Biogas originates from bacteria in the process of biodegradation of organic material under anaerobic (without air) conditions [15]. 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.

i. *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 [16]. 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.

ii. *Total Solid (TS)*

The amount of solid material without considering the liquid part is termed as Total Solid (TS) [16]. Total solid is the material unit that indicates the production rate of Biogas. The favourable total solid value for smooth fermentation is 8%.

iii. *Fresh Discharge*

Fresh discharge is the total amount of manure including moisture content directly obtained from the com, chicken, human etc. [16].

iv. *Liquid Part*

Liquid part is the amount of water to be added with fresh discharge to make the TS value is 8% [16].

III. Research Methodology

We have designed a biogas plant with respect to human and kitchen waste of four hostel and a dormitory at a university campus and according to area of roof space of a academic building and four hostel, & We are establishing a solar panel which act as an ideal model for reducing load shedding and at the absence of load shedding it will provide electricity at national grid.

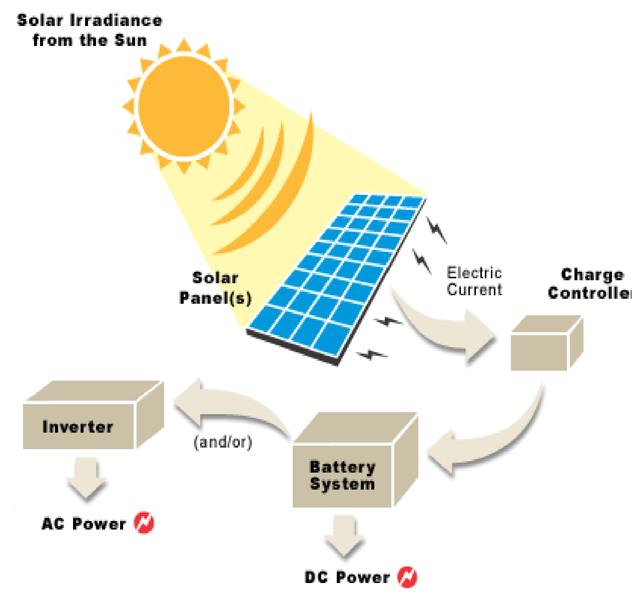

Figure 1 : Solar energy generation method

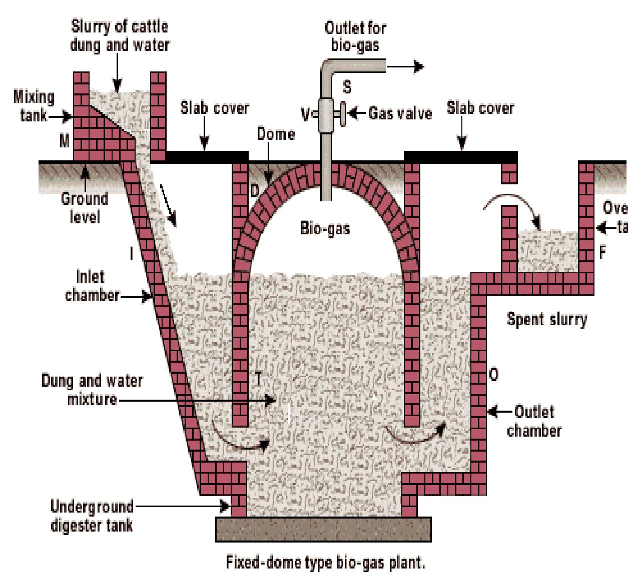

Figure 2 : Biogas based power plant design

The conversion of sunlight into electricity is defined as the solar power. It has done with the help of directly using photovoltaic (PV), or indirectly using concentrated solar power (CSP). CSP use lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam. Photovoltaic Cell converts light into electric current using the photoelectric effect which is the basic principle of solar power generation.

IV. Solar Panel & Biogas Plant

The determination of Solar panel requirements and the composition of Biogas are provided below.

a) Determination of Solar Panel Requirements

For 100 Watt Solar Panel required area is = 7.392 square ft. Consider, Four Student Hostel and One Academic Building where roof space of each hostel is 4000 sq.ft. and Academic Building is 5000 sq.ft. respectively. For 4000 square ft. of every hostel 54.11 KW power can be generated and total panel required in every hostel = 540 pieces. For 5000 sq. ft. of Academic Building 67.64 KW power can be generated and total panel required in every hostel = 670 pieces.

Building Name	Load Emergency KW	Quantity of Light KW	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				

b) Composition of Biogas based Plant

The average composition of biogas is shown in table with respect to percentage 55%-75% biogas is methane gas.

Table 1 : Composition of Biogas

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

V. Calculation of Digester Volume

a) Calculation of Digester Volume for Hostel from Human Waste

Digester volume for student hostel-1:

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 = (496×0.5) Kg = 248 Kg.

TS of fresh discharge = (248×0.2) = 49.6 Kg.

To make the TS value of 8% for favourable 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.

49.6 Kg solid equivalent $=\frac{100\times 49.6}{8}$ Kg = 620 Kg .

Working volume of digester = Q × HRT =620×40= 24.8 m^3.

From geometrical assumption,

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

or, 24.8 = 0.8 × V

or, $V = \frac{24.80}{0.80} = 31\ m^3$

Similarly, For hostel 2, V=31 m^3

& For hostel 3, V= 31 m^3

& For hostel 4, V= 31 m^3

Parameter of digester volume for hostel 1 from human waste:

Since, V= 31 m^3

$D=1.3078\ V^{(1/3)}$

Or, D= 4.10 m

Again, $V_3= (3.14\times D^2\times H)/4 = (3.14\times 4.10^2\times 0.5)/4 = 6.6\ m^3$

Here, H= 0.5m(Calculated).

Then, f_1 = D/5 = 4.10/5 = 0.82 m

f_2 = D/8 = 4.10/8 = 0.50 m

$V_1= 0.0827\ D^3 = 0.0827 \times 4.10^3 = 5.60\ m^3$

$V_c = 0.05\ V = 0.05\times 31 = 1.55\ m^3$

Respectively, we can find these data's for Student Hall-02, 03 & 04.

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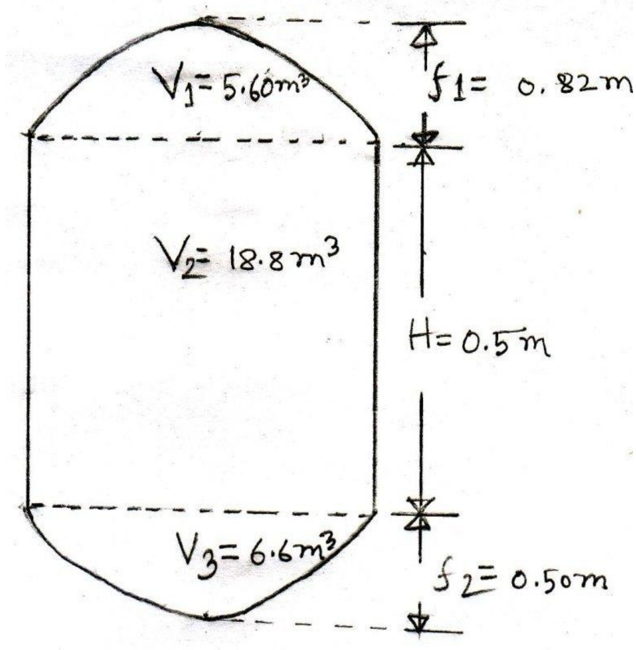

Figure 3 : Design of Digester Volume of Student Hall 1, 2, 3 & 4

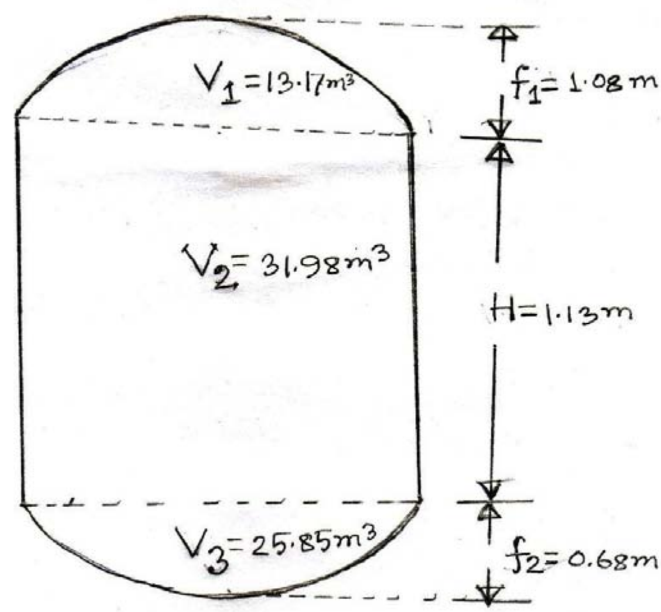

Figure 4 : Design of digester volume for Kitchen waste

b) Calculation of Digester Volume for Kitchen

Digester volume for kitchen:

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 = 2184×0.10Kg =218.40 Kg.

TS of fresh discharge = (218.40×0.52) = 113.568 Kg.

To make the TS value of 8% for favourable 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 $= \frac{100\times113.568}{8}$ Kg = 1416.60 Kg .

Working volume of digester = Q × HRT =1416.60 ×40=56.784m³.

From geometrical assumption,

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

or, 56.784= 0.8 × V

or, $V = \frac{56.784}{0.80}$ = 70.98 m3 =71 m3

Parameter of digester volume for Kitchen:

Since, V=71 m³.

D=1.3078 $V^{(1/3)}$

Or, D= 5.42 m

Again, V_3= (3.14×D²×H)/4 = (3.14×5.42²×1.13)/4 = 25.85 m³

Here, H= 1.13m(Calculated).

Then, f_1 = D/5 = 5.42/5 = 1.08 m

f_2 = D/8 = 5.42/8 = 0.68 m

V_1= 0.0827 D³ = 0.0827 × 5.42³ = 13.17 m³

V_c= 0.05 V = 3.55 m³

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 favourable 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 $= \frac{100\times20}{8}$ Kg = 250 Kg .

Working volume of digester = Q × HRT =250×40= 10.00 m³.

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From geometrical assumption,

Vgs + Vf= 80% of V

or, 10.00 = 0.80 × V

or, $V = \frac{10.00}{0.80} = 12\ m^3$.

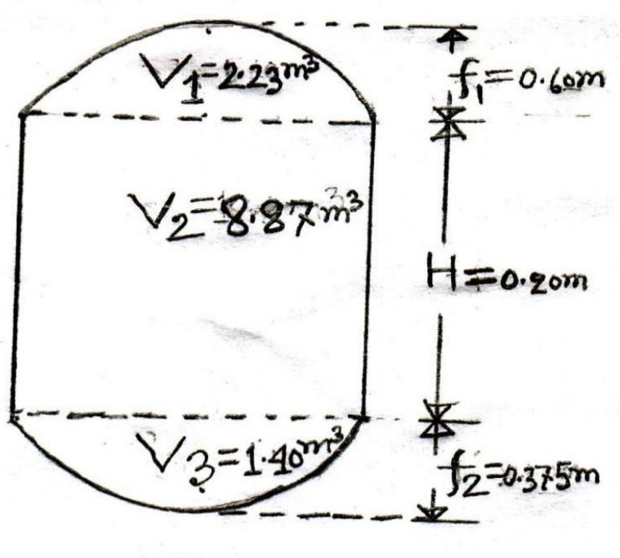

Figure 5 : Design of digester volume of Teachers' Dormitory

d) Parameter of Digester Volume for Teachers Dormitory

Since, $V=12.50\ m^3$

Then, $D=1.3078\ V^{(1/3)}$

Or, D= 3 m

Again,

$V_3= (3.14\times D^2\times H)/4 = (3.14\times 3^2\times 0.20)/4 = 1.40\ m^3$

Here, H=.20 m(Calculated).

Then, $f_1 = D/5 = 3/5 = 0.60$ m

$f_2 = D/8 = 3/8 = 0.375$ m

$V_1= 0.0827\ D^3 = 0.0827 \times 3^3 = 2.23\ m^3$

$V_c= 0.05\ V = 0.05 \times 12.50 m^3 = 0.62\ m^3$

VI. Electricity Generation Capacity & Load Distributions

The total generation capacity from human waste, kitchen waste and solar energy is given in the table-2 shown in below.

Table 2 : Total Generation Capacity from Human waste, Kitchen Waste, and Solar Energy

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
Student hostel 1,2,3,4	DC	Solar energy	54*4 = 216
Academic Building	DC	Solar energy	67
		TOTAL	370.86

Table 3 : Identification of Important Loads

Position	Type	Waste Type	Power (KW)	Volume and Roof space respectively of Biogas and Solar
Student hostel 1,2,3,4	AC	Human	8.54*4 = 34.16	31m of each Digester
Teachers Dormitory	AC	Human	3.41	12m of Digester
Student hostel 1,2,3,4 & Teacher's Dormitory	AC	Kitchen	50.29	71m
Student hostel 1,2,3,4	DC	Solar energy	54*4 = 216	4000 sq. ft. of each Hostel
Academic Building	DC	Solar energy	67	5000 sq. ft.
		TOTAL	370.86	

The important loads are listed as the table-3 as shown. Now, the distributions of the loads are given below:

- *Load-1 :* Teacher's room (60) = 60× (23(Light) +70(Fan)) = 5.58 KW
- *Load-2 :* Chairman Room (11) = 11× (23(Light) +70(Fan)) = 1.00KW (Approximately)
- *Load-3 :* Server= 15 KW
- *Load-4 :* Classroom (22) = 22× (2×23(Light)) = 1KW
- *Load-5 :* 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.

The duration of the operation of the loads are shown in the table-4 in below.

Table 4 : Operation time of loads based on priority of loads

Time of Day	00:00 – 06:00	06:00 – 08:00	08:00 – 14:00	14:00 18:0	18:00 – 24:00
Running Load			Load1	Load	Load1
				Load	Load2
	Load3	Load3	Load2	Load	Load3
			Load3		
	Load5		Load4	Load	Load5
Total Load (KW)	49.40 KW	15 KW	22.58 KW	22.5 KW	55.98 KW

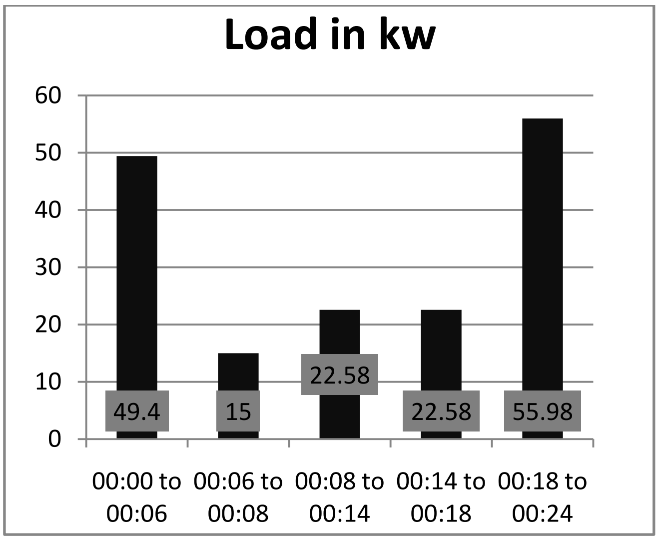

Figure 3 : Distribution of Renewable energy

VII. Cost Benefit Analysis & Savings

Since, 1 Unit= 1 KWh=5 Taka

From the time duration table:

In time (00:00-06:00) = 49.4×8*5=1482Taka

In time (06:00-08:00) = 15*2*5= 150 Taka

In time (08:00-14:00) = 22.58*6*5=677.40 Taka

In time (14:00-18:00) = 22.58*4*5= 451.60Taka

In time (18:00-24:00) = 55.98*6*5=1679.40 Taka

The total per month savings

=1482*30+150*30+677*30+451.60*30+1679.40*30

= 1, 33,212 Taka.

Table 5 : Total demand of load on University campus

Building name	Load in KW	Quantity of light	Rating per light (watt)	Quantity of fan	Rating per fan (watt)
Student hostel 1,2,3,4	92.256	992	23	992	70
Teachers dormitory	11.6	200	23	100	70
Academic building	115.32	1240	23	1240	70
Server	25				

a) Load Distributions

- *Load A :* Teacher' room (60) =60*(23(light) +70(fan)) =5.58 KW
- *Load B :* Chairman Room (11) =11*(23(light) +70(fan)) =1.00 KW
- *Load C :* Server=25KW
- *Load D :* Classroom (22) = 22*(3*23(light) + 3*70 (fan)) = 7.678KW
- *Load E :* Student hostel 1,2,3,4 & teacher's dormitory :

  Student hostel 1, 2, 3, 4 = 992*(23(light) +70(fan)) = 92.256 KW

  Teacher's dormitory=200*23(light) + 100*70(fan) =11.6 KW

  Student hostel 1,2,3,4 + Teacher's dormitory = 92.256+11.6=103.856 KW

Table 6 : Time Duration Table

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 B
	Load C	Load C	Load C	Load C	Load C
			Load D	Load D	
	Load E				Load E
Total Load (KW)	128.856 KW	25 KW	39.258 KW	9.258 KW	135.436 KW

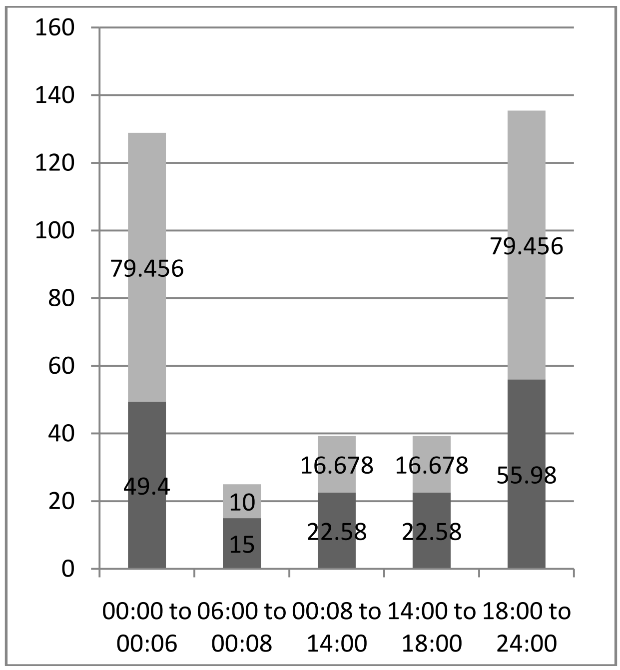

Figure 4 : Distribution of Renewable energy assuming no load-shedding

Table 7 : Cost Analysis during on no load-shedding

Time of Day	Load in KW (from renewable energy)	Load in KW (from BPDB)	Total cost (from renewable energy) in Taka	Total cost (from BPDB) in Taka
00:00-06:00	49.40	79.456	49.40*6*5=1482	79.459*6*5=2383.68
06:00-08:00	15.00	10.000	15*2*5=150	10*2*5=100
08:00-14:00	22.58	16.678	22.58*6*5=677.4	16.678*6*5=500.34
14:00-18:00	22.58	16.678	22.58*4*5=451.6	16.678*4*5=333.56
18:00-24:00	55.98	79.456	55.98*6*5=1679	79.456*6*5=2383.68
			Total cost= 4440 TK/Day	Total cost= 5701.26 TK/Day

Total cost= 4440 Taka (R.E) + 5701.26 Taka (BPDB) =10141.26 Taka. Total per month cost= 10141.26*30= 304,237.8 Taka.

From renewable energy,

Per month cost= per month saving= 4430*30 = 133,200 Taka.

Assumption of load shedding period: During the load shedding, only the emergency load is connected:

Table 8 : Demand on Load-shedding period

Load shedding period	Demand (KW)
11 am – 12 pm	22.58
03 pm- 04 pm	22.58
07 pm – 09 pm	55.98

During on load shedding, Total per day cost = (22.56*2*5+55.98*2*5) Taka= 785 Taka. Per month saving = 785*30 Taka = 23568 Taka. During the load shedding time, total saving per month on a University campus = (133200-23568) Taka = 109632 Taka.

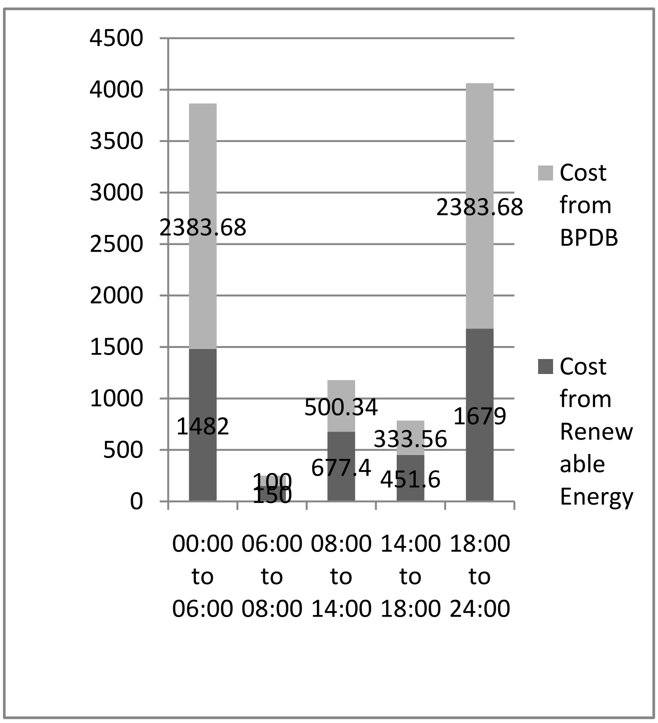

Figure 5 : Cost Analysis Curve

VIII. Conclusion

Bangladesh has a great opportunity to generate biogas and solar based power plant 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.

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