Prospects and Utilization of Renewable Energy in Bangladesh: A Review Article

Rahamat Ullah Tanvir, Muhammad Rubayat Bin Shahadat, Manoj Ghosh, Mohammed Khan

Abstract— A majority of the people around the world are largely dependent upon fossil fuels like oil, natural gas, and coal on fulfilling their energy needs. It is necessary to find alternative energy sources as the fuels will be depleted within a certain period of time due to its limited reserve. Renewable energy is a sustainable energy source that will play a pivotal role in full filing the ever increasing energy demand. As it is clean energy and does not emit any hazardous gas or materials to the environment, it is likely to be the preferable energy source to provide energy and environmental security. Bangladesh is a developing country and it is facing difficulties in supplying energy to maintain its economic growth as well as sustainable development. Though Bangladesh has a very negligible carbon footprint, but it is one of the most vulnerable nations in the world for the effect of climate change. Renewable energy can be the only option which can reduce the associated risks. This review article studies different sources of renewable sources in Bangladesh and possibilities of contributing to meet the energy crisis. This study also provides a synopsis of present scenario and initiatives that are taken by different governmental and nongovernmental organizations to promote the generation and use of renewable energy.

Index Terms— Biomass, energy crisis, fossil fuel, geothermal energy, renewable energy, solar energy, tidal energy, wind energy etc.

1 Introduction

BANGLADESH is a developing country and the demand for energy is increasing rapidly in different sectors. As the country is flourishing with more industries, mitigating the demand for more power is becoming a challenge. The current population of Bangladesh is about 164 million and has the lowest energy consumption per capita in south Asia region. The energy use per capita in Bangladesh is 215.52 kg of oil equivalent where other countries in the neighborhood such as India and Sri Lanka have energy use per capita of 606.05 kg and 457.52 kg of oil equivalent respectively (World Bank 2013). This means Bangladesh still could not reach the expected productive potential.

As the demand is increasing, the crisis for energy is being acuter. Approximately 51% people of Bangladesh are dwelling in the off-grid areas having no access to electricity [1]. Moreover, the over-dependency on fossil fuels leads to various environmental hazards. This gap between the supply and demand is expected to widen in the following years. To overcome those energy barriers, renewable energy sources can be pivotal. Renewable energy offers a degree of advantage over the fossil fuel as they are regenerative, hardly have any effect on the environment and can be produced at a large amount with the help of proper technology. Bangladesh has a great possibility in harvesting energy from different sources. The widely known sources of renewable energy are solar, biomass, wind, wave energy, tidal energy, geothermal energy and hydropower. Among all those, solar and biomass have the most potential prospect in Bangladesh. To promote the production of renewable energy, appropriate government policy as well as the availability of proper technology plays a very important role. The government of Bangladesh has formulated a new policy to promote renewable energy sector which sets a goal to generate 5% of total energy from renewable sources by 2015 and 10% by 2020 [2]. Various government and non-government organizations are working to promote renewable energy sector and to increase the generation of renewable energy. Several limitations are impeding the generation of renewable energy in this country. Some noteworthy hindrances to generating renewable energy could be inadequate access to new technologies, geographic location, low budget, bad government policies etc. Bangladesh has a huge possibility in the field of renewable energy if proper technologies and government goodwill is available.

This paper reviews the present scenario and the prospect of several renewable energies in contrast of Bangladesh. The limitations to achieve the desired level of renewable energy production are also discussed in this study.

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2 Solar Energy

The geographic location of Bangladesh is in between 20.30° N and 26.38° N latitude and 88.04° E and 92.44° E longitude. This is an ideal location having a total area of 1.49E+11 m² for solar energy generation. The average solar radiation is 5 kWh/m² that descend over the land for approximately 300 days per annum. Maximum solar radiation occurs during the months March to April and the minimum radiation occurs during the months December to January.

A study estimated that in Bangladesh, the daily sunlight

hours vary 7 to 10 hours which is subjected to further reduction by approximately 54% due to cloud, rainfall and fog. So this huge amount of solar energy has a large potential which can be used in various sectors in Bangladesh. The resulting effect would be the reduction of the traditional fossil fuel based power consumption which will further ensure a green environment for our future generation [3]. There are two ways to harness solar energy- (1) Photovoltaic Cells and (2) Solar Thermal Energy [4]. Generally, a PV cell is a solid state electronic device which converts the sunlight into electric current based on the concept of photoelectron effect.

Materials used for photovoltaic solar cells include monocrystalline silicon, polycrystalline silicon, amorphous silicon, cadmium telluride, and copper indium sulfide. This variation of materials basically offer varying level of efficiencies, with the current average efficiency of a solar cell ranging from 8%-20%. Historically says that PV panels were used for off-grid purposes, avoiding construction of long and expensive power lines to remote areas. Off-grid PV systems have normally use storage devices like- Battery to store excess electricity so that it can run the cell for a few hours in the absence of sunlight [5]. Due to the advancement of technology and research, the cost of new photovoltaic power is dropping rapidly. It is expected that the cost of solar energy will be comparable to the cost of conventional energy by the end of 2020 if the advancement continues [6], [34]. Solar thermal energy is depicted as a form of renewable energy in which the sun is used to generate heat for various purposes. Solar thermal energy has been used for a variety of tasks for thousands of years. With the advancements of technology, the applications of solar thermal energy expanded substantially [7]. This has low operating cost and high efficiency which can be utilized by using thermal storage [8]. Monthly global solar insolation at different cities are presented in the following table.

Table 1: Monthly Global Solar Insolation at Different Cities of Bangladesh (in kWh/m^2/day)

Month	Dhaka	Rajshahi	Sylhet	Bogra	Barishal	Jessore
January	4.03	3.96	4.00	4.01	4.17	4.25
February	4.78	4.47	4.63	4.69	4.81	4.85
March	5.33	5.88	5.20	5.68	5.30	4.50
April	5.71	6.24	5.24	5.87	5.94	6.23
May	5.71	6.17	5.37	6.02	5.75	6.09
June	4.80	5.25	4.53	5.26	4.39	5.12
July	4.41	4.79	4.14	4.34	4.20	4.81
August	4.82	5.16	4.56	4.84	4.42	4.93
September	4.41	4.96	4.07	4.67	4.48	4.57
October	4.61	4.88	4.61	4.65	4.71	4.68
November	4.27	4.42	4.32	4.35	4.35	4.24
December	3.92	3.82	3.85	3.87	3.95	3.97
Average	4.73	5.00	4.54	4.85	4.71	4.85

Source: Dr. Shahida Rafique, Dhaka University (1988 to 1998)

Solar insolation data can be found from different sources. Renewable Energy Research Centre (RERC) at Dhaka University, Bangladesh Meteorological Department and the Department of Mechanical Engineering, Bangladesh University of Engineering and Technology have got time series data of solar insolation of Dhaka and other major cities [33]. Besides, some other governmental and non-governmental organizations also have time series data of sunshine hours, the temperature difference in different places, global radiation, beam radiation and diffuse radiation. But for precise estimation and simulation of different solar energy applications, several other parameters are required which are not available at the moment.

2.1 Implemented Projects by Bangladesh Power Development Board (BPDB)

Bangladesh Power Development Board has already implemented the Hill Tracts Electrification Project in Juraichori, Barkal and Thanchi Upazilla of Rngamati district. Under three phases, 1200 sets Solar Home Systems of 120 W each, 30 sets Solar PV Street Light Systems of 75 W each, 3 sets Solar PV Submersible Water Pumps of 1800 W each, 6 sets Solar PV Vaccine Refrigerators for the Health Care Centers of 360 W each and 2 sets 10 kW capacity Centralized Solar System for market electrification has been installed. The total capacity of the PV systems that have been installed under this project is 173.81 kW [15].

In the fiscal year 2008-09, BPDB implemented another two solar electrification projects in Angoorpota and Dohogram Chitmohol. Under this program, BPDB implemented 2 sets Solar Home System of 50 W each, 2 sets Solar Home System of 80 W each and 8 sets Solar Home System of 100 W each. A total of 1.06 kW Solar PV Systems have been installed in Angoorpota and Dohogram Chitmohol. BPDB implemented a total of 20.16 kW Solar PV System during this time. In the fiscal year 2010-2011, a total of 43.37 kW Solar PV System has been implemented in Dhaka, Chittagong and Cox's Bazar. In the fiscal year 2011-2012, BPED has implemented total 63.86 kW PV systems at different locations of the country such as- Bidyut Bhavan, Khagrachori BPDB Rest House, Swandip Power House, Sales & Distribution Division of Fouzdarhat and Rangamati. In the fiscal year 2012-2013, BPDB has implemented total 93 kW solar PV systems at different locations of the country [15].

2.2 Ongoing Projects by Bangladesh Power Development Board (BPDB)

Some major projects of Bangladesh Power Development Board that are now operational are- 650 kW solar mini-grid power plant at Sunamgonj, 8 MW grid connected power plant at Kaptai, 3 MW grid connected power plant at Jamalpur, 30 MW solar park project at Kurigram and solar street lightening projects in seven city corporations of the country [15].

2.3 Projects under Planning

BPDB has planned to install 1 MW Grid Connected Solar Power Plant at Rajshahi, 500 kW Grid Tied Solar System at Chandpur, 500 kW Solar Mini Grid Power Plant in Swandip. It has also planned to implement the Solar Park Projects under the Roadmap of ADB's 500 MW Solar Power Mission at different places of the country [15].

3 Biomass

Biogas is produced when there is a biological breakdown of organic material and other things in absence of Oxygen. Organic wastes such as dead plant and animal material, animal dung and kitchen waste can also be converted into a biogas. Biogas can also be originated from the biogenic material. Biogas consists of 40-70% methane, 30-60% carbon dioxide and 1-5% other gases [9]. In Bangladesh, the most promising renewable energy is biomass. Most of the households, especially the rural households in Bangladesh use biomass fuels. However, there is a limitation of supply from biomass sources. The main reason is the scarcity of land. The main positive side of biomass energy is that it does not emit many harmful gasses compared to other conventional energy sources. It basically emits two gasses- carbon dioxide and ethanol. The carbon dioxide which is emitted by the biomass energy is captured back for its own use whereas all the fossil fuels release it in the environment which is responsible for greenhouse effects and climate change. The source of biomass is abundant in Bangladesh. It is a universal form of renewable energy. The main reason is, different types of organic matter can produce various products [10]. The components of a biogas based electricity generation system are a generator, a biogas collection tank and a digester. There are also some piping and controls that are required for the operation of a biogas based electricity generation system. The biogas is produced in the anaerobic digester because of anaerobic fermentation which is provided every day with livestock manure in the form of cattle dung [9]. IDCOL had a target of setting up 37,669 biogas plant within 2012 and also planned to set 25% of total biogas plant to be placed in the northern region which is yet to be brought under the national gas grid [11].

A non-governmental organization named Grameen Shakti is working to promote biogas. They have completed 13,500 biogas plants throughout the country. Another non-governmental organization named Seed Bangla Foundation proposed to build a biogas power plant in Rajshahi of 25 kW capacity [9].

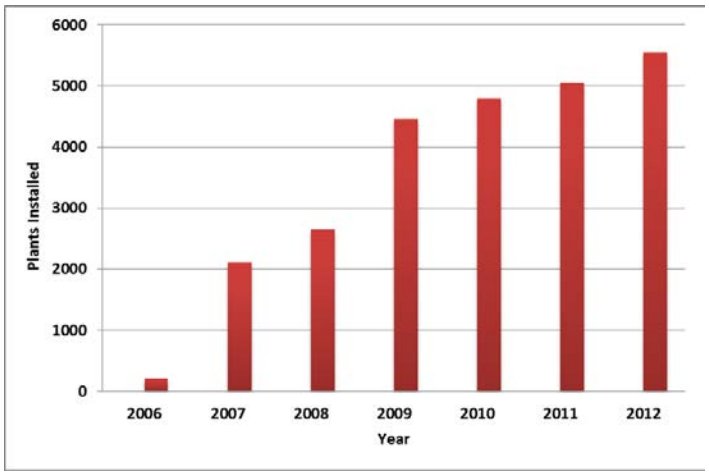

Fig. 1: Biogas plant construction in Bangladesh by NDBMP [9]

Some organizations are also working independently to promote biogas plants with their own funds. Such as- Grameen Shakti has built 3664 biogas plants, BRAC built 3664 plants of their own [12]. A total of 18713 biogas plants have been set up by IDCOL and other organizations since May 2011 [9].

4 Wind Energy

The wind is an important source of renewable energy. As the country is situated in the tropical region, it has a lot of wind flows throughout the year [13]. But not all the areas have the potential to harness wind energy. The potential places for harnessing wind energy are- river sides, offshore islands, lands with large open space, coastal areas, Sea beach where the wind flows strongly [15]. Bangladesh has seven hundred Km coastal line. As a matter of regret, an analysis was performed by CWET India which showed that wind energy resource of Bangladesh is not good enough for grid connected wind parks [14]. At a glance, references show that Bangladesh has a population of 160 million and electrification rate is 59.60%. Total electrical energy installed capacity is 12229 MW (2016) [15] and total installed wind energy is 1.9 MW. Wind energy potential in Bangladesh is over 20,000 MW [16], the wind speed being less than 7 m/sec. The research in the field of wind energy in Bangladesh has not expanded well yet. Previous research shows that some places in the southern region of the country have the potential for harnessing wind energy [17]. Based on these studies, it can be said that small wind turbines can be put to use in the coastal and offshore islands to harness wind energy [18].

4.1 Wind Data from Bangladesh Meteorological Department

Bangladesh Meteorological Department takes wind data at a lower height. But normal hub-heights of modern wind turbines vary from 20 to 40 m. Hence using this data while designing modern wind turbine may cause failure of the system [13].

4.2 Implemented Projects by BPDB

Bangladesh Power Development Board has already installed 4 grid connected wind plants each of which has a capacity of 225 kW at Feni. It has also installed 50 wind turbines each of which has a capacity of 20 kW at Kutubdia in 2008. The latter is a Wind Battery Hybrid Power Plant.

Steps have been taken to install 15 MW Wind Power Plant across the coastal regions of Bangladesh after one year Wind Resources Assessment in Muhuri Dam Area of Feni, Mognamaghat of Cox's bazar, and Parky Beach of Anwara in Chittagong, Kepupara of Borguna and Kuakata of Patuakhali. Wind Mapping is going on at Muhuri Dam area of Feni and at Mognamaghat of Cox's bazar by Regen Power tech Ltd. of India. Installation of Wind Monitoring Stations at Inani Beach of Cox's bazar, Parky Beach of Anwara, Sitakundu of Chittagong and at Chandpur under USAID TA project is underway for implementation [15].

4.3 Wind Data Analysis by BUET at Gazipur

Bangladesh University of Engineering and Technology (BUET) recorded the wind speed data from August 1997 to July 1998 on a daily basis using a data logger. The nature of the wind regime has been determined from these data with the help of Weibull function. The following table shows the wind speed data for one year where K and C are the shape factor and scale factor respectively [13].

Table 2: Standard deviation method derived from one-year data at Chandona (Aug.'98 -Jul.'99)

Month	K	C (m/s)	V_{mean} (m/s)
January	2.95	3.06	2.74
February	2.80	3.31	2.95
March	2.45	3.69	3.27
April	2.56	4.85	4.31
May	2.53	4.76	4.23
June	2.90	5.28	4.20
July	3.20	3.77	3.20
August	2.21	3.74	3.31
September	2.08	3.12	2.76
October	2.18	2.54	2.21
November	2.31	2.63	2.33
December	3.00	2.56	2.29

4.4 Wind Energy Study Project (WEST)

Table 3: Monthly average wind speeds from seven WEST stations at 25 meters height [13].

Month	Name of the wind speed monitoring station					
	Patenga	Cox's Bazar	Teknaf	Char Fashion	Kuakata	Kutubdia
September'96	3.36	3.69	3.46	3.34	3.77	3.58
October'96	3.20	3.74	3.30	3.70	2.18	3.98
November'96	2.61	2.93	2.29	Lost	1.98	3.23
December'96	2.97	1.78	1.44	3.90	3.35	3.38
January'97	3.25	2.33	1.99	2.80	3.18	3.67
February'97	2.66	1.99	1.90	2.69	3.37	3.29
March'97	3.13	2.42	2.26	3.54	4.84	3.53
April'97	2.88	1.84	1.65	3.29	4.93	3.11
May'97	4.96	3.97	3.09	4.81	6.28	4.89
June'97	5.83	4.64	3.26	5.76	7.31	5.90
July'97	5.67	4.80	4.33	5.22	7.34	6.17
August'97	5.13	4.31	4.03	5.17	Lost	5.34

4.5 Projects under Planning by BPDB

BPDB has planned to implement 50-200 MW wind power project at Parky Beach area, Anawara in Chittagong on IPP basis. According to Power Division of Bangladesh and BPDB, there are 22 highly potential sites for Wind Resource Mapping in Bangladesh. There is also a plan to establish Wind monitoring stations for comprehensive Wind Resource Assessment. It has also plan to expand On-shore wind power plants along the coastline of coastal regions of Bangladesh.

4.6 Wind Energy Program under Grameen Shakti

Grameen Shakti installed 3 hybrid power stations having a capacity of 1.5 kW and another one having a capacity of 10 kW in four cyclone shelters of Grameen Bank [13].

4.7 Wind Energy Program under Bangladesh Rural Advancement Committee (BRAC) [13]

Program 1-

1. Energy Resource: Wind Turbine
2. Number of installation: 3
3. Capacity of installation: 0.9 KW
4. Location of Installation: Coastal Area

Program 2-

1. Energy Resource: Wind-Diesel Hybrid System

2. Number of installation: 7
3. Capacity of installation: 4.32 KW
4. Location of Installation: Coastal Area

4.8 Wind Energy Program under Bangladesh Center for Advanced Studies (BCAS) [13]

1. Energy Resource: Wind Turbine
2. Type of installation: Water pumping windmill irrigation
3. Capacity: 1X1.0 KW, 3X1.5 KW, 1X10 KW
4. Location of Installation: Patenga, Chittagong.
5. Functional Status: Functioning

5 Hydropower

Hydropower is one of the oldest power sources on the planet. As it produces no air pollution hydropower is considered to be the most significant and eco-friendly renewable energy source. Being economic and technically beneficial most countries give priority to develop hydropower. In the United States of America, 11 states get 10 percent of their electricity from hydropower. In case of Washington State, over 70 percent of the total electricity comes from hydropower. Theoretically, China has the richest hydro resources on the planet [19].

In ancient Greece, hydropower was generated when flowing water spins a wheel or turbine. Even today flowing water is forced through a penstock, which carries water to turbines and generator rotated by the turbines generates electricity. Some hydropower facility can meet the sudden change in demand for electricity as they can go to zero power to maximum output very quickly. Scientists are also trying to discover a method to harness the energy that is produced through the movements of the ocean [19].

5.1 Hydro Energy Scenario & Prospect of Micro Hydro Power Application in Bangladesh

In Bangladesh, the scope of hydropower generation is actually very limited as most of the country has plain terrains except some hilly region in the northeast and southeast parts of the country. Being the largest hydropower station of Bangladesh, Karnafuli Hydro Power Station has the capability of generating up to 230 MW. Firstly, in 1962 with two hydro turbine alternators put 80 MW electricity. In January 1982, the third generator of 50MW started power generation. Two more alternators having 50 MW capacity were installed in 1988 to exploit the additional potential. It is operated by Bangladesh Power Development Board (BPDB). BPDB has also identified two other prospective sites for hydropower generating stations in Sangu River (140MW) and Matamuhuri River (75MW) [20].

However tiny waterfall in the Chittagong Hill Tracts (CHT) and rivers like Karnafuli, Shangu, Matamuhuri with a lot of canals, tributaries have good potentials for mini/micro hydropower units. The first micro hydro power plant in Bangladesh has been installed by Aung Thuwi Khoi Marma, a residence of Mongjaipara village, Bandarban. The plant is based on indigenous technology which uses wooden waterwheel to drive a locally procured generator. At first the electricity generated from this 10 kW power plant was supplied to a local Buddhist temple. But now he is trying to provide 140 families of his village with electricity generated through his micro hydro power plant run at his own cost [21]. 50-70 kW Mohamaya Irrigation-cum-Hydro Power Project at Mirersorai, Chittagong and rehabilitation of 50 kW Micro-Hydro Power Plant at Barkal Upazila of Rangamati district are two of the ongoing projects of BPDB.

6 Ocean Wave Energy

Ocean wave energy is generated directly from the waves of the oceans. It can be potentially a significant source of electricity for Bangladesh. This wave energy can also be used for water desalination or pumping of water other than generating electricity. According to [22], "The Oscillating Water Column method is technically feasible and becoming attractive in this purpose.

This type of wave energy harnessing device is being commissioned by several countries such as the United Kingdom, Ireland, Norway, India and so on. Bangladesh has the potential to harness wave energy from the Bay of Bengal [23].

Any site in the world with an average wave power level of over 15kW per meter has the potential to generate wave energy at competitive prices. From the atlas shown in the figure, it can be seen that for the Bay of Bengal the value is 8 kW per meter of crest width. So, at present Wave power is not a viable option for Bangladesh [24].

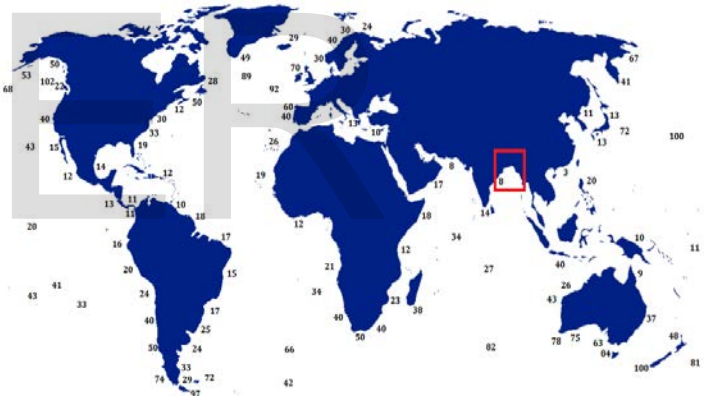

Fig. 2: Annual average wave power in kilowatts per meter of crest width for various sites around the world.

7 Tidal Energy

Tidal energy is harnessed from the energy of tides using proper technology. This is one form of Hydropower. As tides are more predictable than wind and sunlight, tidal energy can easily be generated from the changing sea levels. The coastal of Bangladesh has a tidal rise and fall of between 2 to 5 meters. Among these coastal areas, with 5-meter tides experienced, Sandwip has the best prospect to generate tidal energy. According to [25], Bangladesh has the opportunity to generate tidal energy in the coastal and near coastal areas using both low and medium head tidal movements. Low head tidal movements use tides having a height of 2 to 5 m which are more appropriate for areas like Khulna, Bagerhat, Barisal, Satkhira and Cox's Bazar. High head tidal movements use tide height of more than 5 m which is only feasible in Sandwip. Depending on the availability of tidal elevation, this can make

a great contribution to the energy security [23].

This tidal range can easily be converted to pollution free clean renewable energy by using the simple low-cost technology of a "tidal wheel" in the sluice gates. The real benefits of this technology however are that it can be applied in a way that simultaneously enables the development of local infrastructure and various resource producing activities such as agriculture and aquaculture along with improved living conditions for the local people [26]. A demonstration tidal power project is being planned in Sandwip, one of the coastal island of Bangladesh, by ISTP of Murdoch University, Australia. ISTP has developed a feasibility plan for rebuilding a recently damaged sluice gate with a trial paddle wheel [REFOCUS March 2001]. If become successful, the tidal project of Sandwip can be replicated in the other coastal areas and which will usher new light in the region.

Table 4: Tidal levels in Coastal Bangladesh [BIWTA, 1999]

STATION	LAT	MLWS	MLWN	ML	MHWN	MHWS	HAT	TD(AT)
Hiron Points	-0.256	0.225	0.905	1.7	2.495	3.175	3.656	3.912
Sundarikota	-0.553	0.036	0.636	1.829	3.022	3.694	4.211	4.764
Mongla	-0.261	0.325	1.194	2.31	3.427	4.296	4.882	5.143
Khal no. 10	-0.444	0.261	1.231	2.664	4.097	5.067	5.772	6.216
Sadarghat	-0.423	0.239	1.1	2.481	3.861	4.722	5.385	5.808
Cox'	-0.339	0.205	1.023	1.995	2.967	3.785	4.329	4.668
S. Island	-0.348	0.191	1.045	1.874	2.703	3.557	4.096	4.444
Sandwip	-0.583	0.238	1.634	3.243	4.851	6.248	7.07	7.653
Char changa	-0.375	0.256	1.06	2.037	3.014	3.818	4.449	4.824
Khepupara	-0.323	0.195	1.025	2.06	3.096	3.925	4.445	4.768
C.Ramdaspur	-0.261	0.189	0.763	2.036	3.309	3.883	4.333	4.594
Barisal	0.134	0.434	0.692	1.539	2.386	2.644	2.944	2.81
Chandpur	0.019	0.256	0.493	2.172	3.852	4.088	4.326	4.307
Nalmuri	0.078	0.37	0.722	2.195	3.669	4.021	4.313	4.235
Narayanganj	0.458	0.585	0.697	2.77	4.844	4.956	5.083	4.625
Galachipa	-0.159	0.283	0.937	1.764	2.592	3.245	3.689	3.848
Patuakhali	-0.143	0.242	0.74	1.575	2.409	2.907	3.293	3.436

Explanation:
MLWS = Mean Low Water Spring, MHWS = Mean High Water Spring, MHWN = Mean High Water Neap, MLWN = Mean Low Water Neap, ML = Mean Level, AT = Astronomical Tide, LAT = Lowest Astronomical Tide, HAT = Highest Astronomical Tide, TR = Difference between lowest and highest tidal height in " m" [18].

8 Geothermal Energy

Geothermal energy is the heat from the Earth. It's clean and sustainable. Resources of geothermal energy range from the shallow ground to hot water and hot rock found a few miles beneath the Earth's surface, and down even deeper to the extremely high temperatures of molten rock called magma.

8.1 Components of Geothermal Systems:

Geothermal systems are made up of four main components: a heat source, a reservoir, a fluid (the carrier that transfers the heat) and a recharge area.

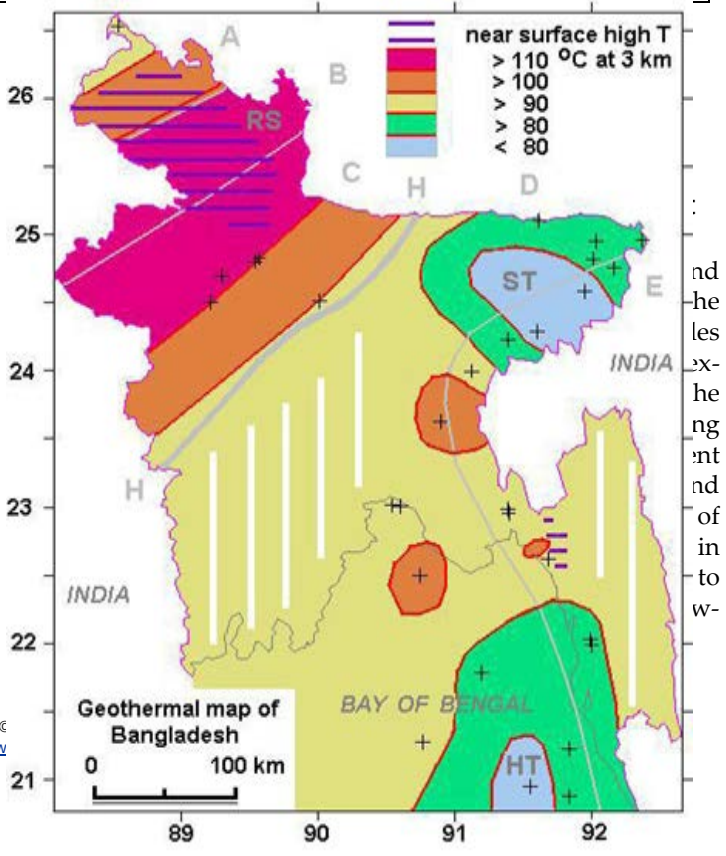

Fig. 3: Geothermal energy potential related to the major tectonic structural regions of Bangladesh [28]

8.3 Geothermal Gradient of Bangladesh

The tectono-stratigraphic set-up of the Bengal basin mostly controls the geothermal gradients of Bangladesh. The evaluation of the geothermal gradient of Bangladesh is necessary to understand individual tectonic elements with respect to the regional tectonic history. Geothermal gradients are measured from corrected Bottom Hole Temperature (BHT) using Horner's plot by adding 10 ^{O}C to the maximum recorded Bottom Hole Temperature. Surface temperature is taken as 24°C for onshore wells and 15°C for offshore wells. It is assumed that the temperature linearly increases with the increase of depth. With this assumption, the temperature of any depth can be expressed by the following equation [29], [30]:

$Tz=To+Tgz/100$

Tz = the wellbore temperature (°C) at depth z (m).

To =the mean surface temperature (°C).

Tg =the geothermal gradient in (°C/km).

8.4 Recent development in Geothermal Sector in Bangladesh

Recently, the Ministry of Power, Energy and Mineral Resources has approved the establishment of the first ever geothermal power plant of 200 MW in the country. Anglo MGH Energy, a Dhaka-based private company has planned this project. Based on the geothermal gradient, Bogra shelf and Rangpur saddle offer good conditions to implement geothermal plants. The set-up cost of a geothermal power plant is very high since it requires drilling wells. But the cost can be reduced by using abandoned onshore dry wells having adequate temperature gradient which is more likely 30 K per kilometer [31]. Geothermal energy produces no air emissions other than steam, and the water used in the conventional hydrothermal process often is injected back into the source reservoir. Because available water can be depleted, as can the heat, if too much cooler water is injected, there has been some discussion as to whether geothermal is truly "renewable" [32].

9 Present Scenario of Renewable Energy in Bangladesh

The consumption of energy is increasing day by day as the population is growing and industrial sector is flourishing. Along with this, the generation and consumption of renewable energy are also increasing. A brief summary of renewable energy consumption in Bangladesh as of 2014 is given in the following table [10].

Table 5: Implemented renewable energy in Bangladesh [10].

Category	Achievement (2014)
Solar Home System (3.3 million)	150MW
Solar System at the roof top of Govt./non govt. building	3 MW
Solar System at Commercial building and shopping mall	1 MW
Solar PV for new connection at roof top of buildings	11MW
Solar Irrigation (193)	1 MW
Wind-based power generation	2 MW
Biomass based power generation	1 MW
Biogas based power generation	5 MW
Hydro Power	230MW
Total	**404 MW**

Source: Power Division, 2014

10 Conclusion

As fossil fuel reserves are limited and energy security, as well as environmental crisis is a big issue, Bangladesh has to be strongly dependent upon traditional renewable sources. There is a considerable opportunity for Bangladesh to meet its future power demand, ensure sustainable development and economic growth through renewable resources. Renewable energy sources discussed above can help Bangladesh to reduce Load-shedding problem, irrigation problem and to solve different energy issues by producing more power. It is high time the government worked with these renewable energy fields to produce electricity instead of depending wholly on conventional method. Notable initiatives have been taken by different organizations of Bangladesh but it is not enough. The Renewable Energy Programs taken by BPDB and Grameen Shakti have become highly appreciable among national and international policy makers. The other private organizations should come forward and join hands with government to solve the future crisis situation.

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