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Solar and Biogas based Hybrid Mini Grid Power System for Off-Grid Region: Bangladesh Perspectives

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ABSTRACT: This study is mainly an analysis for the solar and biogas hybrid mini-grid system for of-grid electrification area in Bangladesh. Energy is a very crucial input for the development of economic, social, industry and technology. Energy plays a vital rule in all spheres our daily life. The source of energy is mainly two types, these are conventional and non-conventional. But for the shortage of fuel, environmental concern and a hike for fuel price are the main reason for decreasing the rate of conventional energy production. These causes are motivating for the use of non-conventional energy or renewable energy or green energy. It improves the quality of life in rural areas in Bangladesh. Bangladesh is a highly developing country. So, Bangladesh has issued a vision to bring the entire country under electricity service by the year 2030 and the target of rises capacity in 24000 MW within the year 2021. A large proportion of the country's population lives in remote rural areas. In short, to meet the target demand, different renewable energy sources require to be integrated. As Bangladesh is an agricultural country, biogas resource is available here and there is a good prospect of solar energy. By the hybrid system, energy will be more cost-effective and reliable. In this study, PVsyst and HOMER softwares are used for the simulation and designing model. PVsyst is used for the solar model and HOMER for the whole hybrid model. In this system, the nominal voltage and capacity of the battery are 36V and 2100Ah, respectively and the selected solar module is 335 Wp. A solar and biogas hybrid system is proposed for the electrification of a rural area at Char Alimabad, kayaria (Union), kalkini (Upazilla), Madaripur (District), Bangladesh.

Keywords: Solar PV, Biogas, PVsyst, HOMER, Renewable energ, Carbon Emission.

1. INTRODUCTION

Bangladesh is a country in the southern Asian with its 161 million (or 29 million households) people in a landmass of 147570 sq km [1]. Fifteen

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million of them connected in the rural areas. Many areas in this country live in an isolated area or so far from the national power grid. So it is very tuff to meet the grid connect this area. The earth receives 175 peta watts (pw) of in incoming solar radiation (insulation) at the upper atmosphere. Approximately, 30% reflected back to space while the rest is absorbing by clouds, oceans, and landmasses. The insulation in Bangladesh varies from 3.8 kWh/m²/day to 6.4kWh/m^2/day. The maximum amount of radiation is available on the month of March-April and minimum on December-January. This indicates that there is a good prospect for solar photovoltaic application in our country [1]. Bangladesh is an agricultural-based temperate country. The weather and area is a very good prospect for poultry farming and dairy farming. So, we are easily getting enough cow dung and poultry dung i.e. the raw material for biogas by poultry farm and dairy farm. Small-scale poultry production has developed in a large number of developing countries around the world as an important source of earning for the rural poor. It has already capable to rise at an annual growth of around 20 per cent during last two decades [2]. By this poultry farm, adjoining it is the opportunity to get economically benefited.

2. SOLAR TECHNOLOGY

Sun is the primary source of energy. The earth receives (1.74 x 1017) watts of power from the sun. The sun radiates 174 trillion kWh of energy to the earth per hour [3].

Bangladesh is blessed with a large amount of sunshine all the year with an average sun power of 500W/m^2/day. There are varieties of technologies that have been developed to take advantage of solar energy. Names of the technologies are: Concentrating solar power (CSP), Solar Photovoltaic (PV), Solar Thermal, Solar fuels. Among them, Solar Photovoltaic is very useful nowadays. The capacity of these components can be determined by estimating the load to be supplied. The basic unit of photovoltaic technology is a photovoltaic or solar cell. A typical crystalline silicon (c-Si) PV cell is composed of a thin wafer consisting of an ultra-thin layer of phosphorus-doped (N-type) silicon on top of a thicker layer (100 - 350 microns) of boron-doped (P-type) silicon. An Electrical field is created where the two materials are in contact, called P-N junction and the direction of Electric Field from n to p side. When sunlight strikes the surface of a PV cell, each photon frees exactly one electron which is directed by the electric field and flows toward the load. Multi, Poly, Mono crystalline silicon solar cell is more widely used due to the lower cost of manufacturing and ease of availability. PV panel manufacturers generally guarantee 90% of initial performance after 10 years and 80% after 25 years [3]. Here, choosing the Mono crystalline solar panel. Solar cells are generally very small each is capable of generating a few watts of electricity and voltage of around (0.6-0.7) volt. About 40 or 60 or 70 or more cells are typically connected in series to make a module.

A. Battery

A rechargeable battery, storage battery or accumulator is a type of electrical battery. It comprises one or more electrochemical cells and is a type of energy accumulator. The lifespan of the battery depends on many parameters related to the way they are operated and to external conditions, in particular, the ambient temperature. This implies that to reach an optimal battery lifespan, one has to install a large enough battery to achieve a suitable depth of discharge.

B. Solar Inverter

A solar inverter is used to convert the DC output of a solar panel into a utility frequency alternating current that can be fed into a grid. Battery backup inverters are special inverters which are designed to draw energy from a battery, manage the battery charge via an on-board charger, and export excess energy to the utility grid. Solar inverters are used for other purposes like maximum power point tracking and anti-islanding protection. An inverters lifespan can extend to more than ten years, but this component is a high-technology product and the replacement of a failing component has to be undertaken by a technician from the supplying company.

C. Charge Controller

A charge controller's job is to regulate the voltage and current coming from and going into the battery. So a charge controller takes the power from somewhere (usually a solar panel installation) and pushes it into the battery at the right levels. It is used to sense when the batteries are fully charged and to stop or decrease the amount of energy flowing from the energy source to the batteries.

3. BIOGAS

Biogas is a clean and efficient fuel. It is a mixture of methane (CH_4), carbon dioxide (CO_2), hydrogen (H_2) and hydrogen sulphide (H_2S). Biogas is generated when bacteria degrade biological material in the absence of oxygen, in a process known as anaerobic digestion. Biogas may be used to generate electricity using a gas-electric generator system. The chief constituent of biogas is methane (65%). The calorific value of biogas is about 6 kWh/m^3, which corresponds to about half a liter of diesel oil. Typical composition of biogas is as below: [4]

Table 1: Typical composition of biogas composition of biogas produced from cattle dung and poultry dung [5] [6] :

Compound	Chemical	%
Methane	CH_4	50-75
Carbon dioxide	CO_2	25-50
Nitrogen	N_2	0-10
Hydrogen	H_2	0-1
Hydrogen Sulphide	H_2S	0-1
Oxygen	O_2	0-3

Table 2: BIOGAS produced from cow dung and poultry dung [5][6].

Electricity From Cow Dung	**Dung from one Cow/Buffalo**	**Cow Dung Required to Produce 1 cubic meter of Bio Gas**	**Electricity Generated from one cubic meter Methane per day**
	10 kg	20 kg	2.14 kwh
Electricity From Poultry Waste	Waste and droppings per Bird/Hen per day	Poultry Litter required to produce 1 cubic meter of Bio Gas	Electricity Generated from one cubic meter Bio Gas per day
	120 gm	5 kg	2.14 kwh

Power generation by using cow dung or poultry dung consists of several process steps, which are shown in figure 1. First, poultry dung is stored in biogas digester (also known as biomass storage) and produced gas in the gasification process is cleaned and supplied it to syngas engine to produce electricity.

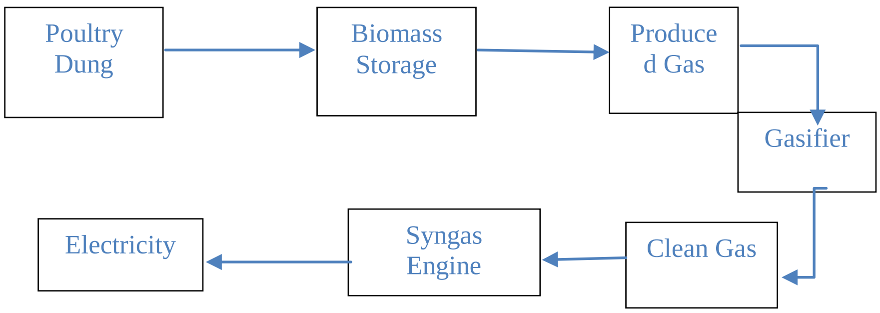

Figure 1: Simple block diagram of electricity generation from the cow dung gasification.

4. PROPOSED HYBRID SYSTEM

The proposed hybrid system is designed for off-grid region for standalone grid extension operation.

The figure 2 shows the block diagram of a typical hybrid power system. The system consists of PV module, inverter, generators, biogas, battery bank, voltage controller and the load.

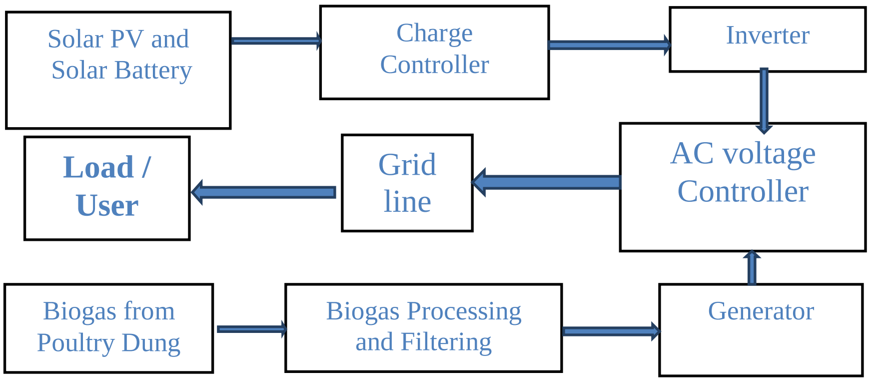

Figure 2: Functional block diagram of a solar and biogas hybrid system.

In this hybrid system, the number of sources of power generations; PV system and biogas system. In the PV system, the solar panel collects light energy from the sun. The capacity of a solar panel is 335 Wp and the number of solar panels used is 367. This solar panel produces electricity and it is transmitted to the inverter and battery.

The battery is an important and costly device for a solar system. For this model, the numbers of selected battery are 114. The battery supplies energy for the inverter. The inverter is a device which converts the DC to AC. It is also known as a converter. The efficiency of the converter is almost 90%. Considering the 25% extra capacity than peak demand. The inverter supplied power for the load by the voltage controller.

In this system, biogas is generated from poultry dung. The generated gas contains a different type of gas like H_2S, CO_2, CO, etc. By processing and filtering pure methane gas is collected. This methane gas is converted into electric current by the biogas generator. The generated energy is transmitted to the gridline through the voltage controller. This controller works for controlling the power of the system that keep remains the same the system voltage. It collected from the two sources and send to the grid line. This grid line contains a specific voltage with small deflection.

The grid line is the transmission and distribution line for a standalone mini-grid system. Loads are connected to the grid line. The load means the users; the users are household users and the other system users are like school, mosque, water pump, street light, shops, etc.

5. LOAD CALCULATION AND PROPOSED AREA

The typical load curve for a rural village is generally composed of a prominent peak in the evening corresponding to lighting use a morning/midday peak and a base load. The base load is generally present in the morning and some cases extend to night hours. In many cases, the peak load is two to five times higher than the highest power level of the base load. The energy demand in rural areas during night hours is quite limited (or non-existent in small villages) and hence the load level during the night is generally very low compared to the evening and morning peaks.

6. PLANT AREA AND LOAD CALCULATION (CASE STUDY)

Area: Char Alimabad, kayaria (union), kalkini (upazilla), Madaripur, Dhaka.

Population: Number of person = 2450   and Number of Family= 490

Types of User: For the calculation of load in this area, here taking the 10 slots. Among them, 4 slots are household user and the other slots are uses for different loads.

Table 3: Plant area load calculation.

Number of slots	Slot name	Number of Users
1	very poor	172 families (35% families)
2	poor	147 families (30% families)
3	solvent	123 families (25% families)
4	very solvent	49 families (10% families)
5	primary school	1
6	mosque	1
7	Shops	5
8	street light	10
9	Water pump	2
10	satellite dish	1

Power Needed for the Area: Per year, almost 50% power supply is done from solar plant and 50% power supplied from the biogas plant.

Total day load =345 kW-hour (per day**)** and Total night load= 525 kW-hour (per day).

Overall Cost and Per Unit Cost: Overall cost includes the solar panel, electronic components, battery, generator, biogas dome, land development cost, transportation cost, power distribution network and other fixed costs. For the hybrid system, the total cost per unit kWh of electricity will be 11.84 BDT ($0.148) (1 BDT= $0.0125).

Table 4: Overall Cost for the Hybrid power system.

Type of Cost	Price in Taka (BDT)	Type in Dollar ($)
Total Solar Cost	1, 70, 35,646.4	212945.5
Biogas Plant Cost	21, 75,000	27187.5
Poultry Farm Cost	22, 39,453.2	28776
Estimated project cost	**2,14,50,099.6**	**268126.245**

7. SOLAR PLANT DESIGN

The various data that's are essential for Solar Power Plant are collected from the project area by field study and calculation of the net power, costs, loss of the per-unit cost (only for PV), etc is taken by PVsyst Software [7]. PVsyst is essential to develop PV technology by optimally and reliably. Pursuing this objective, the PVsyst software is a tool that allows its user to accurately analyze different configurations and to evaluate the results and identify the best possible solution. It deals with grid-connected, stand-alone, pumping and DC-grid (public transportation) PV systems and includes extensive meteo and PV systems components databases, as well as general solar energy tools**.**

Table 5: stand alone solar plant data**.**

Parameter	Value
Total Plant Capacity	123 kWp
Longitude & Latitude	90.3 & 23.0
Total Module area	787 m^2
Constant Power Over the year	122 MWh/year
Net Investment (all taxes included)	276613 US$
Total yearly cost	19753 US$
Energy Cost (Per Unit Cost)	0.166 US$/kWh

The design consideration of Stand Alone Solar PV plant is given below by the PVsyst software:

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Stand Alone System: Main results

Project : **Stand alone Off grid project at Char Alimabad**

Simulation variant : **New simulation variant**

Main system parameters	System type	**Stand alone**			
PV Field Orientation	tilt	23°	azimuth	0°	
PV Array	Nb. of modules	367	Pnom total	**123 kWp**	
Battery	Model	S2-3560 AGM	Technology	sealed, AGM	
battery Pack	Nb. of units	126	Voltage / Capacity	**36 V / 21000 Ah**	
User's needs	Daily household consumers	Constant over the year	global	122 MWh/year	

Main simulation results				
System Production	**Available Energy**	**143.1 MWh/year**	Specific prod.	1164 kWh/kWp/year
	Used Energy	121.4 MWh/year	Excess (unused)	6.0 MWh/year
	Performance Ratio PR	45.7 %	Solar Fraction SF	99.2 %
Loss of Load	Time Fraction	0.8 %	Missing Energy	0.9 MWh/year
Investment	Global incl. taxes	276613 US$	Specific	2.25 US$/Wp
Yearly cost	Annuities (Loan 5.0%, 25 years)	19626 US$/yr	Running Costs	126 US$/yr
Energy cost		**0.16 US$/kWh**		

Figure 3: PVsyst stand-alone off grid project result**.**

8. DESIGNING AND MODELLING OF HYBRID SYSTEM WITH HOMER

The Hybrid Optimization Model for Electric Renewable (HOMER), which is copyrighted by Midwest Research Institute (MRI) is a computer model developed by the U.S. National Renewable Energy Laboratory (NREL) to assist the design of power systems and facilitate the comparison of power generation technologies across a wide range of applications. HOMER is used to model a power system physical behavior and its life-cycle cost, which is the total cost of installing and operating the system over its lifetime. HOMER allows the modeler to compare many different design options based on their technical and economic merits.

It also assists in understanding and quantifying the effects of uncertainty or changes in the inputs. HOMER performs three principal tasks: simulation, optimization, and sensitivity analysis based on the raw input data given by the user. In the simulation process, the performance of a particular power system configuration for each hour of the year is modeled to determine its technical feasibility and life-cycle cost. In the optimization process, many different system configurations are simulated in search of the one that satisfies the technical constraints at the lowest life-cycle cost.

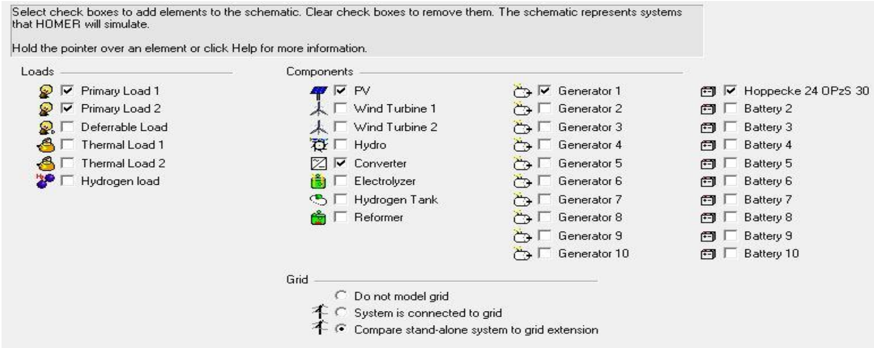

Figure 4: Add/remove equipment to consider.

At the beginning of the program the "Equipment to Consider" window appears where adding equipment to as a part of the system designed. The hybrid system consists of electric loads, solar resources, biomass resources and system components such as PV, generator, battery, and converter as shown in figure 4.

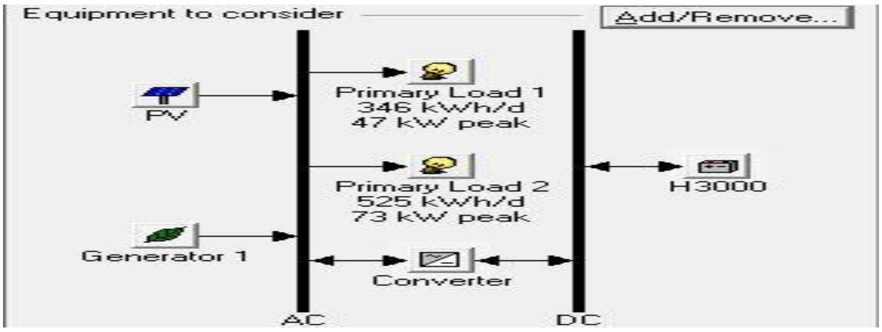

Figure 5: Hybrid power system configuration with stand-alone system to grid extinction.

In figure 5, the primary load is 1 for day load and primary load 2 is for night load. In this analysis, we have designed the hybrid renewable system with a biogas generator. Here, solar Photovoltaic panel is used as renewable resource and biogas is produced from biomass sources.

Bangladesh has good prospects of solar photovoltaic generation. The average insulation in Bangladesh is 5 kWh/m^2/day. The average solar insulation is 5.58 kwh/m^2/day for kalkini, Madaripur, Bangladesh as shown in figure 6. Homer uses the solar resources input to calculate the PV array power. For this location, the time zone is (GMT+6.00) but in Homer, Bangladesh is missing so we chose the time zone (GMT+6.00) Novosibirsk, Bhutan, Sri Lanka.

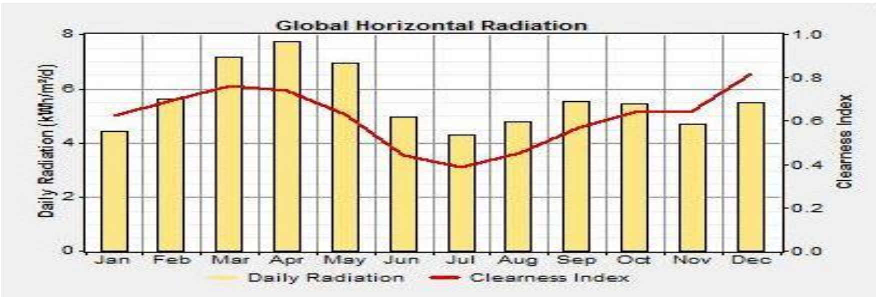

Figure 6: Monthly solar radiation thought out the year.

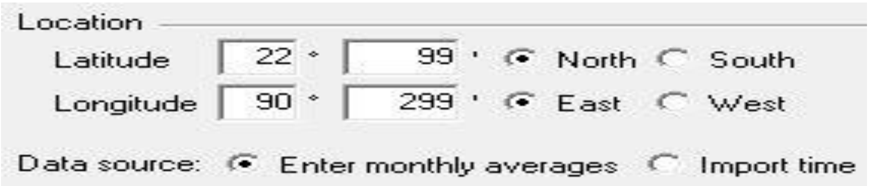

Figure 7: Solar location data profile.

Biomass is the oldest source of energy known to humans. The term biomass encloses a large variety of materials, including wood from various resources, agricultural residues, and animal and human waste. Bangladesh is an agree-based country and main sources of biomass are agricultural residues. And in villages, mainly in near Barisal, poultry and cow is still exploited for plowing land and farming. So, animal dung is available in resourceful amount. We need to focus to use this biomass energy for rural electrification. And that will be helpful for our financial headway. In figure 8 shows that the available poultry dung need is 1.25 ton/day.

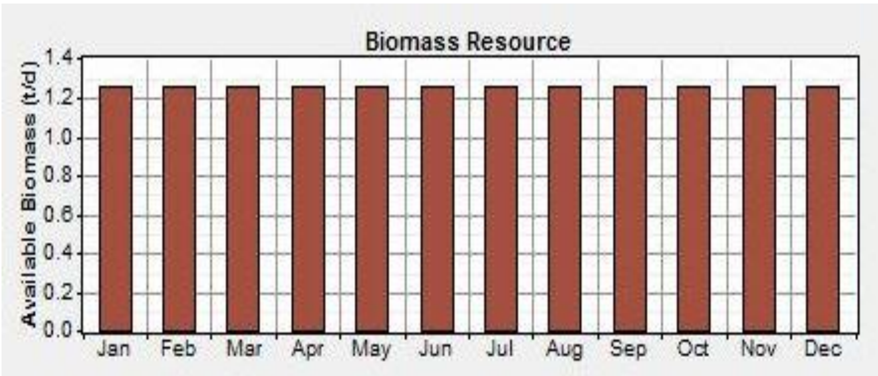

Figure 8: Biomass resource available the whole year.

9. RESULTS

A. *Electrical Simulation Result*

By observing figure 9, the load met by PV array has 208843 kWh/yr and Biogas is 204674 kWh/yr. In other words, the percentage shared by PV array is 51% and the biogas generator is 49%. The care should be taken that the reliance on PV array and Biogas is almost identical. The most important factor of the plant is that the capacity shortage of the system is 0% i.e. it is obtainable the entire year.

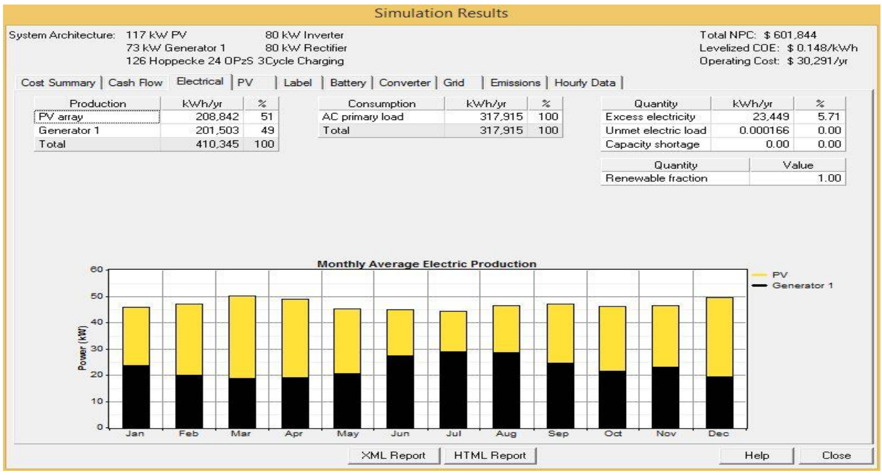

Figure 9: Simulation result electrical.

Initially, the PV array cost is high but the operation and maintenance cost of PV array for the life span of 25 years will be almost nil except for the change of batteries for every 6 years. In the case of biogas generator, the initial cost of the generator is less, but the operation and maintenance cost is 16.3375 BDT/kWh. The diesel Requirement per kWh is 0.25 liter [8].

B. *Carbon Emission*

A Carbon Credit is a generic term for any tradable certificate or permits representing the right to emit one tone of carbon dioxide or the mass of another greenhouse gas with a carbon dioxide equivalent (tCO_2e) equivalent to one tone of carbon dioxide[9][10]. Certified Emission Reductions (CERs) are a type of emissions unit (or carbon credits) issued by the Clean Development Mechanism (CDM) Executive Board for emission reductions achieved by CDM projects and verified by a DOE under the rules of the Kyoto Protocol [9].

Pollutant	Emissions (kg/yr)
Carbon dioxide	41.5
Carbon monoxide	1.56
Unburned hydrocarbons	0.173
Particulate matter	0.118
Sulfur dioxide	0
Nitrogen oxides	13.9

Figure 10: Emission of the plant.

In figure 7, the emission of carbon dioxide per year 41.5 kg and the total emission the whole year is 57.251 kg. But, from Coal, the CO_2 emission rate is 1400 gram/KWh, form Oil the CO_2 emission rate is 1150gram/KWh and from Natural gas, the CO_2 emission rate is 600gram/KWh. So, from the hybrid system, the emission is saved from natural kg as, oil, Coal plant respectively 248 tons/year, 475 tons/year, 578 tons/year. So, the hybrid system is more environments helpful.

C. *Overall Result*

In figure 11, the optimization result showed how cost and power generation differs for the system with the solar system and without solar generation. Here, the cost differs in those two cases. In this system, we have calculated the 117kW solar capacity but in PVsyst the generation capacity is 123kW. This is the extra generation capacity. It ensures system reliability. The excess electricity is near 5.71%. So, the system is also capable to supply energy in whole time without any load-shedding.

Double click on a system below for optimization results.

	PV (kW)	Label (kW)	H3000	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Biomass (t)	Label (hrs)	Batt. Lf. (yr)
	117	73	126	80	$ 214,621	30,291	$ 601,844	0.148	1.00	236	2,929	6.6
		73	126	80	$ 65,493	47,682	$ 675,024	0.166	1.00	453	5,293	8.1

Figure 11: Optimization result of the Hybrid System

The overall net cost of electricity only for biogas system is \$0.166 and the cost of electricity for Hybrid Power System (both solar and biogas system) is \$0.148 or 11.84 BDT (1 BDT= \$0.0125).

10. CONCLUSIONS

There are many remote villages in Bangladesh which are far away from the main grid so those are still un-electrified. This paper discussed the renewable hybrid system with solar PV and biomass which helps in overcoming all these of-grid problems in a cost-effective way. In this paper, the load requirement of this village is calculated and in order to satisfy this load, the energy requirement is predicted. As we know that the reserve natural gas in Bangladesh is diminishing quickly, The Government should take proper steps to promote renewable energy activities. Both sunlight and the bio-gas are available in Bangladesh abundantly. According to the simulation results the projected hybrid system is economically feasible and the estimated cost per unit kWh of electricity is 11.84 BDT in this proposed system. So, the proposed system can be an effective solution to the energy crisis in the un-electrified rural area of Bangladesh.

REFERENCES

[1] Ahmed M R, Hazra S R, Rahman M M, Bhuiyan R J, (2015) Solar-Biomass Hybrid Systam: Proposal For Rural Electrification in Bangladesh, Electrical and Electronics Engineering: An International Journal (ELELIJ) 4(1), 1-11.

[2] Ali M M, Hossain M M, (2012), Problems and Prospects of Poultry Industry in Bangladesh: An Analysis , https://bea-bd.org/site/images/pdf/15.pdf.

[3] Gupta Sonam, (2016) A review study on HOMER based economic analysis of solar –biomass hybrid generation, International Journal of Scientific and Technical Advancements, 2(4), pp. 227-230.

[4] www.sswm.info , accessed on January, (2017) *http://www.sswm.info /content/biogas-electricity-small-scale.*

[5] *www.forestry.gov.uk*, accessed on January, (2017).

[6] *www.perfectgasgenerators.in*, accessed on January, (2017).

[7] PVsyst Software Online available at www.pvsyst.com accessed on February 9, (2017), and Homer software available in online, at www.homerenergy.com.

[8] Homer energy/marginal generator cost, accessed on February (2017) (Last Updated: Jul 20, 2016 04:15PM MDT).

[9] N.H.Shiblee, Dhaka, Bangladesh, December (2013) "Solar energy in urban Bangladesh: An untapped Potential", *ChE Thoughts, Volume-04, Issue- 01.*

[10] For carbon reduction Potential, *http://www.iea.org/co2highlights /co2highlights.pdf*, accessed on December, (2016).