Feasibility study of Wind Home System in Coastal Region of Bangladesh

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Abstract - Recent study and analysis on wind energy assessment in Bangladesh show that some of the coastal areas are fairly potential for small scale wind electricity generation system. Wind speed varies from 4m/s to 5.5 m/s at the height between 25m to 50m. Therefore a technical and economical feasibility analysis has been done for small wind home system for the coastal region of Bangladesh. HOMER and RETScreen software and monthly averaged measured wind speed for four coastal locations have been used for this purpose. It has been found that depending on the home users, load demand, capacity shortage and fraction of excess electricity, cost of useful energy varies from 24 to 39 Tk/kWh which is comparable to solar home system and diesel generator system for low scale consumers. Considering diesel system as a base case, for a 400 W capacity of Wind Home System (three home users) in coastal areas at a speed of 5m/s the IRR, pay back period and benefit-cost ratio are found to be around 16%, 8 years and 2 respectively. As the turbine cost decreasing and diesel cost increasing therefore sensitivity analysis also has been done. Results show that considering energy consumption, environmental effects and remote accessibility most of the coastal regions are viable for wind home system.

Keywords: Wind Home System, Coastal Bangladesh, Wind energy, Feasibility study

Introduction

Government of Bangladesh (GoB) has declared its vision to provide electricity for all by the year 2020, though access to electricity in Bangladesh is one of the lowest in the world; coverage today stands at around 32% of the total population and has a large unsatisfied demand for energy, which is growing by 10% annually. Per capita energy generation is also very low, only 158 kWh/year (FY 2005) [1,2]. However the rural areas of Bangladesh, where 76% of the population lives, have an even lower coverage (around 10%) and are seriously deprived of the electricity facility. Therefore survey, exploration, exploitation of different conventional and renewable energy sources like natural gas, coal, oil, hydropower, solar, wind and establishment of power generation plants and networks for transmission and distribution of electricity are being done by government and other related organizations. Very recently solar and wind energy resources assessment for Bangladesh have been done under the UNEP/GEF global project of Solar and Wind Energy Resource Assessment (SWERA) [3]. Study and analysis under this project show that some the coastal inlands and off-shore islands of Bangladesh should be fairly potential for small scale wind energy system [4,5].

Day by day wind energy activities in Bangladesh is growing up but slowly. A few number of small wind only, wind-solar hybrid systems have been installed so far by Grameen Shakti, and Local Government Engineering Department (LGED) [6]. As the measured data for some coastal locations are available therefore detailed techno-economical analysis now are essential for small wind home energy system (WHS) and in this research work this analysis has been done. Energy demand that is met by a typical and very popular 50W Solar Home System (SHS) has been considered for detailed analysis. To draw a system technically, hourly energy demand, resource availability and energy production are very

much essential and therefore HOMER, renewable based system optimization tool, has been used. The power curve and details are available for 400W capacity SW Air X wind turbine as the smallest wind turbine in the HOMER. So, energy demand for single to five home users has been considered. Developed stand alone WHS has been then compared with SHS for similar capacities. Diesel has been considered as a base case for economic viability analysis in the RETScreen software. As the diesel cost is increasing and on the other hand wind turbine cost is decreasing, sensitivity analysis has also been done.

Present Situation in the Coastal Region

In the coastal zone, access of electricity is lower than 3% out of 10 million people and in most of the islands national grid will not come for many years, if at all [7]. Most of the people of rural and remote coastal areas are using kerosene for lighting as well as for cooking along with fire wood. In some of the off-grid locations diesel generators, operated and maintained by private entrepreneurs or cooperatives, are playing the key role for supplying electricity for few hours in the evening. Mostly these generators are located in the rural markets for meeting the lighting demand of the shops and nearby households. Tariff of the electricity is very high. A survey of World Bank in 2000 shows that the cost of electricity from diesel genset was in the range from 15 to 32 Taka/kWh and usually the bill was collected on daily basis at a rate of Taka 3 to 8 per lamp when the cost of diesel was 16 Taka/Litre [8]. But every year price of imported diesel and kerosene is being increased, now it is 30 Taka/Litre, and therefore cost of electricity using diesel is also increasing.

Wind Energy Study in the Coastal Region

In Bangladesh, adequate information on wind speed over the country and particularly on wind speed at hub heights of wind machines is not available. A number of previous studies showed that the wind monitoring stations of Bangladesh Meteorological Department (BMD), situated in built up areas, measure low wind speed near the ground level at height of around 10 meter but the seacoast and coastal islands should have a good many locations with prospective wind speed [9-14]. Data analysis and study show that seasonal effect is very strong in Bangladesh. During monsoon period (May – Aug), when the strong south / south-westerly wind comes from the Bay of Bengal after traveling a long distance over the water surface speed becomes very high and for rest of the month, wind blows from the North / North-east and comes from the inland, it is low where in Oct – Nov it is minimum. Again hourly wind speed variation is low during the windy months but for rest of the months it is high. As energy depends on the cube of speed, $\overline{v^3}$ therefore the available energy should be higher for coastal wind in Bangladesh than for locations having the same annual wind speed with a low speed variation [4,5].

Table1: Measured wind speed and estimated solar radiation for some of the coastal locations in Bangladesh

	Measured wind speed (m/s) at 25m height					GHI**	
	Kuakata	Charfassion	Chittagong	Kutubdia	St Martin*	St Martin	Kuakata
Sep-96	3.64	3.34	3.36	3.6	4.47	3.99	4.29
Oct-96	2.18	3.70	3.20	4.0	4.11	4.34	4.36
Nov-96	1.93	3.30	2.61	3.5	3.53	4.54	4.55
Dec-96	3.35	3.09	2.97	3.7	4.11	4.15	4.19
Jan-97	3.17	2.80	3.25	3.8	5.03	4.63	4.67
Feb-97	3.37	2.69	2.66	3.5	4.7	5.05	5.02
Mar-97	4.84	3.54	3.13	3.9	4.24	5.64	5.68
Apr-97	4.93	3.29	2.88	3.6	3.79	6.44	6.05
May-97	6.27	4.81	4.96	5.0	5.07	4.93	5.43

Jun-97	7.31	5.76	5.83	6.1	6.17	3.40	3.71
Jul-97	7.34	5.22	5.67	6.3	5.56	3.37	3.97
Aug-97	5.88	5.17	4.90	5.5	5.78	3.77	4.01
Ave	**4.52**	**3.95**	**3.79**	**4.4**	**4.71**	**4.52**	**4.66**

* speed at around 30m height and averaged (1999 – 2001) [source-BCAS, BCSIR]
** GHI – Global Horizontal Irradiance, [source- SWERA toolkit]

Techno-economical Feasibility Analysis

Wind power output from the turbine based on the data for some coastal locations have been calculated and compared it with similar capacity and cost of PV panel. Assuming similar cost of other necessary parts for solar and wind system total production cost of electricity was calculated. Then a typical solar home system (SHS) for 50W capacity which is being used in most of the rural areas in Bangladesh has been considered for wind home system (WHS). Both technical and economical viability of WSH under different circumstance have been analyzed using HOMER, RETScreen and some manual calculation. Detailed of these analyses are given below;

Technical Analysis

As wind speed and power varies from location to location, therefore expected energy production over the life time period of the selected wind turbine has been calculated for different coastal locations. On the other hand over the coastal areas variation of solar radiation is not strong and therefore one of the best locations has been considered for solar energy analysis. Assuming USD $4000/kW for both small wind turbine and PV module the energy production cost has been calculated. Except wind turbine and PV module all other necessary devices and instruments are locally made and available. Battery with charge controller (initially 7800 Tk/kWh) and other installation supports cost (15000 Tk/kW) have been taken from the current market price. Also yearly operational and maintenance cost (350 Tk/year), periodical cost for battery change and other instruments (5200 Tk/kWh) have been added.

Table2: Energy production from a specific 400W capacity wind turbine and from related solar PV module (same capacity) and production cost of energy for different coastal place

	St Martin		Kutubdia		Charfassion		Kuakata		St Martin		
Sp	EP	EC	EP	EC	EP	EC	EP	EC	GHI	EP	EC
4.0	295	16.70	323	15.80	336	15.68	354	15.19	4.0	560	12.19
4.5	397	13.20	424	12.65	437	12.58	460	12.28	4.5	640	11.13
4.7	445	12.11	467	11.78	478	11.72	501	11.40	4.7	668	10.81
5.0	507	11.01	531	10.71	540	10.68	561	10.35	5.0	716	10.34

Here, Sp - Wind speed in m/s, EP - Energy Production in kWh/year, EC - Cost of Energy in Tk/kWh,
GHI – Global Horizontal Irradiance in kWh/m^2/day, Present exchange rate, USD $1 = BDT 65 Tk (Dec 2005)

This simple calculation shows that small wind turbine should be compatible with solar system for small energy system. But it is clear that not 100% of energy is used from any system. Due to seasonal, monthly and hourly variation of wind and solar energy a large amount of energy is wasted. Also hourly load demand plays an important role for selection of energy source. Peak load demand is another problem for system designing and therefore has a large influence on cost of energy uses.

To be clear about techno-economical feasibility of stand alone wind home system a typical 50W solar home system (SHS) has been chosen (around 25000 Tk/system) which is being used widely in the remote and rural areas of Bangladesh.

Simple calculation shows that to provide energy for this load at 5hours per day it needs 100Wp solar module and 480Wh battery capacity but the 50W typical system provides around 77% of the demand.

Considering system cost along with yearly O & M and periodical cost for battery replacement, the cost of energy is found to be around 38 Tk/kWh.

Then HOMER has been used to find out the technical viability of Wind Home System and RETScreen is used for financial viability. A typical load curve has been generated based on the rural household load use information and suggestion for minimize the peak load during evening and the period of watching TV. Typical load curve for a single home user of the same 50W capacity typical SHS is given bellow where adjusted annual average is 0.184 kWh/day or 67 kWh/year with a peak load demand of 0.028 kW

For a typical 50W SHS –

1. Module, Battery capacity & controller: Siemens 50Wp, 12V-100 Ah, 10 Amp
2. No of Load and capacity : 4 FL (4x7W), B/W TV (15W), cassette player (5W)
4. Uses hours per day : 5 hours
5. Demanded load : 0.24 kWh/day or 87.7 kWh/year
6. Total Load served (kWh/day) : 0.15 kWh/day or 55 kWh/year

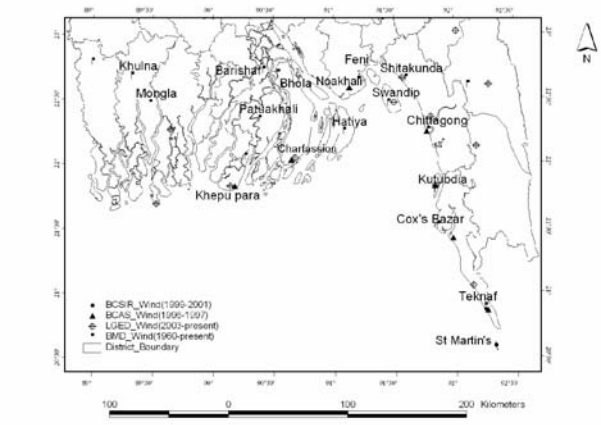


Figure 1: Wind monitoring stations in coastal part

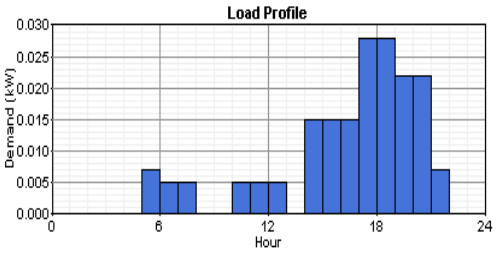
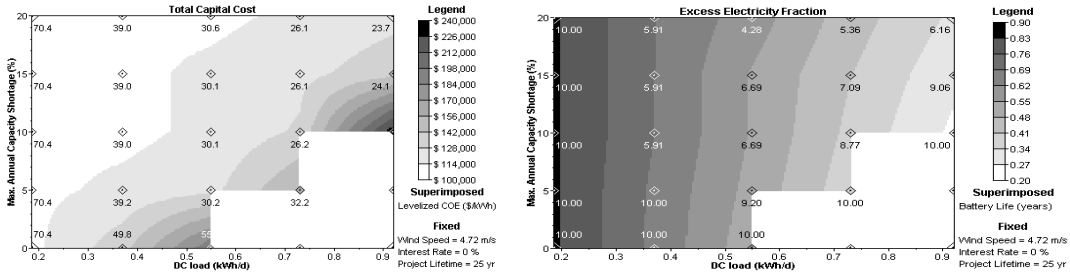


Figure2: A typical load curve for single home rural user

Load demand and cost of parameters, project life time and all other than wind turbine are same as in case of solar home system. System has been used for meeting the load demand of single to five home users. Due to high wind power variation in the coastal areas individual analysis for St Martin, Kutubdia, Kuakata and Charfassion have been done. Detailed technical analysis for St Martin (comparatively low power density area) has been given below;

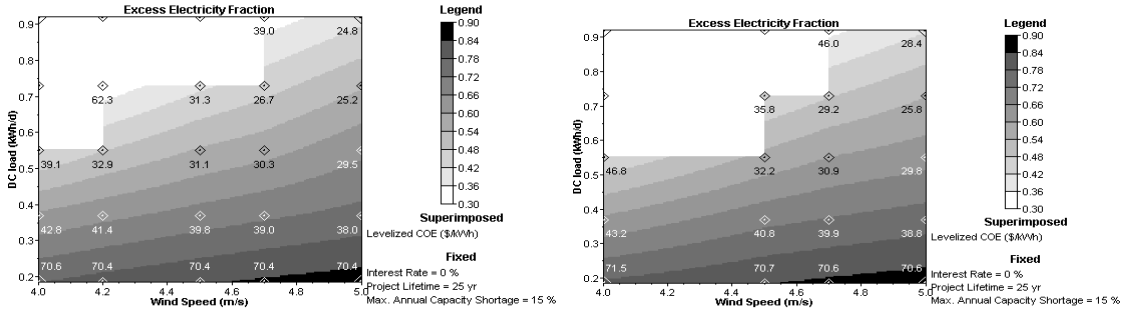
It is clear from the above analysis that for around 5 to 10% capacity shortage WHS is comparable to SHS. Again there is a large fraction of excess electricity in WHS and it can be minimize by adjusting the hourly load demand and thus the cost of electricity will be lower. The capacity shortage is mainly due to low wind speed in the month of October and November. Same analysis for other coastal locations has been done and almost similar results have been found. Figure4 shows some of the results for Kutubdia and Charfassion.

It was found earlier that in Bangladesh wind speed is very low during October and November but the overall annual power density is high. Therefore use of wind home system has only problem in this period. And it can be overcome to reduce the load demand. On the other hand detailed technical analysis has been done based on hourly data and therefore it is found that the excess energy is due to high wind speed in summer and capacity shortage in winter and also for peak load demand.



3(a) 3(b)

Figure3: (a) Cost of electricity and initial capital cost for WHS in St Martin for single to five home users with different maximum annual capacity shortage, (b) expected battery life time and fraction of excess electricity.



4(a) 4(b)

Figure4: Cost of useful energy with excess electricity fraction for (a) Kutubdia and (b) Charfassion

Financial Analysis

RETScreen was used to find out the financial viability of wind and solar home system. No doubt that both diesel and SHS is much better than kerosene light. In terms of single SHS, compare with diesel system is problematic. In Bangladesh, no single home rural user uses diesel genset individually. They use diesel generated lighting system which are commercially available. It is assumed that for same appliances that are used in SHS user needs to pay a minimum 4 taka for 100 Wh load. That means that from commercially available diesel generated system user has to pay around 40 Tk/kWh where as market price of diesel oil is now 30 Tk/ litre with Govt subsidies (real cost is around 50 Tk/litre). Annually cost of fuel (kerosene and diesel) in Bangladesh is increasing at a high rate. During last 4 years from October 2001 to Dec 2005 diesel and kerosene price goes up from 16 Tk/litre to 30 Tk/litre. Therefore WHS and SHW should be financially viable in most of the costal areas. Current market price of Diesel genset is taken as $400 USD/kW. Yearly O & M cost has been taken as same as for other systems. Considering energy cost escalation, inflation and discount rate as 5%, 6% and 8% respectively for both of the system, following table shows the financial viability of SHS and WHS where diesel is the base case;

Table 3: Financial analysis of SHS and WHS for three home users

Parameters	For SHS	For WHS at St Martin			For WHS at Kutubdia		
	At 4.6 kWh/m^2/day	4 m/s	4.7 m/s	5 m/s	4 m/s	4.7 m/s	5 m/s
Internal Rate of Return (%)	14.5	7.9	13.3	15.9	5.9	13.4	16.1
Simple Pay back (Yr)	8.1	16.4	10.0	8.2	17.2	9.7	8.0
Yr-positive cash flow (Yr)	8.1	12.4	8.4	7.1	14.6	8.5	6.9
Initial Cost (Taka)	59,800	123,000	117,000	110,500	136,000	117,000	110,000
Benefit – Cost – ratio	1.77	0.98	1.63	1.97	0.80	1.64	2.01

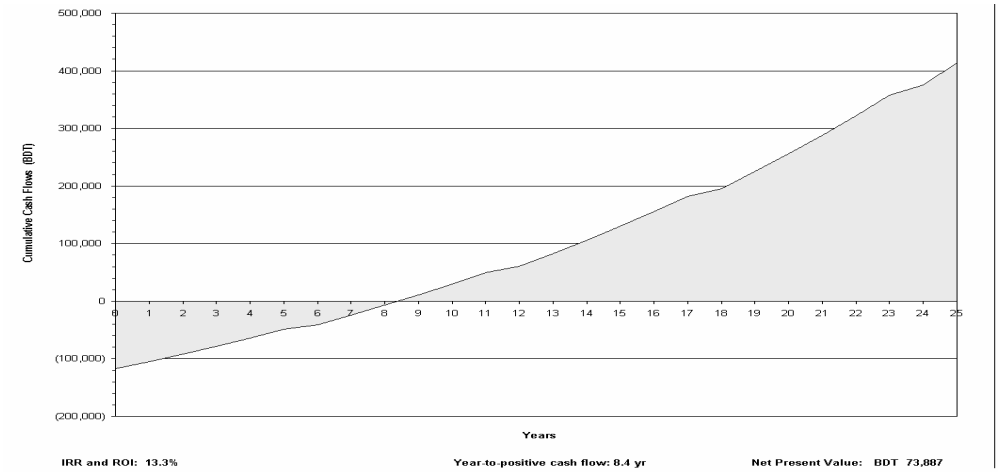


Figure5: Cumulative year to positive cash flow for wind home system in St Martin at 4.7m/s

Sensitivity analysis

In case of wind turbine it is found that the cost is decreasing rapidly and manufacturers are also producing highly efficient low power wind generators. Market for small wind systems are growing up. Life time is being increased. On the other hand due to current oil crisis and future consideration diesel and kerosene costs are increasing day by day. Table4 &5 show the effects of changing system and diesel cost on the pay back period and IRR in case of St Martin for three home users WHS.

Conclusion

Technical analysis shows that WHS for coastal islands is quite better than SHS. In some places this system may have equal effect. But for some coastal inlands like Patenga, Kuakata this system may not be feasible due to very low wind speed in Oct and Nov. For large variation of wind speed a countable amount of excess energy is available which can be utilized by controlling the peak load and using other devices like fan during the summer period. Results show that cost of useful energy from WHS for different places varies from 24 to 39 Tk/kWh which is definitely acceptable for coastal remote areas. Financial and sensitivity analysis also show the positive results. Therefore, remote coastal inlands and islands in Bangladesh should be a potential market for WHS.

Table 4: Sensitivity analysis of Year to positive cash flow for WHS at St Martin for the speed of 4.7 m/s

Initial costs	**Change**	**Avoided cost of energy (Tk/kWh)**				
(Tk)		32	36	**40**	44	48
93,600	-20%	8.5	7.7	7.1	6.5	6.0
105,300	-10%	9.3	8.5	7.7	7.1	6.6
117,000	0%	10.1	9.2	**8.4**	7.7	7.2
128,700	10%	10.9	9.9	9.0	8.3	7.7
140,400	20%	12.2	10.5	9.7	8.9	8.3

Table 5: Sensitivity analysis of IRR for WHS at St Martin for the speed of 4.7 m/s

Initial costs	**Change**	**Avoided cost of energy (Tk/kWh)**				
(Tk)		32	36	**40**	44	48
93,600	-20%	13.0%	14.7%	16.4%	17.9%	19.5%
105,300	-10%	11.6%	13.2%	14.7%	16.2%	17.6%
117,000	0%	10.4%	11.9%	**13.3%**	14.7%	16.0%
128,700	10%	9.4%	10.8%	12.2%	13.5%	14.7%
140,400	20%	8.5%	9.9%	11.2%	12.4%	13.6%

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