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PROSPECTS OF HYBRID RENEWABLE ENERGY SYSTEM IN OFF GRID ISLANDS OF BANGLADESH

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Abstract- *Hybrid renewable energy system is an excellent solution for electrification of remote off-grid islands where the grid extension is difficult and not economical. Such system incorporates a combination of one or several renewable energy sources such as solar photovoltaic, wind energy, biomass energy. Our thesis discusses different system components of hybrid renewable energy system and develops a general model for rural villages of Hatiya to find an optimal combination of energy components for a typical rural community minimizing the life cycle cost.*
The developed model will help in sizing hybrid energy system hardware and in selecting the operating options. Hybrid system using Wind, solar PV and biomass generator are found to be the optimal combination for the electrification of the rural villages in Hatiya, Bangladesh, based on the case study. The model is developed using simulation tool HOMER.

Keywords: Solar photovoltaic, Wind energy, Biomass energy, Hybrid energy, Off-grid islands.

1. INTRODUCTION

At present, 53% of the total electricity generation of Bangladesh is from the power plants under public sector and 47% of the net generation of the country is from private sector [1]. Even though many extra units both from public and private sector have been added to the national grid, the power crisis is still a big issue in the country. So due to high demand, maximum generation of 2087 MW in 1995-1996, 2114 MW in 1996-1997, 3218 MW in 2001-2002, 3458 MW in 2002-2003, 3622 MW in 2003-2004, 3751 MW in 2004-05, 3812 in 2005-06, 3718 in 2006-07, 4130 MW in 2007-08, 4037 MW in2008-09, 5800 MW in 2010-11,6319.5 MW 2011-12 could not remove power crisis in the country [2]. Renewable energy can help us improve the condition of power crisis and help us move forward economically and environmentally. Moreover, the environmental drawbacks of renewable energy sources are minimum.

Moreover still many parts of the country is out of national grid specially island those are far away from main land. It's not possible to bring those islands under national grid. So renewable energy is a great option to produce electricity in those islands. For rural and off-grid islands of Bangladesh hybrid power system combining renewable sources can be a good option for sustainable power production.

Hybrid renewable energy systems (HRES) are becoming popular for remote area power generation applications due to advances in renewable energy technologies and subsequent rise in prices of petroleum products. A hybrid energy system usually consists of two or more renewable energy sources used together to provide increased system efficiency as well as greater balance in energy supply. It is very effective for rural remote areas

In order to obtain electricity from a hybrid system reliably and at an economical price, its design must be optimal in terms of operation and component selection. Many attempts have been tried to explore a relatively simple method for designing hybrid energy systems. An algorithm based on energy concept to optimally size solar photovoltaic (PV) array in a PV/wind hybrid system was reported [3]. Different system developments in hybrid energy system for Thailand were published [4]. A simple numerical algorithm was used for unit sizing and cost analysis of a stand-alone wind, solar PV hybrid system [5]. A linear programming technique was developed for optimal design of a hybrid wind/ solar PV power system for either autonomous or grid-linked applications [6]. Different aspects of PV, wind diesel and battery-based hybrid system including optimal sizing and operation has been detailed in [7,8]. A probabilistic performance of stand alone Solar PV, wind energy system with several wind turbines of same or different sizes, with PV models and storage batteries has been presented[9]. A hydro-based system was discussed in synchronized operation with wind energy [10]. Pre-feasibility study on hybrid energy based on wind and fuel cell system was published in [11].

This paper attempts to develop a general model to find an optimal hybrid system among different renewable energy combinations for a rural community in off-grid islands, minimizing the total life cycle cost while guaranteeing reliable system operation. For optimize use of renewable sources to generate electricity makes it feasible to generate electricity in a place that is isolated from grid connection. Hatiya off-grid island of Bangladesh near Chittagong sea coast Solar PV, wind, biomass and battery backup are considered in the model.

2. OBJECTIVES

Our thesis work mainly aims to study about different sources of renewable energy to develop a hybrid model for the optimum use of renewable energy using renewable energy sources to generate electricity. The main objectives are:

a) To study about prospects of hybrid power system using renewable energy sources in off-grid islands of Bangladesh.
b) Propose a small hybrid model using wind, solar and biomass in Hatiya as an off-grid islands using HOMER simulation software.
c) Feasibility study of the hybrid model..

3. THEORETICAL OVERVIEW

3.1 Hybrid Energy System

Its types of energy system that incorporates two more renewable sources of energy like solar PV, wind energy, biomass energy and hydro power and may be a diesel generator for backup. Hybrid energy system and develops a general model to find an optimal combination of energy components for a typical rural community minimizing the life cycle cost.

3.2 Configurations Of Hybrid Energy Systems

Three types of configuration models for hybrid energy system [12]

a) Series hybrid energy systems.
b) Switched energy hybrid systems.
c) Parallel hybrid energy systems.

4. HOMER

Begin the National Renewable Energy Laboratory (NREL) has developed HOMER, an optimization model that considers hourly and seasonal variations in loads and resources, simple performance characterizations for each component, equipment costs, reliability requirements, and other site-specific information. HOMER ranks the configurations by life-cycle cost and can automatically perform sensitivity analyses on any subset of its inputs. It is intended for prefeasibility analysis when the interest spans a broad range of inputs, either because the input data is uncertain or because the analysis covers a large area with differing conditions. In addition to performing optimized configurations, HOMER provides hourly energy flows through each component, the impact of several simple load management strategies, and economic information such as the cost of energy and net cost of the system.

HOMER is intended for use by renewable energy or rural electrification professionals. The output capabilities of HOMER are significant. Any of the annual outputs (including the optimal system type) can be plotted versus one or two sensitivity variables. HOMER reports both optimal and near-optimal solutions

5. RENEWABLE ENERGY SCENARIO OF HATIYA

5.1 Project Site Information

Hatiya is one of such location where diesel power is use. The location of Hatiya in relation to the relative intensity of solar radiation in Bangladesh and Hatiya island still experiences between 4 and 4.5 kwh/m^2/day in the winter month of December. As regards the availability of wind energy, there is specific data measured by Bangladesh Metrological Department shows, the critical month with lower wind velocities are the winter months (November-February). Good wind speeds (5m/s to 7m/s) are available during the summer and especially during the monsoons, when the solar energy radiation generally remains low.

5.2 Geographical Information

Hatiya is situated in $22^0 22^/$ N $91^0 7.5^/$E / $22^0 367^/$N 91.225^0 E coordinates. Hatiya is an island and also an upazila of Noakhali district in the division of Chittagong, Bangladesh. Hatiya upazila with an area of 1508.23 sqkm, is bounded by Soubornocor and Ramgati upazilas on north, Bay of Bengal on the south and east, Monpura upazila on the west. This upazila consists many big and offshore islands.

Figure 5.2: Map of Hatiya upazilla

5.3 Case Study

The evaluation is based on a typical village of Hatiya called Burirchar. There are no grid connection in the island so in village. Only diesel generators of KW ratings for supplying in Hat, Bazar and other public places. For individual domestic use there is no source of electricity. The principal demand of electricity is for fan, lighting and television. In this study the electrical appliances in the village include 10 W compact fluorescent lamps, 50 W ceiling fan and 60 W television. From the detailed study, data collection and survey conducted, it is estimated that wind energy can be very effective to produce electricity in the locality. Solar energy and biomass energy,diesel generator can be combined for hybrid energy system.

5.4 Renewable energy resources

5.4.1 Wind Energy

Due to geographical location the place is rich of wind energy. Average wind speed is very much favorable for wind turbine installation. The wind speed in different months at 10 m height is found as follows [13].

Table 1: Average wind speed(m/s) of Hatiya in different months as follows

Month	Average wind speed(m/s)
January	3.41
February	4.34
March	5.20
April	5.89
May	6.13
June	6.11
July	5.98
August	5.19
September	4.88
October	5.46
November	3.75
December	3.5

5.4.2 Solar Energy

For our project area location 22°22′N 91°7.5′E cleanness index and daily radiation (kWh/m^2/day) in different months of the year is presented in the table.

Table 2:Cleanness Index and daily radiation in Hatiya in different months

Month	Cleanness Index	Daily radiation(kWh/m^2/d)
January	0.581	4.153
February	0.557	4.567
March	0.534	5.055
April	0.494	5.178
May	0.467	5.129
June	0.354	3.932
July	0.328	3.607
August	0.364	3.863
September	0.395	3.862
October	0.512	4.379
November	0.560	4.128
December	0.592	4.027
Average	0.465	4.322

Scaled annual average is taken 4.32 kWh/m^2/d

5.4.3 Biomass

As a village it is mainly dependent on agriculture. Seasonal corps and domestic waste is a great source of biomass energy.Biomass energy resources is taken is presented in the table.House hold waste wood and fallen leaves can be a good source of biomass. Biomass is assumed to be 20kg available everyday in the village.

Table 3: Biomass data in different months

Month	Available Biomass (Tonnes/day)
January	0.020
February	0.020
March	0.020
April	0.020
May	0.020
June	0.020
July	0.020
August	0.020
September	0.020
October	0.020
November	0.020
December	0.020
Average	0.020

5.5 Load calculation

Table 4: Appliances for single home user

Appliances	Number	Capacity(W)
Light	2	20
Fan	2	100
TV(Colour)	1	60
Total		180

It is estimated that nearly 200 homes live in the village. Total connected load for 200 homes is 36 KW.
Each Generally for a family use electricity 2 CFL lamp of 10W for 5 hours, and 2 ceiling fan of 50 W for 5 hours,1 TV of 60 W for 4 hours.

6. BLOCK DIAGRAM OF SIMULATION WORK IN HOMER

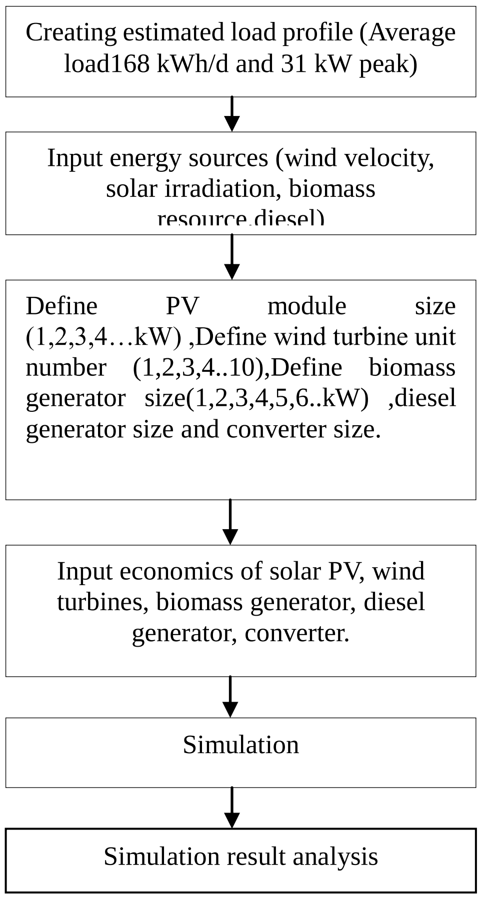

Fig 6: Block diagram of simulation work in HOMER

7. SIMULATION IN HOMER

7.1 Hybrid System Structure

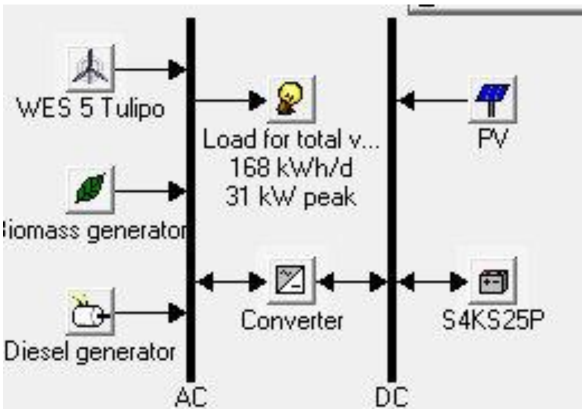

Figure 7.1: Hybrid system for project area

From HOMER simulation the optimized hybrid energy system architecture is:
1 KW of PV
11 of WES 5 Tulipo
1 KW Biomass generator
10 KW Diesel generator
1 KW converter
2 of Surrette 4KS25P

7.2 Defining Renewable Energy Resources

7.2.1 Wind Resource

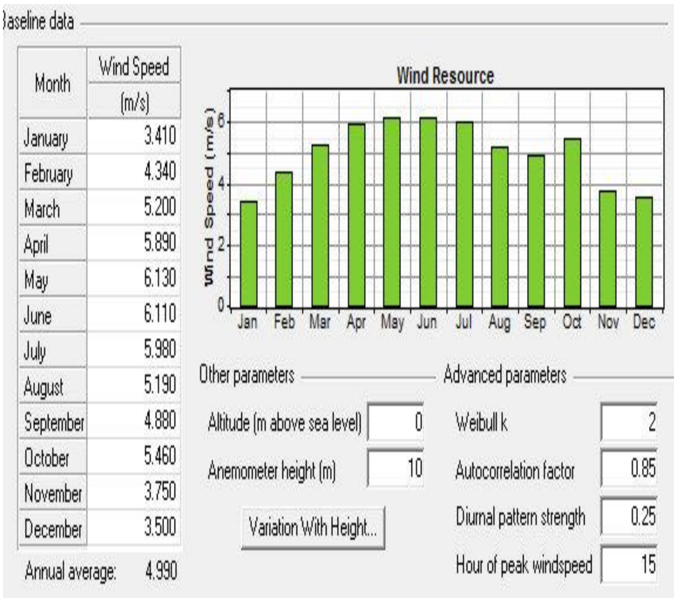

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Figure 7.2.1: Wind resource input

7.2.2 Solar resource

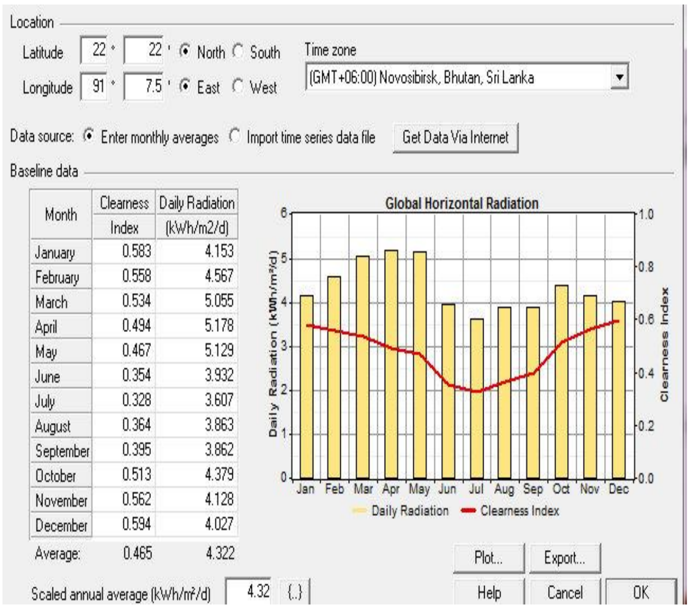


Figure 7.2.2: Solar resource input

7.2.3 Biomass Resource

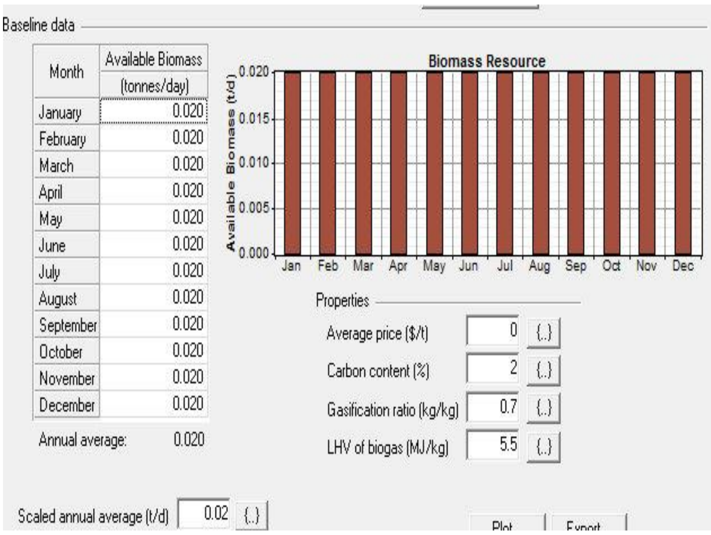


Figure 7.2.3: Biomass resource input

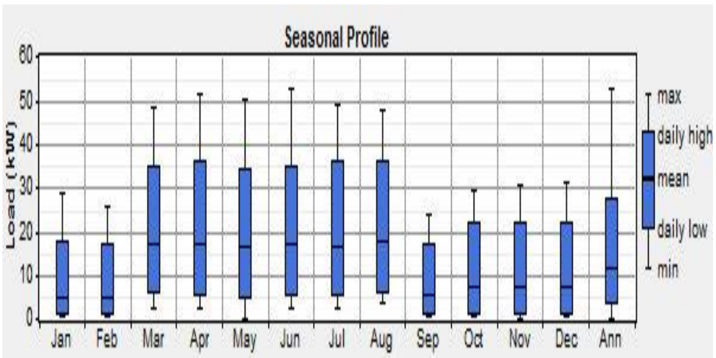
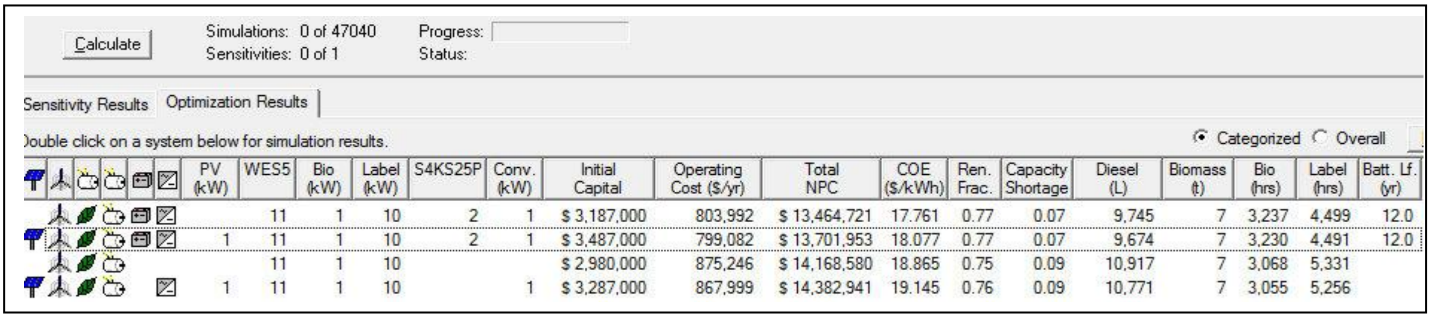


Figure 7.2.4: Peak load in different months

7.3 Options of hybrid system combination:



PV (kW)	WES5	Bio (kW)	Label (kW)	S4KS25P	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Capacity Shortage	Diesel (L)	Biomass (t)	Bio (hrs)	Label (hrs)	Batt. Lf. (yr)
	11	1	10	2	1	$ 3,187,000	803,992	$ 13,464,721	17.761	0.77	0.07	9,745	7	3,237	4,499	12.0
1	11	1	10	2	1	$ 3,487,000	799,082	$ 13,701,953	18.077	0.77	0.07	9,674	7	3,230	4,491	12.0
	11	1	10			$ 2,980,000	875,246	$ 14,168,580	18.865	0.75	0.09	10,917	7	3,068	5,331	
1	11	1	10		1	$ 3,287,000	867,999	$ 14,382,941	19.145	0.76	0.09	10,771	7	3,055	5,256	

Figure 7.3: Different options of hybrid system combination

From HOMER simulation result we choose the 2nd scheme as it includes all the renewable resources with diesel generator. Combine of 1 kW solar PV,11 of WES 5 tulipo wind turbines, 1kW biomass generator, 2 Surrete4KS25P ,10 KW diesel generator and 1 kW converter ensures the electricity availability for the village

8. SIMULATION RESULT ANALYSIS

8.1 Simulation result Analysis

8.1.1 Electrical results:

Electrical results show that PV shares 1% of load demand and generates 1,253 kWh/yr. Wind turbine shares 74% of load demand to generates 78,951 kWh/yr.Biomass generator shares 3 % of the load demand and generates 2,774 kWh/yr. Biomass generator shares 3% of the load and generates 2,774 kWh/yr. Diesel generator shares 23% load demand and generates 24,328 kWh/yr .Total production from the hybrid system is 107,305 kWh/yr. AC primary load is 59,293 kWh/yr. Excess electricity is 47,488 kWh/yr which is 44.3% of the total production. Renewable fraction is 0.77.

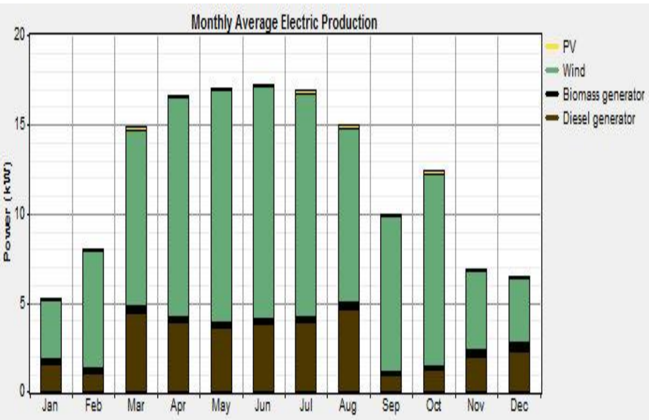


Figure 8.1.1: Monthly average electric production

8.1.2 PV Results

1 kW PV array operates 4371 hr/yr to generate 1253 kWh/yr at levelized cost og f 18.7 Tk/kWh.

Table 5: Result for PV

Quantity	Valu e	Units	Quantity	Value	Units
Rated capacity	1.00	kW	Minimum output	0.00	kW
Mean output	0.14	kW	Maximum output	0.95	kW
Mean output	3.43	kWh/d	PV penetration	2.04	%
Capacity factor	14.3	%	Hours of operation	4,371	hr/yr
Total production	1,253	kWh/y r	Levelized cost	18.7	$/kW h

a. Results for PV

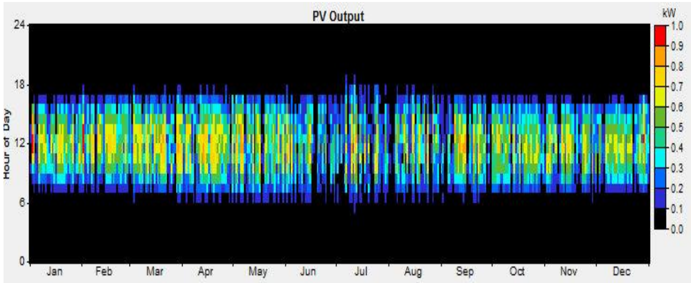


Figure 8.1.2: PV output through out the day in different months

8.1.3 Wind Results

27.5 kW wind generator operates 7843 hr/yr to generate 78,951 kWh/yr at levelized cost of 3.72 Tk/kWh.

Table 6: Result for wind turbine

Quantity	Value	Units	Quantity	Value	Unit s
Rated capacity	27.5	kW	Minimum output	0.00	kW
Mean output	9.0	kW	Maximum output	28.9	kW
Capacity factor	32.8	%	wind penetration	129	%
Total production	78,951	kWh/ yr	Hours of operation	7,843	hr/yr
			Levelized cost	3.72	$/k Wh

b. Result for wind turbine

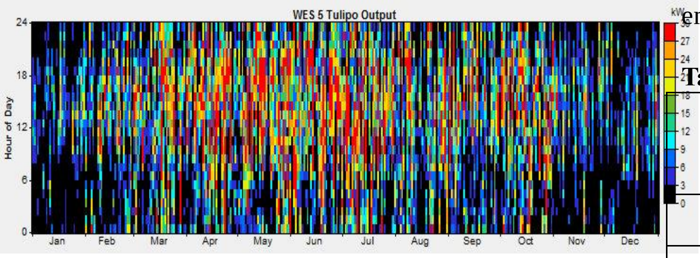


Figure 8.1.3: Wind turbine production through out the day in different periods of time

8.1.4 Biomass Generator

1kW biomass generator operates 3230 hr/yr to generate 2774 kWh/yr at fixed generation cost 10.5Tk/hr.

Table 7: Result for biomass generator

Quantity	Value	Units	Quantity	Value	Units
Hours of production	3,230	hr/yr	Electrical production	2,774	kWh/yr
Numbers of starts	1,320	starts /yr	Mean electrical o/p	0.859	kW
Operational life	4.64	yr	Min. electrical o/p	0.300	kW
Capacity factor	31.7	%	Max. electrical o/p	1.00	kW
Fixed generation cost	10.5	$/hr	Bio. Feedstock consumption.	7.26	t/yr
Marginal generation cost	0.00	$/kWh	Specific fuel consumption	1,831	Kg/kWh
Fuel energy input	7,762	kWh /yr	Mean electric efficiency	35.7	%

c. Biomass generator results

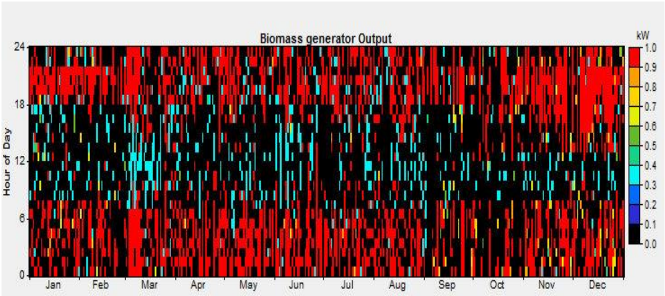


Figure **8.1.4**: Biomass generator output throughout the day in different period of time.

8.1.5 Emissions

Use of diesel generator and biomass generator causes emission of different gases.

Table 8: Emission throughout the year

Pollutants	Emissions (kg/yr)
Carbon dioxide	25,476
Carbon monoxide	62.9
Unburned hydrocarbons	6.97
Particulate matter	4.74
Sulfur dioxide	51.2
Nitrogen oxides	562

Figure **8.1.5**: Emissions throughout the year

9. CONCLUSION AND FUTURE WORK

9.1 Conclusion

To serve power to the furthest corner of the country use of renewable energy has no alternative. Hybrid energy system ensures the minimum price the generated power and optimum use of renewable sources. A general optimization model for finding an optimal combination of community-based hybrid energy systems is developed for off-grid island conditions. This compatible model is applicable to renewable power generation in any rural areas of off-grid island. A decision support system designed and developed using this model to help a designer in sizing the hybrid power system hardware and in selecting the operating options on the basis of overall system performance and economics when site specific conditions and load profiles are known.

For electricity supply in the rural areas of Hatiya combination of wind, solar PV and biomass energy and diesel generator is very much effective.Additional diesel generator increase reliability and reduce initial cost . Our proposed model ensures reliable and electricity supply and also ensures low cost of energy. The hybrid model depicts that it is possible to supply electricity for 24 hours and low unit cost. The total renewable energy fraction of electricity is 77%, which is mostly from renewable energy.

9.2 Future Work

Bangladesh faces shortage of electricity. As a result lots of rural village and islands are still out of grid connection. Hybrid renewable energy system can play a key role for electrification of those areas. In future we are interested to work in the implementation of hybrid energy system in those areas.

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