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Exploration of Economic Sustainability of Renewable Resources in Producing Electricity in Bangladesh

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Abstract

Various renewable and non-renewable energy sources were used to generate heat and electric power for decades. The depletion of finite resources was not an issue of concern until the end of the 20th century. Circumstances in both industrialised and developing countries now provide renewable resources with unique advantages to meet the increasing demand for electricity in a long-term sustainable global economy. Climate change, coupled with high oil prices, and increasing government support are driving indicators for increasing renewable energy legislation, incentives and commercialisation. Renewable energy is derived from natural processes that are replenished constantly. That's why solar radiation, tides, winds and hydroelectricity are perpetual resources that are in no danger of a lack of long-term availability. Developing countries like Bangladesh face an extreme power crisis due to lack of fossil fuels, which is a great economic impediment. The objective of this study is to know whether the use of renewable resources for producing electric power will be economically sustainable for developing countries like Bangladesh. In rural and remote areas, transmission and distribution of energy generated from fossil fuels can be difficult and expensive. Producing renewable energy locally can offer a viable alternative. Moreover, renewable energy can directly contribute to poverty alleviation by providing the energy needed for creating businesses and employment.

1. Introduction

The squandering use of fossil fuel in the last century has caused massive climate change through the greenhouse effect and produced large-scale environmental pollution. The paucity of non-renewable energy resources and the necessity for reducing CO_2 emissions have impelled the world to lean towards 'green energy' for electricity generation. Green energy refers to the environmentally friendly and non-polluting energy sources that include hydro, wind, geothermal and solar.

Bangladesh is located in the northeastern part of South Asia between 20.40^0 and 26.38^0□ North Latitude and 88.01^0□ and 92.41^0□ East Longitude. The total population is more than 140 million with an average population density of about 875 per square kilometre (among the highest in the world). 76.9% of the population is living in the rural areas [1].

Bangladesh needs to achieve and sustain an annual economic growth rate of at least 6-7 percent to alleviate poverty and realise desirable socio-economic and human development. To achieve this growth target for Gross Domestic Product (GDP), it is absolutely essential that the minimum electricity growth rate should be maintained at a factor of 1.5 of GDP growth. The provision of adequate and reliable supply of electricity at a reasonable cost is a pre-requisite to attain this goal. Besides, Bangladesh is still at a very low level of electrification with only 15 percent of its population (about more than 140 million) having access to electricity, and per capita generation is only 95 kWh per annum. The conventional resources in Bangladesh are inadequate for supplying the energy needs to bring about a significant improvement in its economy for a long period, say for about 50 years. Therefore, it is essential to think about the renewable energy sources available in the country and develop technologies to harness them. In developing countries like Bangladesh, renewable energy plants are considered mainly as an option for remote locations where the infrastructure needed to supply electricity from the grid is not affordable.

2. Present Conditions of Power Generation in Bangladesh

The electricity sector in Bangladesh is handled by three state agencies under the Ministry of Energy and Mineral resources (MEMR). These are:

- Bangladesh Power Development Board (BPDB)
- Dhaka Electric Supply Authority (DESA)
- Rural Electrification Board (REB)

In the year 2009, the maximum power generation in Bangladesh was 4,162 MW [2] compared to that of the previous year of 4,130 MW. Due to the shortage of available generation capacity with respect to the increasing demand, Bangladesh Power Development Board (BPDB) had to resort to load shedding, which varied up to 30.49 % of maximum demand. Load shedding was imposed on 351 days in 2009, compared to 358 days in the previous year. However, in 2009 the duration of load shedding increased mainly due to shortage of generation caused by a shortfall of gas supply to the gas based power plants and shutdown of plants for maintenance. The maximum demand served in 2009 was 4,162 MW against the forecast demand of 6,066 MW as per the updated Power System Master Plan (PSMP-2006) [2]. The total net energy generated during 2009 including private sector independent power producers (IPPs) was about 25,622 GWh (excluding energy purchased by REB from private sector generators), which is an increase of 5.39 % over that of the year 2008 [2].

Although the total installed capacity was 5493 MW including 1330 MW from IPPs and 351 MW from temporary “rental power plants” (excluding REB), the maximum available generation was only 4162.10 MW [1]. The reasons for lower availability were:

1. Some plants were out of operation for maintenance, rehabilitation & overhauling;
2. Capacity of some plants were derated due to aging; and
3. Gas supply shortage.

The installed capacity mix including IPPs is shown below [2]:

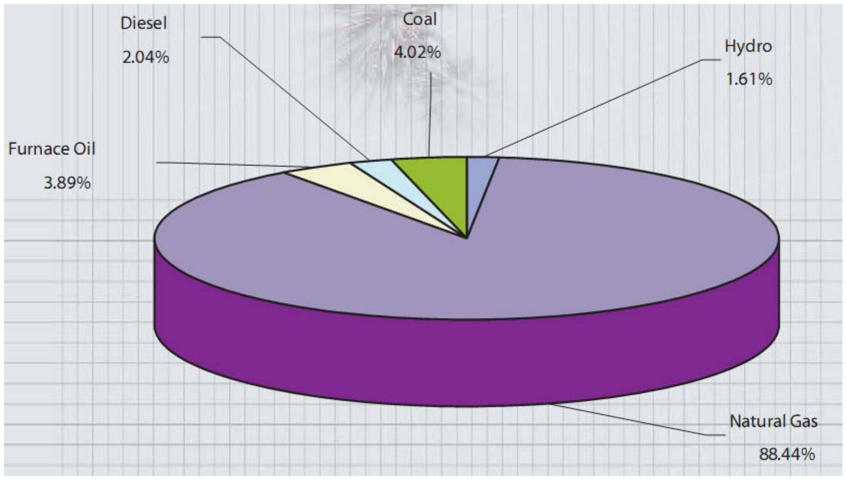
Table 1: Installed Capacity of Power Plants in Bangladesh according to type of plant and fuel

By type of plant		By type of fuel	
Hydro : 230 MW	(4.19%)	Gas : 4542 MW	(82.69%)
Steam Turbine : 2638 MW	(48.03%)	Furnace Oil : 280 MW	(5.09%)
Gas Turbine : 997 MW	(18.15 %)	Diesel : 191 MW	(3.48%)
Combined Cycle : 1359 MW	(24.74%)	Hydro : 230 MW	(4.19 %)
Diesel : 269 MW	(4.89 %)	Coal : 250 MW	(4.55%)
TOTAL : 5,493 MW	(100.00 %)	TOTAL : 5,493 MW	(100.00%)

Total net energy generated by the public (BPDB) and private sector power plants (IPP) by type of fuel were as follows [2]:

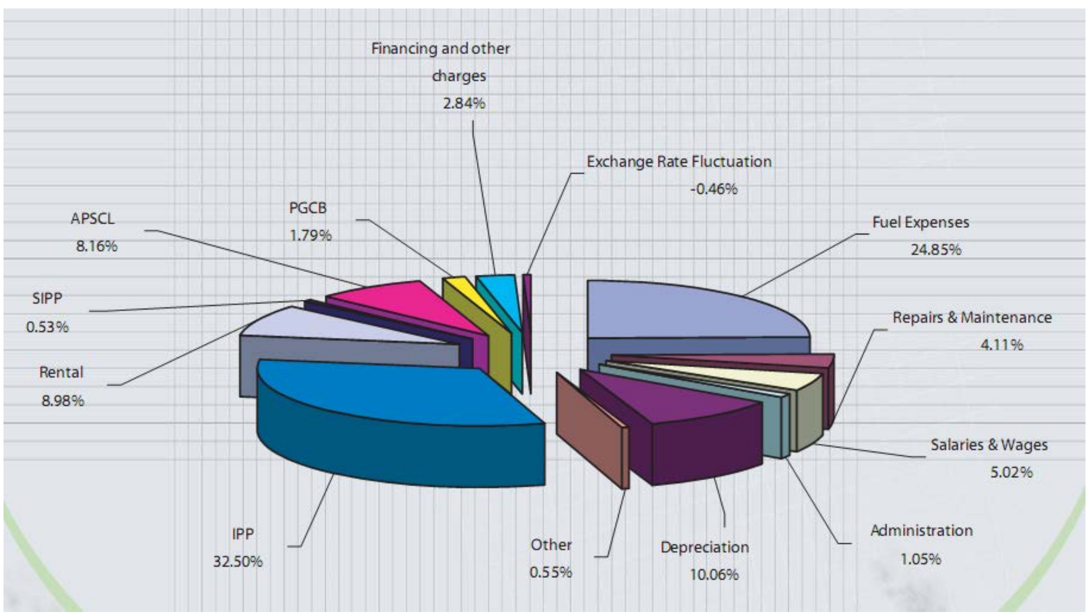
Table 2: Net generation of electricity in Bangladesh

Hydro	Karnafully	413.65 GWh	(1.62%)
Natural Gas	Ashugonj, Ghorashal, Haripur, Chittagong, Sylhet etc.	22660.75 GWh	(88.44%)
Furnace Oil	Khulna	996.41 GWh	(3.89%)
Diesel	Bhola, Thakurgaon, Barishal	520.52 GWh	(2.03%)
Coal	Barapukuria	1030.60 GWh	(4.02%)
Total	Plant Location	25,621.93 GWh	(100%)



Total Net Generation: 25,622 MkWh

Figure 1: Generation Pattern (Year-2009)[2]



Supply Cost: Tk. 3.07 / KWh Average (0.05 A$ / KWh)

Billing Rate: Tk. 2.56 / KWh (0.05 A$ / KWh)

Figure 2: Electricity Supply Cost (Year –2009)[2]

Table 3 indicates that, in the year 2009, the total duration of grid failure was 76 hours 22 minutes, which was about 6.97% lower than the interruption in the year 2008 [2]. In the year 2009 (Figure 1), gas & hydro based energy generation was 88.44% & 1.61% respectively and liquid fuel based generation was 5.93 % and coal based generation was 4.02 % of total net generation compared to 86.25% & 3.91% and 5.57 % and 4.27 % respectively in the year 2008.

Table 3: Interruption of national grid for FY 2008 and 2009[2]

Sl. No.	Type of Fault	Total Number of Faults		Total Duration	
		FY 2008	FY 2009	FY 2008 Hours/ Minutes	FY 2009 Hours/ Minutes
1.	Partial Power failure due to trouble in generation	155	95	15/45	06/44
2.	Partial Power failure due to trouble in grid S/S Equipment	14	15	28/14	50/43
3.	Partial Power failure due to fault in transmission line	7	14	32/17	16/55
4.	Partial Power failure due to the lightning on transmission line/Thunder Storm	02	02	02/03	00/32
5.	Partial Grid failure	06	05	03/40	01/28
6.	Total Grid failure	01	00	00/06	00/00
	Total	**185**	**131**	**82/05**	**76/22**

In Figure 3 it is clearly seen that the fuel consumption is increasing day by day.

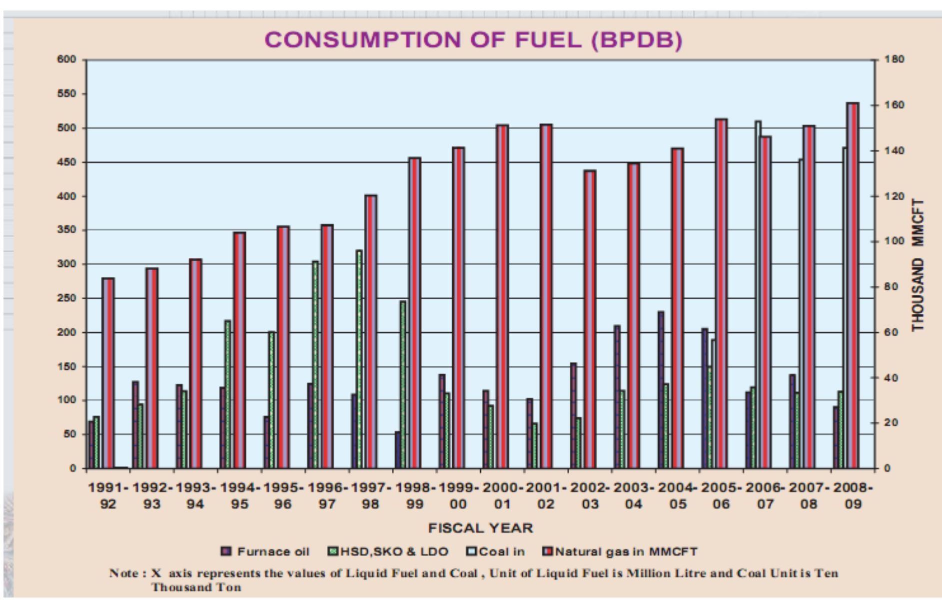


Figure 3: Consumption of fuel (BPDB)[2]

Figures 1, 2 & 3 indicate that natural gas is widely used in Bangladesh for electricity generation. Currently about 400-430 million cubic feet of gas is supplied per day for electricity generation. If this rate of consumption of gas only for electricity generation continues (which uses 45% of the total gas consumption), the gas reserve will last 60 to 65 years. So we have to think about the alternatives of natural gas so that we can compete with this growing power crisis in the near future.

3. Renewable Energy Resources in Bangladesh

Renewable energy sources are those that are naturally regenerated, or renewed, within a useful amount of time: wood and other substances produced by living things (biomass), natural heat from the earth's interior (geothermal), moving or falling water (hydropower), the wind, the sun, and the ocean. Renewable energy has zero purchase prices and has non-depleting sources whose conversion into energy is free from emission and radiation, contrary to the conventional fossil fuels (oil, gas and coal) and nuclear fission materials. Bangladesh is endowed with a plentiful supply of renewable sources of energy. Out of the various renewable sources, solar, biomass, peat and hydropower can be effectively used in Bangladesh (Government of Bangladesh, 1991).

Renewable energy practices in Bangladesh are:

- **Solar Energy**-The radiant energy from the sun
- **Wind Energy** -The force of moving air.
- **Biomass Energy**-Plant material (including wood) or organic waste
- **Hydro-power Energy**- The force of moving water from rivers or storage reservoirs

4. Renewable Energy Technologies in Bangladesh

4.1 Solar Energy

Bangladesh receives an average daily solar radiation of 3.82 to 6.24 kWh/m^2, which is a very favorable range for solar energy extraction. The country has a total area of 1.47×10^{11} m^2 and average 3.5 kWh/m^2 solar intensity falls on this land over 300 days per annum. Even if one percent of this land is used to harness solar energy for power generation at an efficiency of 10%, a total of 5.2×10^{09} kWh units of electricity can be generated annually [3]. This solar energy can be harnessed in two ways:

- Photovoltaic (PV); and
- Concentrating Solar Power (CSP) technology.

In Bangladesh, PV monopolises power generation from solar energy so far. The current installed capacity of Solar PV is 15 MWe, which is only 0.33% of the total power generation [4]. The Bangladesh Government has already included CSP in the Renewable Energy Policy 2009 [3]. As CSP will soon become a factor of 3 cheaper than PV, it would be a better choice to deploy CSP plants for harnessing solar energy on a large scale to minimise the current and future power crisis of Bangladesh.

To tackle this alarming situation and to meet the future demand, the government of Bangladesh is planning to construct some new power plants [5]. From Figure 4 it is seen that the capital cost of Concentrating Solar Power (CSP) is somewhat greater than other technologies, but the levelized cost is lower than Supercritical pulverized coal (SCPC) and Integrated gasification combined cycle (IGCC) with carbon capture and storage. The shortage of domestic gas and coal leads the government to think of imported coal and furnace oil based power plants. Considering the environmental issues and the colossal work of importing and storing such a large amount of fuel, renewable energy, especially CSP, can be a worthy choice for new power plant construction.

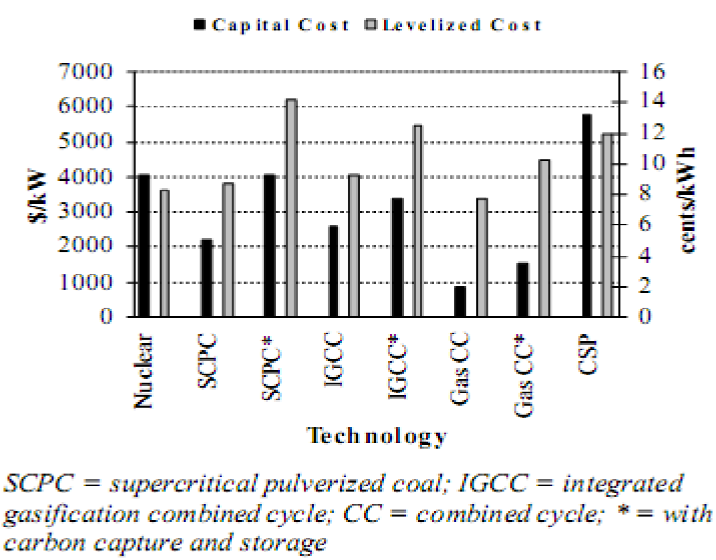


Figure 4: Cost comparison of different power generation methods [5]

Bangladesh is a country with abundant solar radiation. The Direct Normal Irradiance (DNI) trend over the year is shown in Figure 5. The annual DNI is nearly 1900 kWh/m^2 [6] in the northern part of the country, which is moderately high compared to the required DNI (2000 kWh/m^2) for a suitable CSP site [4]. Bangladesh is a densely populated country. Therefore it is difficult to find a huge and vacant area that is needed for CSP technology. But CSP can also be deployed at a smaller scale in dispersed areas. In the cities, especially in the capital Dhaka, solar dish technology can be easily employed on the rooftops of countless high-rise buildings. Recently Bangladesh Bank (BB), the central bank of Bangladesh has installed a solar system on the rooftop of it's main building to reduce pressure on the demand for electricity. The solar system, expected to last about 20 years, has an 8 kilowatt capacity In the rural areas, one solar dish of 25 KWe placed in an open place can serve nearly 200 families. Glass and steel are the main materials for parabolic trough power plants. Bangladesh has currently become self-sufficient in glass production; even glasses are now also being exported to many countries [7]. Furthermore, nearly 250 steel re-rolling mills are manufacturing steels in the country [8]. If domestic glass and steel are used to construct the solar field of the parabolic trough power plant, the plant can be erected with much less capital investment. Therefore, for large-scale production, parabolic trough technology can be implemented in rural areas.

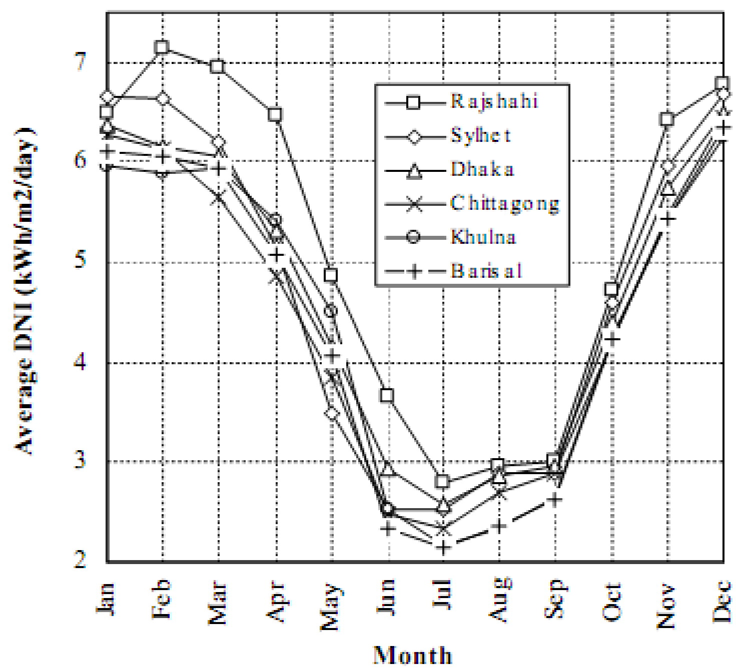


Figure 5: Monthly Average Direct Normal Irradiance (DNI) per day in Bangladesh [6]

The largest PV solar home system (SHS) available to date in Bangladesh is of 120 We with a price of $713 (A$ 820.55) [9]. The cost of a solar dish of 25 kWe is $150,000 (A$ 172,626)and is expected to become $50,000 (A$ 57,542) soon [10]. The cost/W for SHS and solar dish are $5.94 (A$6.84) and $2 (A$ 2.3) (projected) respectively. The CSP technology therefore can be a lucrative choice for the vendors to deploy in both large scale or off-the-grid versions.

4.2 Wind Energy

Wind energy has the potential to provide mechanical energy or electricity without generating pollutants. Wind electricity for decentralised systems or hybrid generation of electricity using other energy sources as complementary to wind energy has now been given some attention, and this could be suitable in low wind regimes for localised small grid systems or battery charging. For low wind speed, wind pumps could also be a viable option. Bangladesh has a 724 km long coastline and many small islands in the Bay of Bengal where a strong southwesterly tradewind and sea breezes blow in the summer months, and there is a gentle northeasterly tradewind and land breezes in winter months.

In Bangladesh, little systematic wind speed study has been made. Data collected by the meteorology department are usually meant for weather forecasting and are insufficient for determining wind energy potential. In an early study report in 1982, 30-years of meteorological data from a number of stations throughout the country were considered. It was found that wind speeds in the districts of Chittagong and Cox's Bazar were the only ones which showed promise. Extending the idea, only coastal area and the bay islands showed promise for possible electricity generation from wind.

Recently, a year's measurement in Patenga (Chittagong) at a height of 20 m in 1995 found that wind speed is higher than the values obtained by the meteorological department. This led to a year-long systematic wind speed study at seven coastal sites in 1996-97 at a height of 25 m by the Bangladesh Centre for Advanced Studies (BCAS), in collaboration with the Local Government and Engineering Department (LGED) and the Energy Technology & Services Unit (ETSU), UK which was financially supported by the British Government. Figure 6 displays the data of this wind speed study.

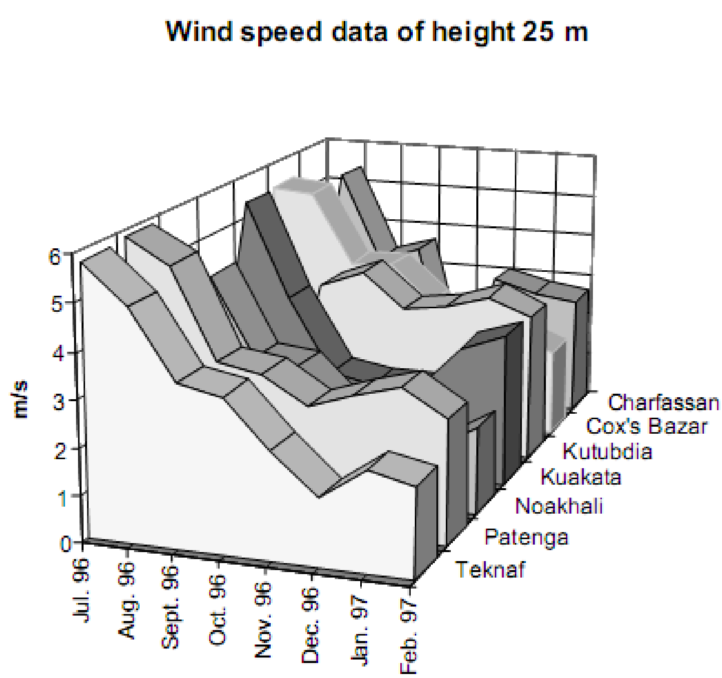


Figure 6: Wind speed data of height 25 m [11]

The BCAS study first made an analysis of available meteorological data and established the following worthwhile information:

- Wind speeds are higher in coastal areas;
- Wind speeds exhibit strong seasonal cycles, lower in the September to February period and higher in summer (March to August); and
- Wind speeds exhibit a diurnal cycle, generally peaking in the afternoon and weakest at night (the trends are also similar in West Bengal, India).

Recently a project on "Feasibility Study on R&D of Renewable Energy (Solar, Wind, and Micro-Mini Hydro)" has been undertaken by the Institute of Fuel Industrial Research (BCSIR). Under this program, wind speed data have been collected at Saint Martin's Island [12].

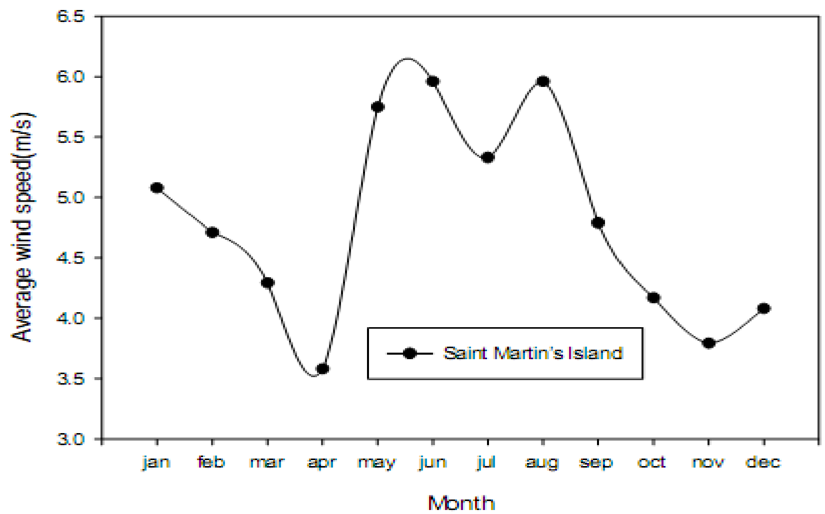


Figure 7: Monthly average wind speed at Saint Martin's Island [12]

Table 4: Monthly average wind speeds in the Saint Martin's Island [12]

Month	V_{av} (m/s)	V_{max} (m/s)
January	5.08	23.32
February	4.71	19.78
March	4.29	18.94
April	3.58	20.03
May	5.75	26.30
June	5.96	29.80
July	5.33	24.20
August	5.96	20.40
September	4.79	17.70
October	4.17	15.90
November	3.79	14.50
December	4.08	15.20

From Table 4 and Figure 7, it can be see that from May to August wind speeds are higher; wind generated electricity and wind pumps can provide irrigation facilities in that time. From Table 4 we find the wind speed is good enough to produce electricity in Saint Martin's Island. Though average wind speed values are less than 7 m/s, we know average hub height is 20 to 40 m, and that will increase the wind speed [13] sufficiently to be feasible for electricity generation. The wind speed is very high during the monsoon period (June-July) and very lean from October to February. From the analysis of wind resource assessment, it is found that 300-600 watt capacities are possible. Wind Electric Generators (WEGs) are preferable and windmills for water pumping are prospective for that site.

4.3 Biomass Energy

Biomass is the most significant energy source in Bangladesh, which accounts for 70% of the total final energy consumption in Bangladesh. The current study indicates that, in 2003, the national total generation and recovery rates of biomass in Bangladesh were 148.983 and 86.276 Mtonne respectively [14]. In energy terms, the national annual amount of the recoverable biomass is equivalent to 312.613TWh. Considering the present national consumption of biomass, total available biomass resources potential for electricity generation vary from 183.865 to 223.794 TWh. Biomass energy potential in the individual districts of the country has been estimated for the planning of small- to medium-scale biomass-to-electricity plants [14]. The main sources of biomass fuels are:

1. Trees (wood fuels, twigs, leaves, plant residues);
2. Agricultural Residues (paddy husk, bran, bagasse, jute stick etc.); and
3. Livestock (animal dung).

Sustainable Rural Energy (SRE) has installed a 10 kW power generation unit which was based on poultry litter. Excess gas from this unit is being used for cooking purpose at the Faridpur Muslim Mission. There are huge replication potentials of such types of bio-energy in our country. Demonstration of a 3.5 kW cow dung based power generation unit at Netrokona district created enthusiasm among the small-scale farmers. Besides that, SRE has also installed two biogas units, one at Kutubdia and the other at Kishoregonj which were based on human excreta. This type of intervention created better health and sanitation facilities as well as meeting energy requirements for cooking and lighting. Furthermore, SRE has installed one pilot biomass gasifier at Faridpur Muslim Mission. This gasifier could save up to 50% fuel wood.

4.4 Hydro-power Energy

Bangladesh is a riverine country with three main rivers (1) Ganges; (2) Brahmaputra; and (3) Jamuna. About 1.4 trillion cubic metres (m^3) of water flows through the country in an average rainfallyear. Numerous rivers flow across the country, which are mostly tributaries of these main rivers. Out of these, 57 rivers are transboundary, which originate from India and Myanmar. Apart from the southeastern region, other parts of the country are mostly flat in nature. Major rivers of the country have high flow rates for about 5 to 6 months during the monsoon season, which is substantially reduced during winter. More than 90% of Bangladesh's rivers originate outside the country, due to which proper planning of water resource is difficult without neighboring countries' cooperation. Downstream water sharing with India is a highly contentious issue in Bangladesh.

In Bangladesh, the annual average rainfall is about 2,300 mm, which varies from 1,200 mm in the northwest to 5,800 mm in the northeast. Most of the rainfall (80 %) occurs during the months of May/June to September/October [15]. In Bangladesh, there are three types of rivers:

1. Major and medium size perennial rivers with most of the catchment area outside the national border;

2. Medium and small size seasonal internal rivers, mainly tributaries and distributaries of the main rivers; and

3. Small and medium both perennial and seasonal border rivers.

At present only 230 MW of hydropower is utilised in Karnafully Hydro Station, which is the only hydroelectric power plant operated by Bangladesh Power Development Board (BPDB) [15]. BPDB is considering extension of Karnafully Hydro Station to add another 100 MW capacity, which will only add energy marginally and be effective to operate as a peak demand power plant. The additional energy will be generated during the rainy season when most of the year's water is spilled. Apart from Kaptai, two other prospective sites for hydropower generation at the Sangu and Matamuhuri Rivers are identified by BPDB, but no pre-feasibility study has been made so far. A brief description of these two sites is given below.

Sangu Project

This would be a new project with an energy output of about 300 GWh per year. For an installed capacity of 140 MW, the annual plant factor is 23%, and it is estimated that the plant would operate in peak demand mode. However, this project needs a detailed environmental, social and economic study in the present day context [15].

Matamuhuri Project

The Matamuhuri development would be a new project of capacity 75 MW and an approximate average energy output of 200 GWh per year. In 1992 under the Flood Action Plan, the Northeast Regional Water Management Project (FAP-6), a preliminary assessment of selected rivers in the Northeast Region, has been carried out. The finding for the most promising rivers and sites shows that they are suitable for development of run-off-river low head schemes. However, to obtain the required head for generating power, a weir or barrage needs to be constructed across the river channel. Based on mean monthly discharges and an assumed 5m head, the hydro potential of the 10 major and medium perennial rivers of the Northeast Region is estimated at about 161 MW of continuous power, with an annual energy production of about 1410 GWh. These are perennial rivers with sufficient flow for power generation throughout the year [15].

5. Development of Renewable Energy Technologies (RETs) in Bangladesh

5.1 Renewable Energy Policy and Institutional Settings

Energy is one of the basic ingredients required to alleviate poverty and socio-economic development. The Government of Bangladesh (GOB) issued its Vision and Policy Statement in February 2000, to bring the entire country under electricity service coverage by the year 2020 in phases, in line with the direction of the Article 16 of 'The Constitution of the People's Republic of Bangladesh' to remove the disparity in the standards of living between the urban and rural areas through rural electrification and development [16]. The energy prospect is generally assessed on the basis of available commercial sources of energy i.e., fossil fuel like gas, coal, oil etc. Worldwide, there is a major transition underway in the energy sector. It is happening due to the following three major reasons [16]:

1. A decline in fossil fuel availability, their predicted gradual extinction in the next few decades and the resultant price volatility due to demand-supply gap.

2. The need to drastically cut global emissions for mitigating climate change (80% reduction by 2050).

3. The need for energy security.

The GOB's objectives of renewable energy policy are to [16]:

- ❖ Harness the potential of renewable energy resources and dissemination of renewable energy technologies in rural, peri-urban and urban areas;
- ❖ Enable, encourage and facilitate both public and private sector investment in renewable energy projects;
- ❖ Develop sustainable energy supplies to substitute indigenous non-renewable energy supplies;
- ❖ Scale up contributions of renewable energy to electricity production;
- ❖ Scale up contributions of renewable energy both to electricity and to heat energy;
- ❖ Promote appropriate, efficient and environment friendly use of renewable energy;
- ❖ Facilitate the use of renewable energy at every level of energy usage;

- ❖ Create enabling environment and legal support to encourage the use of renewable energy;
- ❖ Promote development of local technology in the field of renewable energy;
- ❖ Promote clean energy for Clean Development Mechanism (CDM); and
- ❖ Policy sets targets for developing renewable energy resources to meet five percent of the total power demand by 2015 and ten percent by 2020.

5.2 Incentives and Financial Mechanism of RETs

A renewable energy financing facility shall be established that is capable of accessing public, private, donor, carbon emission trading and carbon funds and providing financing for renewable energy investments. The Power Division of the Ministry of Power, Energy and Mineral Resources, the Ministry of Finance and the Sustainable Energy Development Agency (SEDA) will formulate a detailed program for providing fiscal incentives including customs and tax exemptions for import and domestic manufacture of sustainable energy equipment. In addition to commercial lending, a network of micro-credit support systems will be established especially in rural and remote areas to provide financial support for purchases of renewable energy equipment. GOB will facilitate investment in renewable energy and energy efficiency projects. SEDA, in co-operation with local government offices, will set up an outreach program to develop renewable energy programs. SEDA will consider providing subsidies to utilities for installation of solar, wind, biomass or any other renewable/clean energy projects. Private sector participation including joint venture initiatives in renewable energy development will be encouraged and promoted. GOB/SEDA may assist in locating the project(s) and also assist in acquiring land for renewable energy project(s). Renewable energy project investors both in public and private sectors shall be exempted from corporate income tax for a period of 15 years. Renewable energy project investors both in public and private sectors shall be allowed to get various fiscal incentives and accelerated depreciation up to 80% may be allowed in the first year. An incentive tariff may be considered for electricity generated from renewable energy sources which may be 1.25 times the highest purchase price of electricity by the utility from private generators. To promote solar water heaters, rates of both electricity and gas may be refixed to discourage electricity and gas use for water heating [16].

Renewable energy project(s) selling electricity from plants shall be required to get a power generation license from the Bangladesh Energy Regulatory Commission (BERC) if the capacity of the project(s) is 5 MW or more. GOB and SEDA, in consultation with BERC will create a regulatory framework encouraging generation of electricity from renewable energy sources. BERC shall approve the energy tariff in consultation with GOB/SEDA as per the provision of the BERC Act 2003 if the capacity of renewable energy project(s) is 5 MW or more. Electricity distributors may offer “green energy” tariffs, which provide consumers an opportunity to co-finance through their electricity bills the development of new renewable energy sources [16].

5.3 Present Status on RETs Development

There have been a number of initiatives through donor supported pilot programs taken by relevant government organisations in Bangladesh to demonstrate renewable energy technologies like solar PV, biogas, solar home systems (SHSs) and improved cooking stoves. Unfortunately, most of the initiatives have not been continued after the completion of the pilot demonstration. This has been due to lack of local stakeholders' interest [17]. The pilot projects, which were taken initially, are summarised in Table 3.

Table 3: Summary of RETs Installation in Bangladesh [18, 19]

Technology	Installed Capacity
Solar	7.5 MW/150,000 SHS (Approximate estimation)
Biogas	25283 Nos.
Wind turbine	2.8 MW
Micro-hydro	10 kW

The maximum electricity that a solar panel can produce is 130 Watt(130 wup). Using this panel, 11 compact florescent lamps of 6 watt power and a 17-20 inche black and white TV can run. A DC current fan can also be run by this solar energy. To procure a solar panel one has to pay 15% down payment, the rest is covered by installments; total costs stand at Taka 68000 (A$ 1116.9). Direct purchase costs 2720 Taka (A$ 44.7) less. The maintenance cost for the panel is very low. The companies also give 20-25 years of warranty. So, although the installation cost of the solar panel is high, it will be more feasible if we think about the long term future.[20]

In this sector, there is scope for both local and foreign investment. There is also scope for both private and public entrepreneurship.It is learnt that the amount of investment in this energy sector in rural areas per year is more than Taka 2500 million (A$ 41.5 million). 60% of this is invested in solar panels, all of which have to be imported from outside Bangladesh. 25% is invested in batteries and the remaining 15% in small mechanical parts. Batteries and accessories are all produced in the country. In the near future, the solar panels will also be produced locally. Now, more than 300000 houses across 465 of the approximately 1000 subdistricts and 16 islands are getting the light of solar energy.

The beneficiaries of this system are about 3 million people. 44 megawatts of electricity are produced every day from the solar projects in Bangladesh.[20]

In order to generate electricity from Wind Energy, BPDB has installed 4x225 kW = 900 kW capacity Wind Mills in the Feni Muhuri Dam area. These machines were hooked up with a nearby REB 11 kV feeder. Additionally, 4 wind measuring towers at a height of 50 meters were installed at Muhuri Dam (Feni), Moghnama (Cox'sBazar), Purki Saikat (Patenga) and Kuakata area. The speed and direction of wind is being measured by two anemometers in each place at a height of 30 and 50 meters respectively [2]. A project for a 1000 kW Wind Battery Hybrid Power Plant at Kutubdia is running on. This project consists of 50 Wind Turbines of 20 kW capacity each.

Some small potential exists for mini hydropower generation in hill tracts area of Bangladesh. A 50 kW generator has been installed at Barkal area of Rangamati district. Installations of compact fluorescent lamps in different offices of BPDB headquarters have already been completed, And more will be installed in different offices of BPDB in phases [2].

Planning for Solar & Wind Projects of BPDB [2]:

1. BPDB is implementing 20.16 kWp Solar Power System (hybrid) to run 8 kW of lighting load at the Prime Minister's office.

2. BPDB has planned to install Solar Home systems in all Officies of BPDB in phases for Lighting Purposes (150-200k WP).

3. BPDB has planned to develop 4grid connected solar power plants with total installed capacity of 10-15 MW.

4. BPDB has planned to expand Wind Power (100 MW offshore) in coastal areas.

6. Benefits of RETs: Bangladesh Perspective

Benefits of RETs are numerous. Only the well-established proven benefits are outlined below which are collected from authentic sources and firmly believed by the author [21].

6.1 Socio-Economic Benefits

From the global experience, it has been observed that RETs are economically viable for distant rural electrification programs, which upgrades the living standard of the rural population. This fact has also been fully endorsed by the Rural Electrification Board (REB), a state-owned utility devoted to rural electrification in Bangladesh since 1978. A large portion of the remote areas is not likely to be covered by the grid network due to inaccessibility and low consumer density. RETs are considered as viable technical options for remote off-grid areas. Deploying RETs will not only provide electricity, it will become a stimulant for other development activities, like poverty alleviation, health care, education, women empowerment, family planning etc. This argument is supported by a research which shows how commercial energy usage is inter-related with infant mortality, illiteracy, life expectancy and fertility in the industrialised and developing countries. A recent USAID study's findings and assessments about impact of the rural electrification program in Bangladesh are as follows [22]:

- 93.7% of the electrified households reported decrease in fuel cost;
- 78.2% reported an increase on working hours;
- 62.0 % reported an increase in household income;
- 81% reported an increase in reading habits;
- 93.7% reported an increase in children's study time;
- 92.0% reported an increase in amusement as well as standard of living; and
- 94.7% reported an improvement in security.

In the subsequent sections, different socio-economic benefits are described briefly.

Employment

RETs are up to three times more employment-intensive than fossil fuel or nuclear power options. This benefit can be easily seen from the global wind energy business. According to a survey by Danish wind energy manufacturers, 17 worker-years are created for every megawatt of wind turbine manufactured and five worker-years for every megawatt wind power installed. In the year 2000, the wind energy industry provided more than 85,000 jobs worldwide and could provide up to 1.8 million jobs by 2020 [23]. Electrification of microenterprises in the off-grid areas can increase income or create new job opportunities for the rural poor which has been observed from the experience of Grameen Shakti which is a leading NGO involved in the RET sector.

Healthcare

At present, a large amount of population is deprived of proper health care due to absence of electricity in remote far-flung areas. RETs can be used by the rural health clinics for lighting and vaccine refrigeration. Understanding this opportunity, South Africa has launched a project to electrify its rural health clinics by Solar Photovoltaic and gained significant benefit.

Education

Like health clinics, most of the rural off-grid schools don't have electricity. These rural schools for different amenities can use RETs. Modern benefits will not only attract more students, but will also retain quality teachers and staff currently unwilling to be posted in the unelectrified areas. In the evening, the school facilities can be utilised for other social services like adult education, health education or recreational activities.

Family Planning

Electrification helps family planning activities. An exhaustive analysis to find out the link between electrification and fertility in Bangladesh shows that the fertility rate among girls is 0.67 in electrified households and 1.17 in nonelectrified households.

Development of Rural Women

If given the chance, rural women can be good entrepreneurs which has been noticed by Grameen Bank whose micro-credit program has been acclaimed all over the world. Renewable energy projects can be implemented in the rural areas of Bangladesh with women's participation. Recently a microenterprise of 33 women in a remote island of Bangladesh has shown a glaring success. This microenterprise is (1) assembling, marketing and selling DC lamps; and (2) charging and leasing batteries using a Diesel genset. Now it is preparing a Solar Electrification Service. Similar projects can be replicated in other places that will contribute to the overall development of rural women.

6.2 Energy Security

It is an established fact that RETs can promote energy security and price stability by diversifying the energy supply. Currently, in the remote areas, usually diesel gensets are used for a few hours in the evening for off-grid electrification. Bangladesh imports diesel with hard-earned foreign currency. It is obvious that substituting the diesel gensets with RETs can diversify the energy mix and thereby save foreign currency. As RETs are modular, energy requirements can be met on-site very quickly and can be scaled up in the course of time with growing demand. Another problem associated with the conventional grid is line interruptions, which in the case of RETs are much less and can be avoided if the user is trained properly.

6.3 Environmental Benefits

Combating Greenhouse Gas Emissions

Bangladesh is most vulnerable to sea-level rise. The population is already severely affected by storm surges. Catastrophic events in the past have caused damage up to 100 km inland. It is hard to imagine to what extent these catastrophes would increase with accelerated sea-level rise. In Figure 8, Digital Terrain Modelling techniques have been used to display the impact of sea level rise in Bangladesh. A three dimensional view of the country has been overlaid with the current coastline and major rivers, and potential future sea levels at 1.5 meters higher. Since this scenario was calculated in 1989, the expected rate of sea level rise has been modified. At currently expected rates, this stage can occur in about 150 years from now [21].

Even a very cautious projection of 10 cm sea level rise, which would most likely happen well before 2030, would inundate 2500 sq. km, about 2% of the total land area. Patuakhali, Khulna and Barisal regions are most at risk from sea level rise. On average, the sea would move in about 10 km, but in the Khulna region, the sea will likely move in further. With the high-end estimates, sea level rise in Bangladesh would inundate 18% of the country by 2100 [21].

So, Bangladesh should encourage clean RETs to combat greenhouse gas emissions to avert the potential threats.

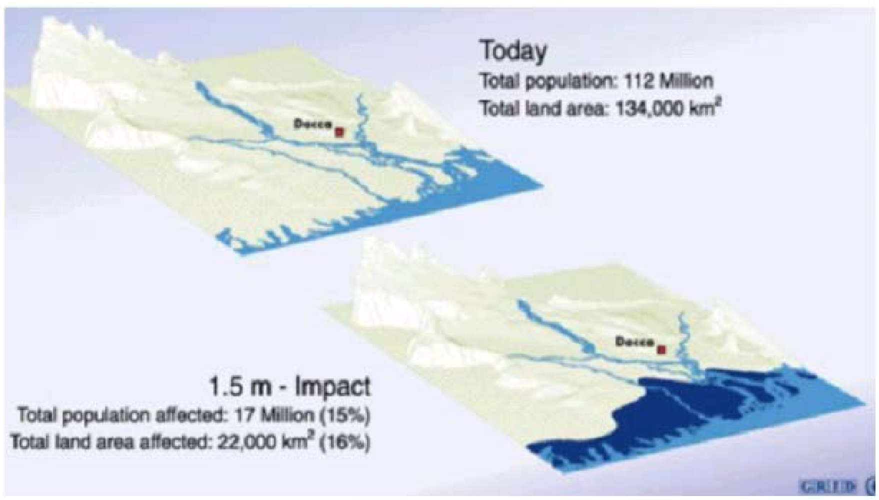


Figure 8: Potential impact of sea-level rise on Bangladesh [21]

Flexibility Mechanisms of Kyoto Protocol

During the Sixth session of the Conference of the Parties (COP), 180 countries have reached agreement on rules for an emissions trading system and other measures that will be used to reach the target, set in Kyoto Protocol in 1997, for a cut of about 5.5 percent between 1990 and 2012 in greenhouse gas (GHG) emissions by industrialised countries. Kyoto Protocol [21] includes 3 flexibility mechanisms, namely:

1. Joint Implementation (JI), described in Article 6, which allows sharing of GHG reduction benefits between developed and developing countries if a developed country enterprise invests in GHG reduction in a developing country;

2. Clean Development Mechanism (CDM), defined in Article 12, which would allow trading of GHG reduction between developed and developing countries. As agreed by the Parties in COP-6, the " Executive Board" will be formed in COP 7 to develop and recommend to COP, at its eighth session, simplified modalities and procedures for the clean development mechanism project activities including

Renewable Energy Project activities with a maximum output capacity equivalent of up to 15 megawatts [COP 6, Part2]; and

3. Emissions trading stated in Article 12, which has been allowed under the Kyoto Protocol between the Annex B (i.e. developed) countries.

It is widely expected that developing countries, including Bangladesh, will receive assistance from developed countries in terms of finance, technology-transfer etc through the above-mentioned flexibility mechanisms.

7. Conclusion:

In the context of Bangladesh, power generation from renewable energy is a more promising and viable option than that of conventional fossil fuel. When compared with electricity generation from conventional sources, the electricity generation from solar energy cannot compete on the cost basis, but its merits are unique so far as the question of serving the rural and offshore communities at remote places in Bangladesh far away from the grid is concerned. In this paper, it is clearly demonstrateded that the other RETs like wind, hydropower and biofuel are also very cost effective, if we think about our near future. By the proper use of renewable energy in generating electricity, Bangladesh can attain its opportunities for reducing CO_2 emissions, job creation, income generation, women empowerment and benefits from a quality environment.

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