Techno-Economic Evaluation of Renewable Energy Based Small Hybrid Model

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***Abstract*— The living standard and prosperity of a nation vary directly with increase in use of power. As technology is advancing, the consumption of power is steadily rising. Sufficient and reliable source of electricity is a major prerequisite for a sustained and successful economic development and poverty reduction. In Bangladesh, the crisis of power is a major problem. Gradually the fissure between demand and production is escalating. Moreover, most of the power plants are gas based which will be phased out in near future. Misuse, system loss and corruption in power sector are the main issue regarding this crisis. Therefore, electricity shortage is an acute crisis in Bangladesh. Most of the rural area is not connected with the national grid. So, agricultural and industrial production is greatly hampering in rural areas. Electrification in rural and isolated area is the crying need of Bangladesh. It is very essential to provide electricity for them. The challenge of energy accessibility needs to be understood in terms of availability as well as affordability for individuals and communities. Bangladesh has good prospects of renewable power generation. Proper utilization of renewable energy is the up most choice for solving the power crisis in Bangladesh because it requires low cost and less risk. There are at most thirty small and isolated islands in Bangladesh. Char Nizam (Latitude: N 22.68, Longitude: E 90.65) is one of the island with 1800 inhabitants in Bhola district of Barisal division in Bangladesh. In this research he have tried to design a feasible system for that area and considered a hybrid system that contains diesel-PV-biogas system. Hybrid Optimization Model for Electric Renewable (HOMER) software is used to find out the final optimization and sensitive analysis of hybrid system. This system satisfies the load demand and reduces CO2 emission which will help to generate green energy.**

Keywords— Biomass, Solar PV, Power generation, Hybrid System, HOME, and Cost of Energy

I. INTRODUCTION

In the face of tremendous social, economic and political pressure to solve power crisis in Bangladesh, it has become to critically important to look for energy solutions beyond the conventional sources like domestic natural gas, coals, hydroelectricity and imported fuels. In the last decade of the nineteenth century construction of new power plants was the main challenge. Gas supply crisis did not exist at that time. But in last 15 years gas supply scenario reached a stage that gas crisis has become alarming even after suspending new gas connections for half of the period. The pressure started diminishing and reserve started depleting. Though planning has been made to expedite gas exploration yet actually very little could be achieved. Consequently, the present government as contingency measure could increase power generation through imported liquid fuel based power plants. The rapid depletion of natural oil and gas reserves due to excessive consumption is leading to serve global competition and political tensions among the powerful nations to control the remaining fossil fuel reserves. Unprecedented increase of energy consumption by rapidly developing nations like China, India and Brazil adding tremendous pressure on the demand and supply of petroleum. Extreme competition and volatility of fuel price in the global energy market is continuously hampering small players like Bangladesh. Discounted petroleum supply from friendly countries, reliance on domestic natural gas, and subsidized fuel supply to the public and private sectors are no longer politically and economically viable options for us. Global warming and the subsequent increase of the sea level and natural calamities due to excessive carbon emission from fossil fuels are causing severe environmental and ecological havoc for low-lying countries like us. The most feasible way out of this multi-dimensional crisis is to increase our reliance on renewable energy like solar power, biogas power. To design a feasible system, we have taken into account a journal article [1].

II. ENERGY SCENARIO

Energy has played the key role in bringing the civilization to reach at this stage and has become one of the basic needs like food, shelter, education and medication. Modern state craft and the economy can't go forward without the support of energy. In spite of financial constraints and gas supply shortages, the government designed a strategy to overcome the crisis and at the same time meet the ever increasing demand for power. It launched immediate, short, medium and long term programs to increase power supply through introduction of fuel mix (gas, coal, liquid fuel, nuclear energy and renewable), demand side management, energy efficiency and conservation. After assessing the latest demand, the government has revised its targets for increasing power generation. The year-wise details of the additional power generation programs, both in public and private, are listed Table-1[2].

TABLE I. PLANT COMMISSIONED DURING 2009-2013 IN MW

Year	2009	2010	2011	2012	2013	Total
Public		255	800	607	587	2249
Private	356	520	963	344	76	2259
Import					500	500
Total	356	775	1763	951	1163	5008

Government has prepared the Power System Master Plan 2010 (PSMP 2010). According to the PSMP 2010 the estimated demand for power would be 19,000 MW in 2021 and 34,000 MW in 2030. 63 plants with a capacity of about 4,915 MW have been commissioned, 33 plants with a capacity of 6,986 MW are under construction. 22 projects with a capacity of about 5,272 MW are under tendering process. Highest generation so far was 7418 MW recorded on July 18, 2014 and it is increasing gradually[3].To achieve this target From January to June 2014: Total 407 MW of capacity Power Plants are commissioned [2]. Commissioned plant in 2014 and set up plan upto 2018 data are presented in Table-2.

TABLE II. YEAR WISE GENERATION ADDITION PROGRAM 2014 TO 2018 IN MW

Year	2014	2015	2016	2017	2018	Total
Public	225	1293	1475	2131	1320	6444
Private	1024	1218	1014	640	630	4526
Total	1249	2511	2489	2771	1950	10970

With new generation addition, the total generation capacity would be 17,000 MW by 2016. By that time some power plants will be derated, contracts of some rental power plants will be over and the dependable capacity would be around 13,000 MW. To meet the vision Government of the Peoples Republic of Bangladesh has set up the master plan to coal and nuclear based power station. Coal will be the dominating fuel in the future generation. The government promised to set up a total of eight coal-fired power plants under their and private. Of them, two big coal fire plants with capacity of 1320 MW each will be set up, one in Khulna and other in Chittagong. The Khulna plant will be set up in joint venture with BPDB of Bangladesh and National Thermal Power Corporation Limited (NTPC) of India. Besides, other coal fired plants will be set up in different locations of Khulna, Chittagong, Matarbari and Moheshkhali [4]. In 2007 the Bangladesh Atomic Energy Commission (BAEC) proposed two 500 MWe nuclear reactors for Rooppur by 2015. An agreement with Rosatom was signed in February 2011 for two 1000 MWe-class reactors to be built at Rooppur for the Bangladesh Atomic Energy Commission (BAEC). Another intergovernmental agreement was signed in November 2011 for the project to be built by ASE-Atomstoryexport (which in mid-2012 was merged with Nizhny Novgorod Atomenergoproekt, NIAEP). Site works started in October 2013, and construction of the first unit is expected from 2015, with operation soon after 2020. And, the proposed second unit construction time is expected from 2020, with operation soon after 2025 [5].

III. AVAILABLE RENEWABLE ENERGY SOURCES

Renewable energy helps in reducing poverty, aid in energy shortage and environmental degradation such as desertification, biodiversity depletion and climate change. Over-exploitation of biomass in meeting the need of energy in the rural areas is causing environmental degradation. Renewable energy helps to solve those problems if it is widely used in the rural Bangladesh where people primarily depend on biomass energy. Power generation in Bangladesh was almost mono-fuel dependent, i.e. indigenous natural gas considering its apparent huge availability. About 89% of power previously comes from natural gas and the rest is from liquid fuel, coal and hydropower. The present share of renewable energy was only 2.5% [6]. Generation fuel mix is represented in Fig-1.

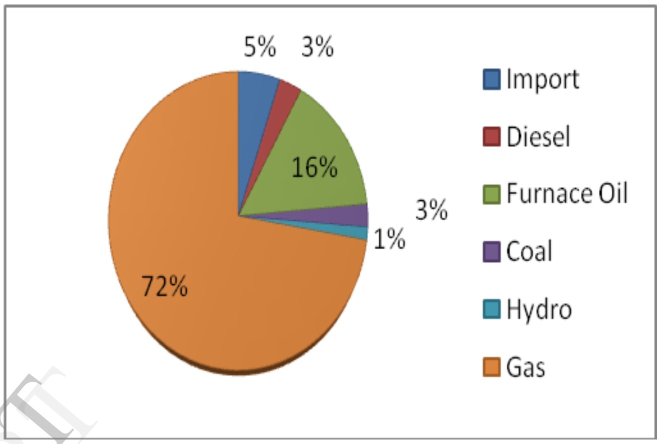


Fig. 1, Generation fuel mix in 2013-14

Bangladesh is endowed with plentiful supply of renewable sources of energy. Out of various renewable sources solar, biomass, peat, and hydropower can be effectively used in Bangladesh. In our country renewable energy such as biomass, solar power and wind power are being used since time immemorial; especially in areas which are outside gas coverage, usage of biomass for cooking and solar power and wind for drying of different grains as well as clothes are known to all. However, we are still lagging far behind in the scientific use of such energy. But currently situation is changing; in rural areas where grid connection is out of range, people are using solar home system. In some cases small scale bio gas power generation is established for private use, but large scale is not yet established. At present, the national capacity of renewable energy based power, excepting hydro-power, is approx. 50 MW [7] as shown in Table-3.

TABLE III. RENEWABLE ENERGY SCENARIO OF BANGLADESH

Category	**Generation (MW)**
Solar Home System	45
Other Solar PV Applications	1
Wind Energy	2
Biomass Based Electricity	<1
Biogas Based Electricity	1
Total	50

A. *Solar Energy & Present Status*

Only 49 percent of Bangladesh's population has access to electricity from the national grid. For the rest of the areas not connected to the grid, life comes to almost a standstill after sun-set. But, Solar Energy is one of the great sources for work out power crisis in Bangladesh. Bangladesh is situated between 20.30 and 26.38 degrees north latitude and 88.04 and 92.44 degrees east which is an ideal location for solar energy utilization. The Rural Electrification and Renewable Energy Development (RERED) Project, supported by The World Bank, is promoting renewable energy options to provide electricity to these remote areas. Implemented by Infrastructure Development Company Limited (IDCOL), the project has made solar home systems available to households and village markets. IDCOL started the SHS program in 2003 to ensure access to clean electricity for the energy starved off-grid rural areas of Bangladesh. The program supplements the Government's vision of ensuring 'Access to Electricity for All' by 2021.About 3 million SHSs have already been installed under the program in the off-grid rural areas of Bangladesh till April 2014. As a result, 13 million beneficiaries are getting solar electricity which is around 9% of the total population of Bangladesh. IDCOL has a target to finance 6 million SHS by 2017, with an estimated generation capacity of 220 MW of electricity [8]. Grameen Shakti (GS), a pioneer in promoting 'green energy', started out in 1996 as a lone player and today is the largest distributor of Solar home service(SHS)- over 700,000 units out of a total of about 1.1 million in the country – contributing to the daily generation of about 60 Mw of solar power. In 2008, the government set a target of five per cent of total energy from renewable sources and 10 per cent by 2020. Government incentives for companies setting up solar plants include a 15-year tax holiday and exemption from paying import duty on equipment. Foreign investors get exemptions on royalties, technical knowhow, technical assistance fees and facilities for their repatriation of profits. Foreigners working in solar energy projects need pay no income tax for the first three years of their stay in this country [9].

B. Hydro-electricity

Bangladesh is a plain delta with having three of the world's major rivers the Ganges, the Brahmaputra and the Meghna flowing through it. Out of all the rivers about 57 rivers are transboundary originating from India and Myanmar [10]. During monsoon the flow rate of most of the rivers is high but it reduces substantially during winter. Hence the scope of hydropower generation is very limited in Bangladesh except in some hilly regions in the northeast and southeast parts of the country. The Karnafuly Hydro Power Station is the only hydropower plant in the country (located at kaptai, about 50 km from the port city of Chittagong), having a capacity of 230 MW by 5 units. It is operated by BPDB (Bangladesh Power Development Board). BPDB is considering the increase of production up to 330MW. Two sites have been chosen for another two Hydro power plants at the Sangu and Matamuhuri rivers, one named The Sangu project (140MW) and the other The Matamuhuri Project (75MW). BPDB has designed a 20kW micro-hydro power plant with the help of RETScreen, developed by CANMET Energy Diversification Research Laboratory of Canada (CEDRL) at Barkal (a sub-district in the Chittagong Hill tracts) waterfall [11].

C. Wind Energy Standing

Bangladesh has seven hundred kilometer coastal line, analysis of upper air data by Center for Wind Energy Technology (CWET) India show that wind energy resource of Bangladesh is not good enough for grid connected wind parks [11]. At present, several wind resource assessment program (WERM, SWERA, WRAP of BPDB) is ongoing in the country. From the previous studies it can be inferred that the small wind turbines can be installed in the coastal regions of the country [12]. The wind speed in some regions of Bangladesh is satisfactory for operation pumps and for generation of electricity. It was found that the wind speed in Chittagong is 2.57 m/sec or more for 4000 hours a year. At this available speed a wind plant can be operated both for generation of electricity and for driving pumps. Recently, several small wind generators have been installed by BRAC (11 small wind turbines in various coastal sites) and Grameen Shakti (two wind generators of 300 W and 1 KW at its Chakoria Shrimp Farm).

D. Biogas

With increasing industrialization and urbanization the demand for natural gas will continue to grow. It is said that the country would require about 13.6tcf of gas upto 2020, about 26.7tcf upto 2030, and about 62tcf upto 2050. With natural gas as the single significant commercial energy resource available in the country, it appears that the present reserve of 11.6tcf will not run beyond 2020. The above situation leaves the rural population to rely on the traditional biomass sources for household supply of energy. Bangladesh is an agricultural country so biomass is available in huge amount. Cattle dung, agricultural residue, poultry dropping, water hyacinth, rice husk etc. used for biomass power generation are available in Bangladesh [13].The

E. Tidal Power

Ocean covers 75 per cent of the earth and has enormous potentiality of generating electricity. It has been estimated that if less than one per cent of total capacity of tidal electricity is generated, it will cover five times of total global requirements. Tidal power plant is a reliable energy source to replace the burning of fossil fuels. In addition, it is a renewable source of energy that produces no greenhouse gases or any type of waste. Tidal stream generator has little environmental impact and can be built offshore [15]. The coastal of Bangladesh has a tidal rise and fall of between 2 to 5 meters [16]. Among these coastal areas, with 5 meter tides experienced, Sandwip has the best prospect to generate tidal energy [16]. Moreover, according to Reference [13], Bangladesh can generate tidal power from these coastal tidal resources by applying Low head tidal movements and Medium head tidal movements, low head tidal movements which uses tides of height within 2m to 5m can be used in areas like Khulna, Barisal, Bagerhat, Satkhira and Cox's Bazar regions and the height tidal movements which use more than 5m of tides can be mainly used in Sandwip. So we can say that with suitable tidal height available, this can be a great source of energy for Bangladesh.

IV. HYBRID ELECTRIC SYSTEM

According to many renewable energy experts, a small "hybrid" electric system that combines home wind electric and home solar electric (photovoltaic or PV) technologies offers several advantages over either single system. Because the peak operating times for wind and solar systems occur at different times of the day and year, hybrid systems are more likely to produce power when you need it. Many hybrid systems are stand-alone systems, which operate "off-grid" -- not connected to an electricity distribution system. For the times when neither the wind nor the solar system are producing, most hybrid systems provide power through batteries and/or an engine generator powered by conventional fuels, such as diesel. If the batteries run low, the engine generator can provide power and recharge the batteries. Both systems are presented in Fig -2.

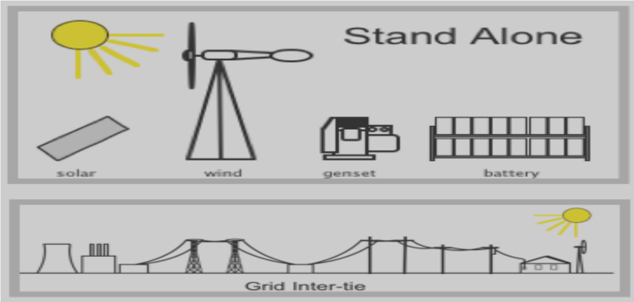


Fig. 2, Stand alone and grid connected hybrid system

The stand-alone hybrid supplies electricity completely autonomously and always includes a battery. The grid inter-tie hybrid is connected to the central-station network which performs a similar function as the battery - to accommodate variations in both the supply and demand. In some circumstances a battery and the grid can both be included for mutual benefit. The stand alone is best suited to rural and remote homes and businesses and the grid inter-tie would be best suited to homes and businesses in large and small cities. The grid inter-tie system could transition to a standalone system in the future with the addition of a battery.

V. Proposed Hybrid Electric System

A hybrid energy system generally consists of a primary energy sources working in parallel with standby secondary energy storage units. HOMER (Hybrid Optimization Model for Electric Renewable) has been used to optimize the best energy efficient system for Char (Island) Nizam, Bhola, Bangladesh considering different load and biogas-diesel-PV combination. Fig. 3 reflects the propose scheme as implemented in HOMER simulation tool. HOMER simulates the operation of a system by making energy balance calculations for each of the8760 hours in a year.

Char Nizam is small Island of Monpura Thana at Bhola district in Bangladesh. There are 1800 inhabitants primarily living on fishing and cultivation [17]. The total area of this Island is 3.75 sq. kilometer and the area belongs to 275 households. The human habitation area is 0.84 sq km, non-distributed khas land – 0.24 sq km, cultivable land is 0.72 sq km and non-cultivable land is 0.12, forestry 4.80 sq km. Forest department holds strict control over emerging land. There also 3 schools and average literacy rate is 24%.

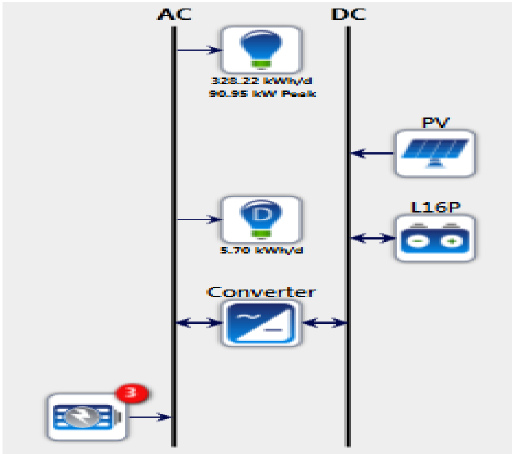


Fig. 3, Stand alone and grid connected hybrid system

A. Electric Load

A community of 1800 people, 275households, 20 shops, three schools and one health-post has been considered for estimation of electric load. Three energy efficient lamps (CFL, 20W each) for each family are considered. A fan (ceiling fan, 100W) for 200 households and two fans for solvent families, one television (70W each) is considered for 150 households. Five lights (20W each) and two fans (40W each) are considered for health post and twenty four lights (20W each) and twenty fans (100W each) are considered for school. For street lightning, 50 street lights (15W each) are considered. For each shops, two energy saving lamp and a fan is considered. Seventy five refrigerators for solvent family and four refrigerators (1.2kWh/day each) for shops and one for health post also considered. Fan load is considered for summer except winter season from evening to next morning for household consumers. For deferrable load, seven water pumps, one for school and health-post and the remainder for household use are assumed. Each water pump has a 150 W power rating with a pumping capacity of 10 liter/min. The pumps supply 20,000 liter per day for 100 families (primarily considered for 100 households instead of 275 households) as 200 litter per family, and 2000 liter per day for school and clinic. These scaled up the annual peak load to 90.95 kW and average primary load 328.22kWh/day represented in Fig. 4 and scaled annual average of deferrable load is 5.70kWh/day. Fig. 5 represents the seasonal load profile.

Metric	Baseline	Scaled
Average (kWh/d)	328.22	328.22
Average (kW)	13.68	13.68
Peak (kW)	90.95	90.95
Load Factor	.15	.15

Load Type: (•) AC ( ) DC

Fig. 4, Overview of primary load

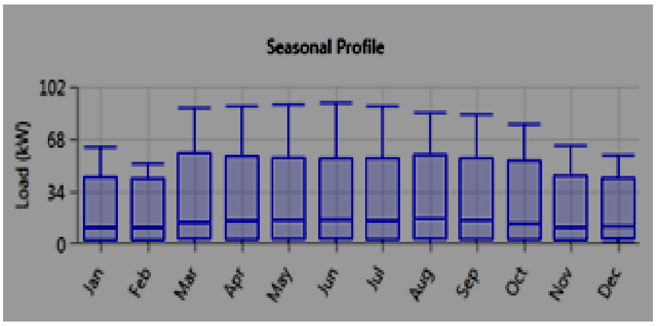


Fig. 5, Monthly load profile

B. *Renewable Resources*

B.1 Solar Resources

Bangladesh has good prospects of solar photovoltaic generation. The average insolation in Bangladesh is 5kWh/m2/day. In this analysis, monthly average global radiation data has been taken from NASA (National Aeronautics and Space Administration) to estimate the generation of solar system. Solar data at Bhola (Latitude: N 22.68, Longitude: E 90.65) in Bangladesh is presented graphically by using HOMER software in Fig. 6. Homer use the solar resources input to calculate the PV array power. And, the synthesized data is obtained by putting the longitudinal and latitudinal value in HOMER software.

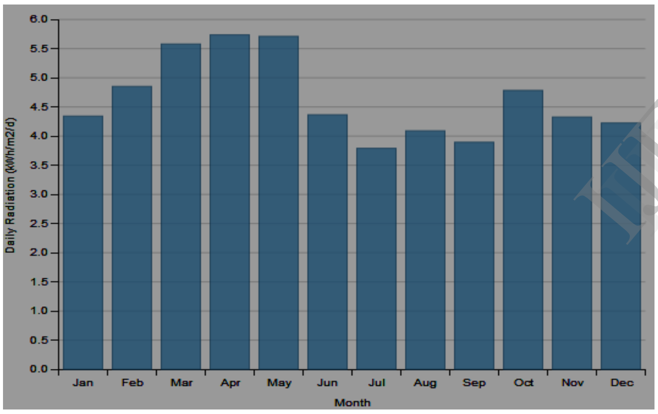


Fig. 6, Solar Radiation data throughout the year

B.2 Biomass Resources

Biomass is the oldest source of energy known to humans. The term biomass encompasses 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 Barisal, cow is still utilized for plowing land and farming. So, animal dung is available in resourceful amount.

Biomass contains stored energy. That's because plants absorb energy from the sun through the process of photosynthesis. When biomass is burned, this stored energy is released as heat.

Many different kinds of biomass, such as wood chips, corn, and some types of garbage, are used to produce electricity. Some types of biomass can be converted into liquid fuels called biofuels that can power cars, trucks, and tractors. Leftover food products like vegetable oils and animal fats can create biodiesel, while corn, sugarcane, and other plants can be fermented to produce ethanol.

More than 25000 bio gas plants are already set up in Bangladesh and they are mainly family sized and used only for cooking purposes. But, we need to focus to use this biomass energy for rural electrification. And that will be helpful for our economic advancement.

B.2.1 Energy Generation by Using Cow Dung

Several types of gasifier e.g. fixed bed updraft and downdraft gasifier, fluidized bed gasifier and bubbling bed gasifier are available in the existing market with different sets of pros and cons. However, the downdraft gasifier is a comparatively cheap and gasification in this type of gasifier can produce a product gas with very low tar current [18].

All the collected cow dung is fed into an anaerobic digester. The digester is built to hold 21 days of farm waste. Bacteria convert the waste into various products, one of which is methane gas. Gas produced by the bacteria builds up the pressure in the concrete vessel, and a pipe delivers the biogas to a modified natural gas engine.

The biogas fuels the engine, which in turn spins an electric generator to create electricity. Waste heat from the engine is used to keep the digester warm and offsets fuel purchase on the farm.

One cow's waste can produce enough electricity to light two 100-watt light bulbs for 24 hours a day. The energy is fed onto the electrical system for distribution to customers. Cow dung gas is 55-65% methane, 30-35% carbon dioxide, with some hydrogen, nitrogen and other traces. Its heating value is around 600 B.T.U. per cubic foot. Cow dung slurry is composed of 1.8-2.4% nitrogen (N_2), 1.0-1.2% phosphorus (P_2O_5), 0.6-0.8% potassium (K_2O) and 50-75% organic humus.

About one cubic foot of gas may be generated from one pound of cow manure at around 28°C. This is enough gas to cook a day’s meals for 4-6 people in Bangladesh. About 1.7 cubic meters of biogas equals one liter of gasoline. The manure produced by one cow in one year can be converted to methane, which is the equivalent of over 200 liters of gasoline.

Gas engines require about 0.5 m3 of methane per horsepower per hour. Some care must be taken with the lubrication of engines using solely biogas due to the “dry” nature of the fuel and some residual hydrogen sulphide; otherwise these are a simple conversion of a gasoline engine.

Power generation by using cow dung consist of several process steps, which are shown in Fig. 7. First, cow dung is stored in biogas digester and produced gas in gasification process in cleaned and supplied it to syngas engine to produce electricity.

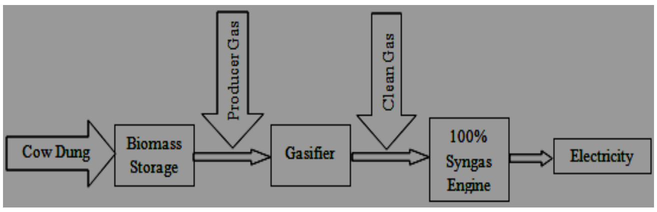


Fig. 7, Electricity Generation by cow dung gasification

B.3 Total Power Calculation

Using the solar radiation available on the tilted surface the hourly energy output of the PV generator can be calculated according to the following equation:

$P=A.x^2+B.x+C$ (in Watts)
Where,
x=solar radiation
P=Power generation

A, B, C are constants, which can be delivered from measured data. By using above formula, solar power generation can be predicted at any solar radiation.

Biogas generator power, $P_{biomass}(W)=$

$$\frac{50\% \text{ of } 100 \text{ kgs animal waste} \times 1000}{2 \text{ kgs animal} \frac{\text{waste}}{\text{kWh}} \times 5 \text{ hours operation a day/year}}$$

Now, The total power, $P_T(W) = P_{solar} + P_{diesel} + P_{biogas}$

C. System Components

In this analysis, the major components are PV panels, biogas disaster, bio fuel generators, diesel generator, batteries, and converters. For economic analysis, the number of units to be used, capital cost, replacement and O&M costs and operating hours to be defined in HOMER in order to simulate the system.

C.1 Solar PV

Sun rays are available with prosperity in Bhola, Bangladesh. Lots of solar home system has been installed. But, there is no set up yet established for off grid networking. In this research, solar photovoltaic is used with biogas and diesel generator for the establishment of a hybrid system. Solar system cost consists of cost with cables and charge controllers. It's known to me by analyzing present market; cost of PV panel with set up cost Tk. 75000 for 1 kW generation. Various costs are represented in Table -4 and cost is considered in BDT. Life time has been taken 25 years and 30kW PV modules are considered.

TABLE IV. PV COST ASSUMPTION AND TECHNICAL PARAMETERS

Parameter	Unit	Value
Capital Cost	BDT/W	75
Replacement Cost	BDT/W	66
Operating & Maintenance Cost	BDT/Yr	100
Lifetime	Years	25
Derating factor	Percent	80
Slope	Degree	22.566
Tracking System	No tracking System	0.05

*1 BDT (Bangladeshi taka) =0.013 $ (USD)

C.2 Biogas Generator

In this research, two set of 10 kW biomass generators are considered to find out the most cost effective system. The main reason of using to fulfill the energy demand in peak hour both for winter and summer season and also meet the terms of backup requirements. As biomass resource is available in prosperity, fuel cost is considered zero. The main cost is considered for biogas generation procedure such biogas disaster, gas cleaning system and biogas power generator. To produce 1KW electricity from biomass, $1200 is required including plant cost and generator cost, i.e. about BDT 9600000 (Considering $1=80 BDT) is required in this purpose [19]. Digester lifetime is considered for 8 years and fuel curve slope and intercept are taken as 0.08 and 1 respectively [20]. Different costs and parameters are given in Table -5.

TABLE V. COST AND PARAMETER OF BIOGAS GENERATOR

Parameter	Unit	Value
Capital Cost	BDT/kW	96000
Replacement Cost	BDT/kW	67200
Operating & Maintenance Cost	BDT/Yr	50
Lifetime	Hours	35000
Load factor	Percent	15

C.3 Diesel Generator

To meet the peak load, diesel generator is used with renewable resources. We mainly scheduled the diesel generator for the time 6 PM to 12 midnight. In HOMER 10 kW diesel generators is considered with 20 kW biogas generators to meet the peak load demand. Diesel generator price is considered by analyzing present market price. Fuel curve slope and intercept are 0.05 and 0.33 respectively [20]. Fuel price is considered here Tk. 68 that's the present market price in Bangladesh.

TABLE VI. COST AND PARAMETER OF DIESEL GENERATOR

Parameter	Unit	Value
Capital Cost	BDT/kW	10000
Replacement Cost	BDT/kW	8000
Operating & Maintenance Cost	BDT/hr	30
Operating Lifetime	Hours	30000
Minimum load ratio	Percent	10
Fuel Curve Intercept	1/h/kWrated	0.05
Fuel Curve Slope	1/h/kWrated	0.33
Fuel Price	Tk	68

C.4Battery

Batteries are used to store the solar photovoltaic output. In rural area like our proposed are, where most of the power is used after day time. So, main target of our system is to store energy at day time and discharge the stored energy after evening. So, batteries are used following through charge controller. Also, a dump load is used for the purpose of removing excess charge and preventing system damage. In this system, the Trojan L16P storage batteries are utilized [21]. In this analysis 150 batteries are considered and the specifications and different costs of batteries are shown in Table -7.

TABLE VII. BATTERY COST ASSUMPTION AND TECHNICAL PARAMETERS

Parameter	Unit	Value
Nominal Voltage	volt	6
Nominal Capacity	Ah(kWh)	360(2.16)
Maximum Charge Current	A	18
Maximum Discharge Current	A	300
Round-trip efficiency	Percent	86
Capital Cost	BDT/kWh	7000
Replacement cost	BDT/kWh	6000
Operating & maintenance Charge	BDT/kWh/yr	50

C.5 Converter

Converter converts the dc power to ac. As, most of the home appliances are operated in ac, dc generation from the PV array is converted to ac following through a controller. In this .proposed system, 70 kW converters are considered for optimum solution. The details of converter cost assumption and different parameters are given in Table -8.

TABLE VIII. CONVERTER COST ASSUMPTION AND TECHNICAL PARAMETERS

Parameter	Unit	Value
Capital Cost	BDT/kW	15000
Replacement Cost	BDT/kW	10000
Life time	Years	15
Efficiency	Percent	90
Rectifier Capacity	Percent	95
Rectifier Efficiency	Percent	85

C.6 System Control Parameters

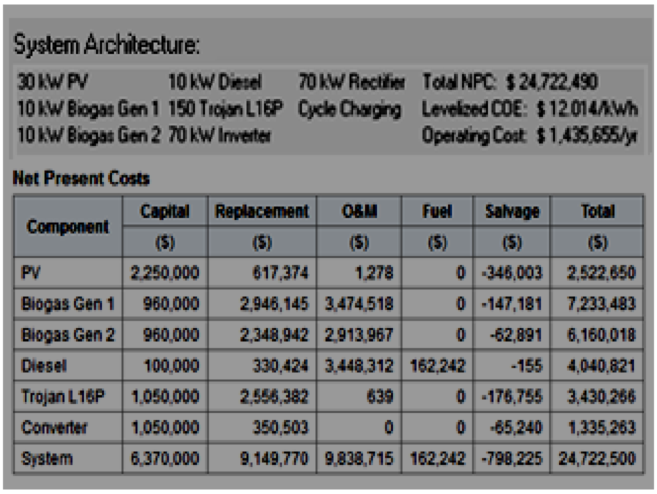
We have tried to design an off grid system in remote location. Bangladesh government declare target to cover all areas in between 2030. So, with considering caution factor, we have considered the project life time 25 years. And, we have tried to design the system for the total Island. Here, the annual capacity shortage is almost is though we considered the shortage varies from 0 to 1 percent. Other consideration and parameters like System control parameters and various constraints are given in Table -9.

TABLE IX. CONVERTER COST ASSUMPTION AND TECHNICAL PARAMETERS

Parameter	Value
Percent of annual peak load	0
Percent of hourly load	15
Percent of hourly solar output	0
Maximum Unreserved energy	0 (%)
Maximum renewable fraction	0 to 100%
Maximum battery life	N/A
Maximum annual capacity shortage	0 to 1%

C.7 Results

The optimal systems performance analysis has been carried out by using HOMER software. In the results, numerous alternative feasible hybrid set-ups with different levels of contribution by the renewable resources were obtained. The project life time is considered for 25 years. The optimized result is calculated for specific solar irradiation 4.64kWh/m2/d. The hybrid system encompass of 30kW PV array, two 10 kW biogas generator, one diesel generator and 150 storage batteries with 70kW converter is economically more feasible with a total net present cost (NPC) of 24,722,490 taka and minimum cost of energy (COE)[22] of tk.12.014/kWh. Optimized result is represented in Fig. 8. Here, we calculated the result taking the annual capacity shortage 0 to1%. In this model, renewable energy generation is 75% of total generation and rest 25% from diesel generation. Also in this analysis, renewable fraction is obtained 0.75 percent and annual capacity shortage is 0.04 percent only.



System Architecture:

30 kW PV	10 kW Diesel	70 kW Rectifier	Total NPC: $ 24,722,490
10 kW Biogas Gen 1	150 Trojan L16P	Cycle Charging	Levelized COE: $ 12.014/kWh
10 kW Biogas Gen 2	70 kW Inverter		Operating Cost: $ 1,435,655/yr

Net Present Costs

Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
PV	2,250,000	617,374	1,278	0	-346,003	2,522,650
Biogas Gen 1	960,000	2,946,145	3,474,518	0	-147,181	7,233,483
Biogas Gen 2	960,000	2,348,942	2,913,967	0	-62,891	6,160,018
Diesel	100,000	330,424	3,448,312	162,242	-155	4,040,821
Trojan L16P	1,050,000	2,556,382	639	0	-176,755	3,430,266
Converter	1,050,000	350,503	0	0	-65,240	1,335,263
System	6,370,000	9,149,770	9,838,715	162,242	-798,225	24,722,500

*All the currency values are considered in terms of Tk. (Taka, Bangladeshi Currency) instead of $(USD).

Fig. 8, Optimized result for diesel-PV-biogas-battery System

VI. CONCLUSION

Bangladesh is running in the crisis zone of power shortage. Socio-economic development is stack into a point for the power crisis. Education is the backbone for the development of a nation. There is a great difference in educational level in rural and urban areas in Bangladesh due to lack of electricity in rural area. In Bangladesh nearly 60% people in rural area have no access to the national grid and around 75% Bangladesh's 161 million citizens live in rural areas. Without electrification of rural area, it is impossible to connect the peoples of those areas to the main stream of development. Therefore, to solve the power crisis at rural area is an emerging need.

In this paper for electrification of rural area, an Island of remote district of Bhola is chosen. The potentiality of solar and biomass is analyzed. Then, based on this potential, a feasibility study for a model community of 275 families and 20 shops, 3 school and 1 community health post has been conducted. The optimize hybrid system was developed considering manufacturing cost and efficiency. The unit price of electricity of the proposed model is around 12.014BDT with a net present cost is around 24,722,490BDT. Though the proposed system is designed considering a model community, the system can be implemented for any community and at any place in Bangladesh. For reasonable unit price, though the net investment is high considering the life time of project, it hopes that the proposed hybrid model will be commercially viable and will be a guideline for electrification of other rural areas in Bangladesh.

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