Energy Security in Bangladesh through Renewable Energy Generation with Cost Analysis

A thesis submitted in partial fulfillment of the requirements for the Degree of Bachelor of Science in Electrical and Electronic Engineering

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CERTIFICATION

This is to certify that this thesis entitled "**Energy Security in Bangladesh through Renewable Energy Generation with Cost Analysis.**" is done by the following students under my direct supervision and this work has been carried out by them in partialfulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering. The presentation of the work was held on 27 June 2021.

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Dedicated to

OUR PARENTS
And
TEACHERS
With Love & Respect

DECLARATION

We do hereby declare that this thesis is based on the result found by ourselves. The materials of work found by the other researchers are mentioned by reference. This thesis is submitted in partial fulfillment of the requirement of the degree of B.Sc. in Electrical and Electronic Engineering. This thesis neither in whole nor in part has been previously submitted for any degree.

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TABLE OF CONTENTS

List of Figure

List of Table

ABSTRACT

Energy security is nowadays a major concern of all researchers all over the world. Bangladesh is a developing country which has not enough natural resources. Most of the Energy demand of Bangladesh meets from non-renewable sources and imported energy from abroad. This type of energy source which meets energy demand never ensures energy security for a country like Bangladesh. Renewable energy generation is no more an alternative, rather it becomes a choice for the power generation to meet the upcoming energy demand. Considering the non-renewable energy unavailability and as well as the environmental impact, renewable energy should be the first choice. As a developing country, using non-renewable energy sources is not cost-efficient and never ensures our energy security. To ensure long-term energy security, it is time to shift our power generation from nonrenewable to renewable energy generation.

This thesis presents a complete overview of Bangladesh's energy sector and also presents an approach to ensure the energy security of Bangladesh by using renewable sources. It also represents an approximate calculation for the renewable power generation cost and returning year.

CHAPTER – 1: Introduction

1.1 Introduction

It is considered that energy is an important parameter in the case of socio-economic development. Energy can play a big role in the development of economic growth, sustainable infrastructure, and also for improvement of lifestyle. The energy consumption level for any society reflects the extent of development. There is an estimation that the total demand for electricity in Bangladesh will reach around 20,000 MW in the year of 2021 [1]. The recent power generation of Bangladesh presents that fossil fuel contributes approximately 80 percent of the total share. A big amount of electricity is imported from abroad each year. The reserve capacity of natural gas and other non-renewable energy sources like oil, coal is now running out. Approximately 93% of Bangladesh's power generating steam plants are based on natural gas [2]. The country will suffer an internal energy struggle as the power generation completely depends on natural resources. It is being planned that coal will be the replacement source of natural gas to generate electricity. For the next 5 years the government is planning to produce 2900 MW power by using coal [3]. But, the reserves of coal are limited. Due to vast use of coal for the future plan of power generation, the amount of CO2 will be immense compared to the previous scenario. The amount of carbon emission from the power plant sector is 40 percent, if the government wants to install more coal-based power plant that will be more threatening for the environment [4]. The country is now facing alarming challenges for energy security where the concerns are increasing amount of imported electricity, a limited number of energy reserves, as well as the amount of electricity demand for the industrialization and improvement of modern life is increasing. The electricity demand will easily surpass the local reserve capacity of coal in the near future. Therefore, to meet the demand, to produce electricity, a significant amount of coal will be needed to be imported and it will be costly and the government and local users will not be benefited. Renewable energy sources can play a vital role for the energy security of Bangladesh and it will be a long-term solution.

Energy generation in Bangladesh is mainly dependent on non-renewable energy sources and a significant amount imported from abroad.

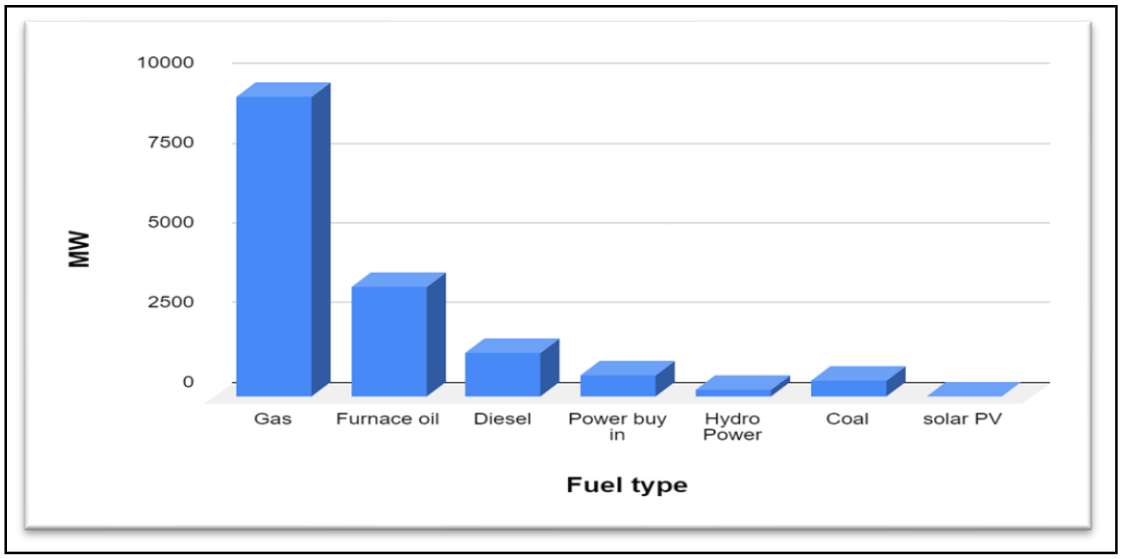

Figure 1.1: *Bar chart of Installed Capacity of Bangladesh (Source: BDB 2019 and SREDA 2020).*

It is clear from the above Figure 1.1 that the most power generation comes from gas and secondly, comes from the furnace oil. Most of the power generation is from nonrenewable energy sources where a negligible amount comes from renewable energy sources, besides that, a good amount of power is imported from abroad. The power sector of Bangladesh alone produces around 40 percent of CO2 [4]. It is an important alert for the power sector in Bangladesh and for the environment. The prime contributor of energy generation is gas which will not run longer than 10 years [5]. A major change is needed in the power generation sector of Bangladesh that is required to implement more power plants based on renewable energy sources. The energy demand will increase as always, and the major changes in lifestyle and the availability of technology and industrialization will make a rapid demand for power in the next decade. Currently, the Bangladesh government has planned to build 66 economic zones across the country for the economic development of the country where 55 are government and 11 are private sites [6]. This economic zone will accelerate the current energy demand. Agriculture and Industry are the two huge sectors where power is mostly consumed. The demand for electricity in these two sectors has been increasing continuously. About 45% of national power is consumed by agriculture and industry throughout the period 1995 to 2010 that is presented by BPDB. Bangladesh is a developing country, so, cost management of power plants is important to make a budget and get an idea how long it will take to return invested money.

1.2 General Overview on Electricity and National infrastructure

Electricity is the driving force of the modern world and everything is directly or indirectly connected to electricity. The energy demand all over the world is increasing and it will maintain continuously. Farming to satellite electricity is everywhere. A country's shape can be determined with the help of the energy structure of that country. Electricity also has a huge contribution to the economic growth of the country. The economy of Bangladesh nationally depends on two sectors which are Industry and Farming. These twosectors are the large consumers of electricity consumption. Electricity is the key feature ofour modern economy and the wheel of modern lifestyle. Electricity has a great impact on the national economy and nation's development. The energy demand should meet and that's why it is needed to ensure energy security. Electricity comes from different power generation plants where different renewable and non-renew resources are used. If there arenot enough sources of electricity then some fuel is imported from abroad and sometimes electricity directly imported from abroad if it is possible.

1.3 Energy Security

Energy security is termed as the capability of a nation to ensure sufficient, affordable as well as continuous energy supplies for its domestic, industrial, in a word for all the energy demand. Energy security is the Energy security will ensure the energy demand for the current scenario and for the future perspective of energy demand. Disregarding the economic and unsteadiness of politics, energy security will be able to meet the energy demand. Energy security is connected to the Energy Dependency, where energy dependency is a scale to measure which calculates the amount of energy consumption is dependent on the imported energy. Less energy dependency indicates more stability in energy security. Energy security collaborates with the national energy demand and the possibilities of natural resources for energy generation.

1.4 Cost Analysis

The cost analysis of a power plant generally takes into account total capital expenditure, operating cost, revenue, and return on investment. It will also calculate the power plant maintenance cost.

1.5 Renewable & Non-Renewable Energy

Energy is generally categorized into two categories:

Non-renewable energy has limited resources and it depletes over time**.** Non-Renewable energy produces greenhouse gases like carbon dioxide.

Non-renewable energy generation power plants use non-renewable sources to produce more power on demand. The non-renewable energy resources are:

- Coal
- Nuclear
- Oil
- Natural gas

Renewable energy comes from the renewable resources which can be replenished with the time. Renewable energy has the least impact on the environment.

Some popular renewable energy resources are:

- Solar
- Wind
- Hydro
- Biomass
- Geothermal

Even though renewable energy has unlimited supply for a long period of time it can't generate enough power if the demand increases in a significant way.

Table 1.1: *Differences between Renewable and Non-renewable Resources*

Differ Category	Renewable Sources	Nonrenewable Sources
Depletion	Renewable energy doesn't reduce over time.	Nonrenewable energy decreased over time.
Sources	1. Solar 2. Wind 3. Hydro 4. Biomass and Bioenergy 5. Geothermal	1. Coal 2. Nuclear 3. Oil 4. Natural gas
Environment Impact	Depending on the sources of renewable energy it may have some impact on the environment but in most cases, they have low carbon emission.	Nonrenewable energy typically releases: 1. Carbon dioxide, 2. Methane,

		And other gasses into the atmosphere that cause greenhouse effects.
Energy Cost	In the long-term perspective renewable energy is cost efficient comparing nonrenewable energy.	The upfront cost of nonrenewable energy is less than renewable energy.
Infrastructure Requirements	Renewable energy generation is expensive and may not be easily available in all countries.	Nonrenewable energy is cost effective and available across the world.
Land Required	To generate renewable energy more space is required comparatively from nonrenewable energy.	Nonrenewable energy generation takes less space than renewable energy.

There are several important differences available between renewable and non-renewable energy considering applications, availability, environmental impact etc. that is presented in the above Table 1.1. It also presents clear and concise ideas about renewable and non-renewable energy.

1.6 Thesis objectives

This thesis has the following objectives:

1. An approximate calculation to meet the energy security using renewable energy generation is done.
2. Evaluation of the impact of nonrenewable energy on the environment is also presented.
3. Identify the importance of renewable energy and some reasons for using renewable energy rather than using non-renewable energy sources considering the current power generation structure of Bangladesh is presented in this thesis.
4. To calculate the cost of power generation of six different renewable energy sources according to their calculated power generation capacity is done in this thesis.
5. To evaluate the returning year of investment for the six different power generation plants of renewable energy is calculated.

CHAPTER - 2: Power Scenario of World and Bangladesh

2.1 In Bangladesh

Bangladesh is a developing country with outstanding economic growth and good GDP. Electricity plays a very important role for this economic growth. The requirement of Electricity is increasing day by day. Now a day's total electricity demand of our country is approximately 20,000 megawatts. And the installed capacity of Bangladesh is 21,419 MW as of September 2019. Most of the electricity of Bangladesh is generated from Gas, and the lowest amount of electricity comes from Solar.

Table 2.1: *Installed Capacity according to fuel type [7]*

Gas	9413 MW (61%)
Furnace oil	3443 MW (22%)
Diesel	1380 MW (6.49%)
Power buys in	660 MW (4%)
Hydro Power	230 MW (1%)
Coal	524 MW (3%)
Solar PV	3 MW (0%)

The current power installation capacity according to fuel type with the percentage of contribution in power generation is presented in Table 2.1. Gas is the most used fuel type used for power generation where solar, as well as renewable energy, has the least contribution in power generation considering the data from Table 2.1.b

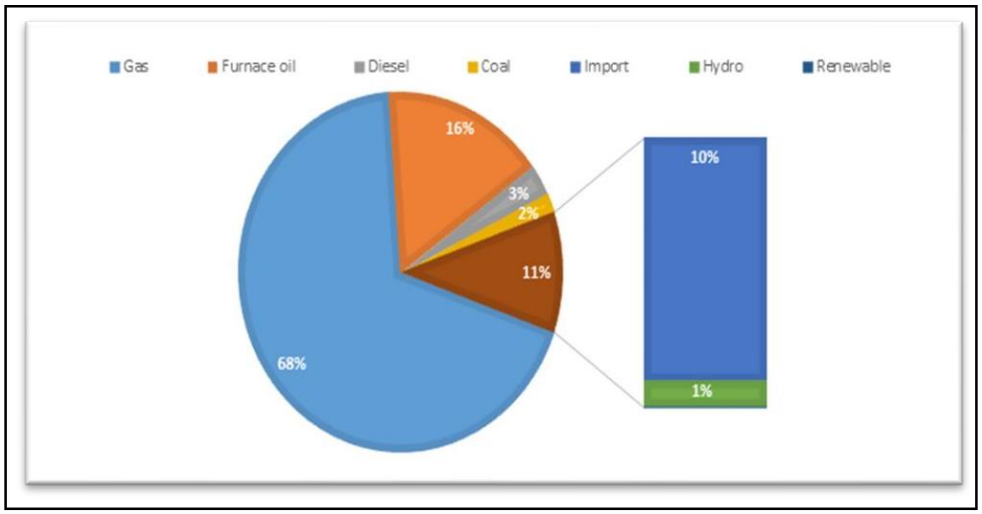

Figure 2.1: *Generation Capacity of Bangladesh (Source: BDB 2019 and SREDA 2020)*

Almost 68% of our total electricity comes from gas then 16% of electricity comes from furnace oil. 3% of total electricity generated from diesel, 2% of electricity comes from coal only which demonstrates in Figure 2.1. We also Import 10% of electricity from abroad. Here it is clear that only a little amount of electricity comes from renewable energy in Bangladesh. As we don't have enough natural resources, it's really a great threat for us.

2.2 In the World

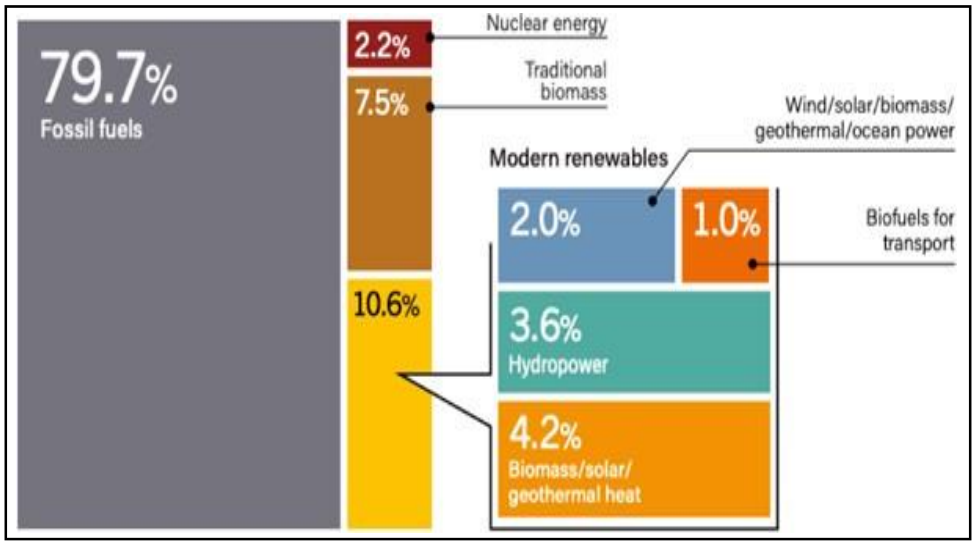

Figure 2.2: *Estimated Global Renewable Energy Share of Total Final Energy Consumption (2017)*

From a world perspective 26.2% of total energy is made from Renewables sources that is presented in Figure 2.2. That's expected to rise to 45 percent by 2040. It’s clear from the figure that the world is going for renewable energy day by day. It’s clear for all that only renewable energy can be the perfect solution for Energy Security.

The Whole world is trying to avoid the non-renewable energy sources as it’s very much harmful for our nature. The main fact is Non-Renewable energy can run out any time.

Where the other country is trying to avoid the non-renewable sources of energy and adopt the renewable energy sources there still Bangladesh is constructing more and more non-renewable power plants.

CHAPTER – 3: Estimated Power Generation

3.1 Introduction

The power generation structure of Bangladesh is mainly depended on the non-renewable energy. The power generation ratio is negligible for the renewable energy comparing to the non-renewable energy. The new power generation plan has also large part of non-renewable energy. The availability of non-renewable energy is in the verge of extinction especially natural gas.

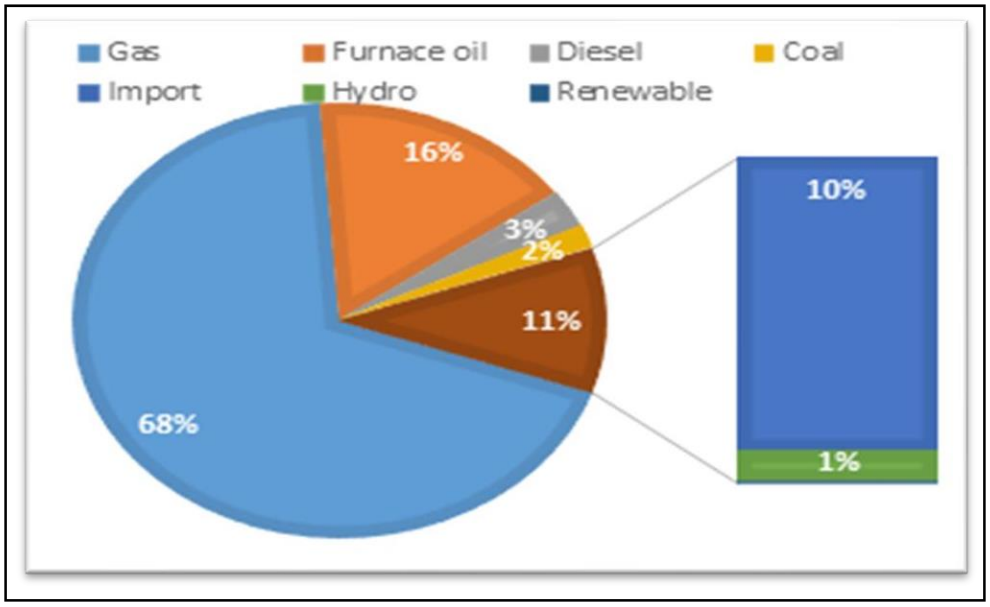

Figure 3.1: *Pie chart for the Installed Capacity of Bangladesh (Source: BDB 2019 and SREDA 2020)*

Figure 3.1 represents the power production structure of Bangladesh and it is clear that the power generation of Bangladesh is mostly dependent on non-renewable energy. The current condition of natural gas reserves in Bangladesh is not supportive as it has limited reserves. Where the most of the contribution in electricity generation is Natural gas. Natural gas contributes around 54 percent of electricity generation, that is half of the country's power generation.

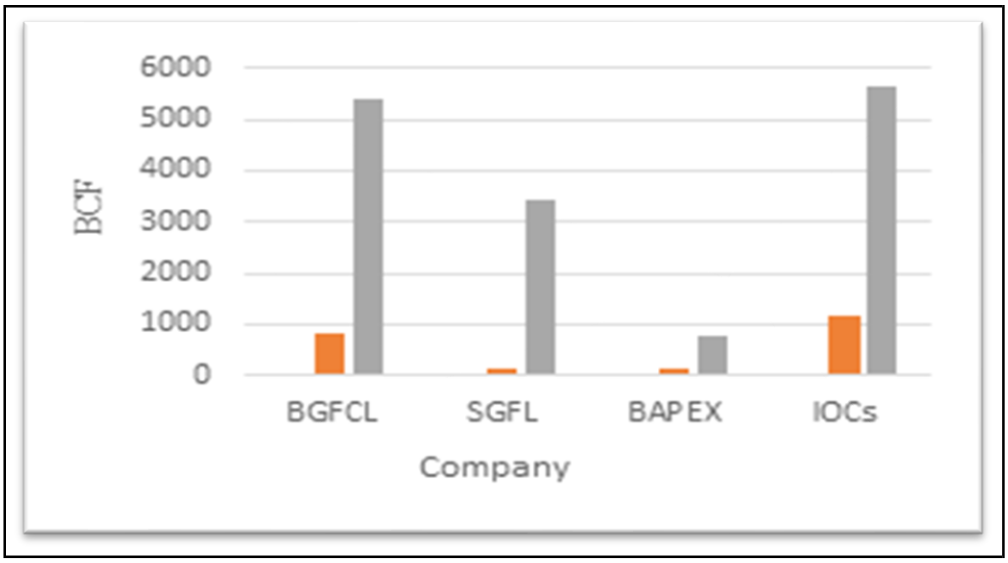

Figure 3.2: *Production and Remaining gas reserves of Bangladesh. (Petro Bangla)*

According to Figure 3.2 the amount of gas reserved by three national companies as well as IOCs in Bangladesh. The total natural gas reserves in Bangladesh is about 12 TCF. The annual consumption rate is around 1 TCF. According to the production rate and gas reserves, this natural resource will run out within only 12 years [5]. Coal is considered to meet the demand or replace natural gas as the resource of electricity production. Considering operational power plants as well as power plants under construction, it is considered that the power generation capacity of Bangladesh by using coal is around 5761 MW. The government has taken a plan to generate approximately 18434 MW with a target to meet the demand that will be from power plants based on coal. The net amount of coal reserve is appraised at 1.756 Giga tons [8]. This all will be the short-term solution for the electricity production that will not be effective for the long term and especially for the energy security of Bangladesh. To ensure energy security, renewable energy is the only solution.

3.2 Estimated Power Generation from Solar

The Bangladesh government has taken a good initiative to use renewable energy sources. Considering renewable energy sources, solar is the most important and it only provides 500 megawatt that is 39.5% of total share in case of renewable energy [9]. The Sustainable and Renewable Energy Development Authority of Bangladesh planned a mini-grid system for

the remote area. This is particularly for the area where electricity hasn't reached yet and this commercial model has been given importance for the implementation of mini-grid projects through the private sector. This mini-grid project set a target to have the capacity 25MW [10]. Bangladesh currently has a total 414.84 MW of solar installed capacity where Off-grid is 326.97 MW and On-grid is 87.87 MW [11].

Table.3.1 *Solar Mini Grid (Source: SREDA)*

Project	Mini grid	Capacity
Established Solar mini grid	11	2.19 MW
Running Placement grid	15	3.17 MW
Planning Future Project	61	-

Solar mini grid projects are described in Table 3.1 with grid number and generation capacity. The Solar Park project has a total of 36 projects with a total capacity of approximately 2110.56 MW. Among the 36 projects already 4 projects are done and running now in production. Also, 11 projects are ongoing and 19 projects are under planning. Among them 2 projects are rejected from the planning phase [11].

Solar rooftop:

The government sees the installation of solar power as a potential sector and has made it a prerequisite to get new power connections by installing solar panels to meet a certain portion of consumer demand. The government is encouraging the several factories to meet their certain demand by installing solar panels. This plan is expected to increase solar power around 20MW.

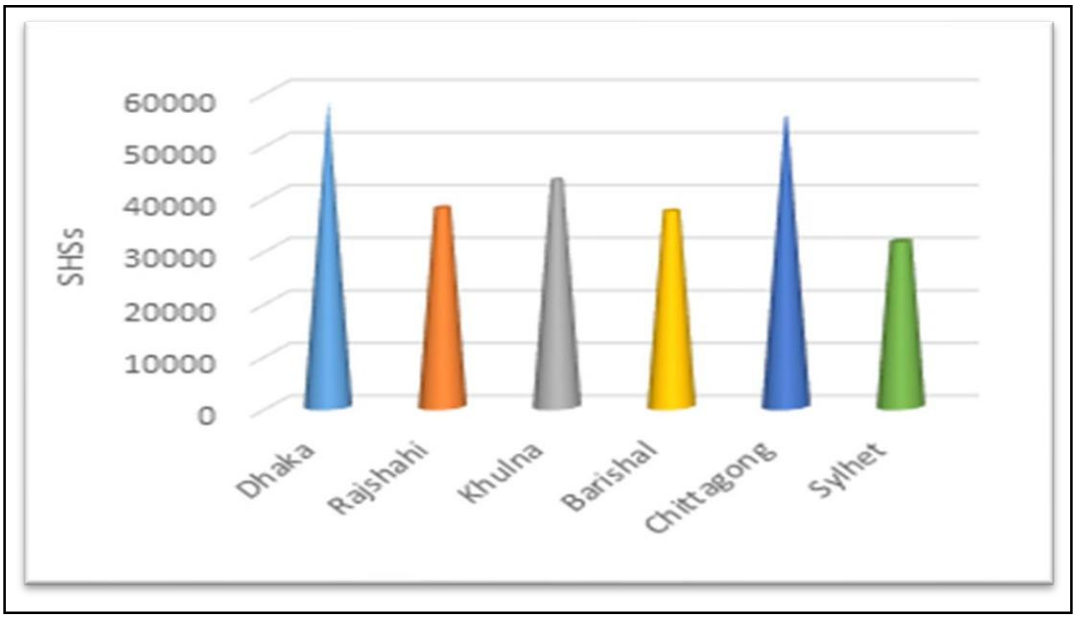

Figure 3.3: *Future Prospects of Solar Energy in Bangladesh [12].*

Figure 3.3 illustrates the number of solar home systems installed all over the country according to each division. Bangladesh has already installed over 50000 SHS and the distribution of the SHS is minimum in Sylhet district and maximum at the Dhaka district [12]. Considering the overall scenario and availability of renewable solar energy sources, there is a good opportunity to get electricity from this country. Bangladesh has 4-6.5 kW/m^2 solar radiation which is comparatively greater than many other countries in the world [13]. It is a subtropical country with 70% plentiful sunlight [14]. In the case of the dry season, Bangladesh gets 7.6-hour sunlight and for the monsoon it is 4.7 hours per day[15]. In each year around 300 days, solar radiation of Bangladesh has an average of 5 KWm^{-2}[15]. Only 100 sq. Feet or 10 sq. meter of rooftop or any sunny place is sufficientfor a 1000W solar system [16]. Around 400 industries have been identified which can consume approximately 20MW of electricity where it is possible to meet the full demand of electricity by using its own rooftop [17]. The average size of a rooftop in Dhaka city is1916 sq. Feet. and in Chittagong city is 2190 sq. Feet [18]. The total number of householdsin Dhaka is about 2034146 [19].

So, the total rooftop available in Dhaka city is 2034146*1916= 3,897,423,736sq. Feet. If it is possible to use only 10% of the total rooftop then the feasible area of the rooftop for the solar panel will be 389742374 sq. Feet.

100 sq. Feet provides 1 kW_p, then from the 389742374sq.Feet.

The total power will be =3897424 kW_p

If the average day time is 4 hours per day, then it's possible to get 15589.696 MW of electricity per day from Dhaka city. Textile sector of Bangladesh has 42 million sq. feet of rooftop and by using this it is very much possible to generate 400MW of electricity [20]. Bangladesh Railways can provide 10 million sq. Feet of the rooftop. By using this rooftop, it is possible to generate 91 GWh of electricity [21]. It can save 54 core taka per year. And in 20 years it will save 1078core [21]. There are almost 9000000 easy bikes (electrical auto) in BD. It is possible to charge all the easy bikes by using the "Solar-powered charging system" and by using this system it is possible to save 900MW electricity [20]. To set up a 10kW of solar charging station requires 1526000BDT. According to the IDCOL only 3.75 crore taka is required for a rooftop solar system which can provide 7555998 units of electricity per year. If the per unit price is 6 takas, then the price of these 7555998 units will be 4.5 crore taka per year.

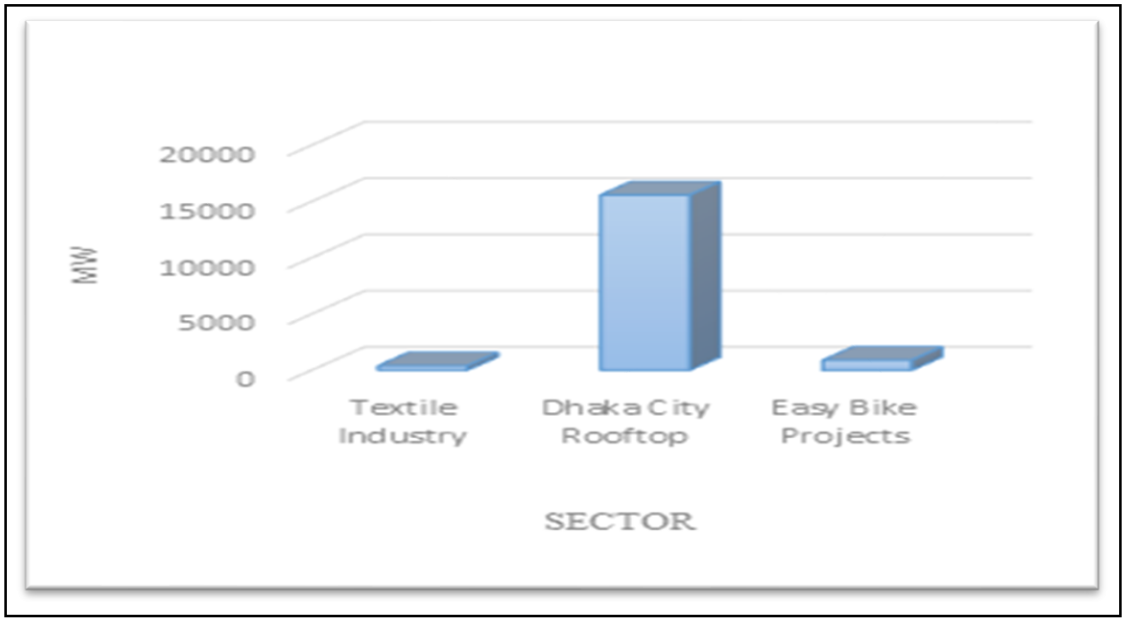

Figure 3.4: *Potential Electricity Generation Sector.*

There are several potential sectors for solar where it is possible to generate a big amount of electricity in this country which is highlighted in Figure 3.4. The total amount of

electricity generated from these sectors will be around 16889.696 MW. This amount of electricity can play a big role in the energy security of the Bangladesh power sector.

3.3 Estimated Power Generation from Waste

The waste management problem is a global challenge not only for our country. Across the whole world, there are approximately 2 billion tons of waste produced every year. But there are also some countries which turn this huge problem into a huge possibility. Waste production is increasing simultaneously with time. The generation of waste will increase by 70% worldwide before 2050. About 12MW electricity is produced from a plant in India which uses 2000 tons of waste per day [22]. Waste management becomes a major problem that is facing Bangladesh right now. Waste is such a by-product of human activities that is not possible to ignore. It is a bitter truth that the environmental condition of Bangladesh is degrading day by day. Production of waste is increasing with the improvement of living standards and greatly for the poor waste management. Waste is now a threat for the environment. Among all types of waste solid waste is increasing significantly and it is the worst waste. It is considered that around 40-60 percent of waste remains in the land for poor planning, insufficient budget in waste management and also for the selection of inappropriate technology [23].

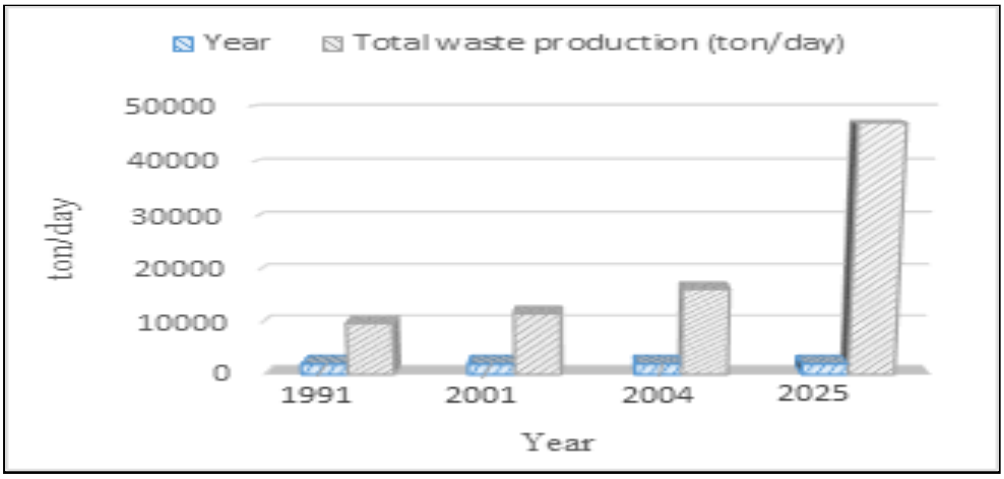

Figure 3.5: *Urban solid waste production in Bangladesh [23].*

It is clearly presented in the above bar chart in Figure 3.5 which demonstrates the urban solid waste production in Bangladesh through the period from 1991 to 2025.It is predicted that in 2025 the total urban solid waste production will reach around 47064 ton/day.

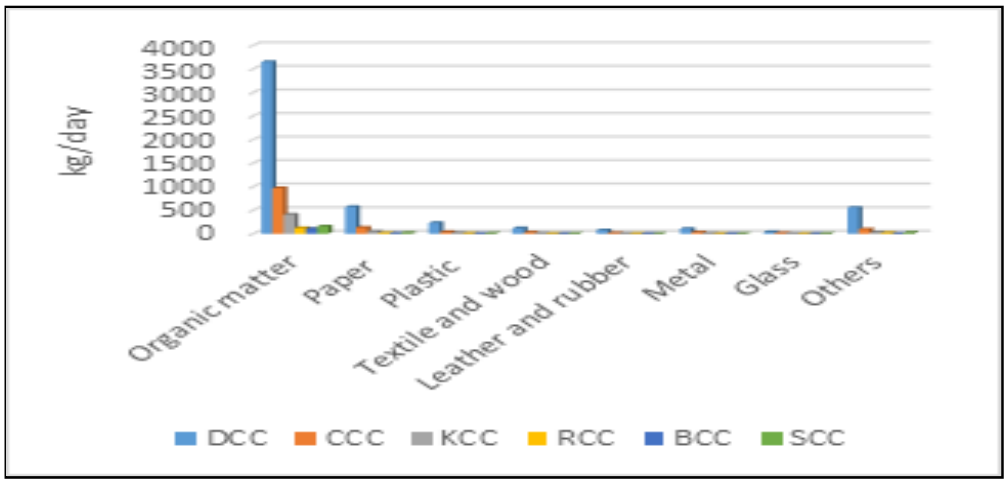

Figure 3.6: *Generation of waste each of Six cities [23].*

The per capita waste generation of six major cities in Bangladesh as well as the waste category is presented in Figure 3.6. Among the big six cities of Bangladesh, Dhaka produces the largest volume of wastages and lowest volume is produced by Rajshahi. Total electricity generation from the waste of six mega-cities will be around 186,408 kW/day [24]. Recently, Bangladesh is facing serious problems due to the huge number of wastes that stress on the carrying capacities of its natural ecosystems and its human service systems. The Bangladesh government is planning to generate electricity as well as thermal energy by using solid waste from the municipality. It is planning to implement a power plant of 1 MW at Keraniganj Upazila which is in Dhaka City. In this power plant around an amount of 55 tons waste will be used per day for generating electricity. This number of wastes will be generated from Keraniganj. This amount of waste will help to generate approximately 450 kW. [24].

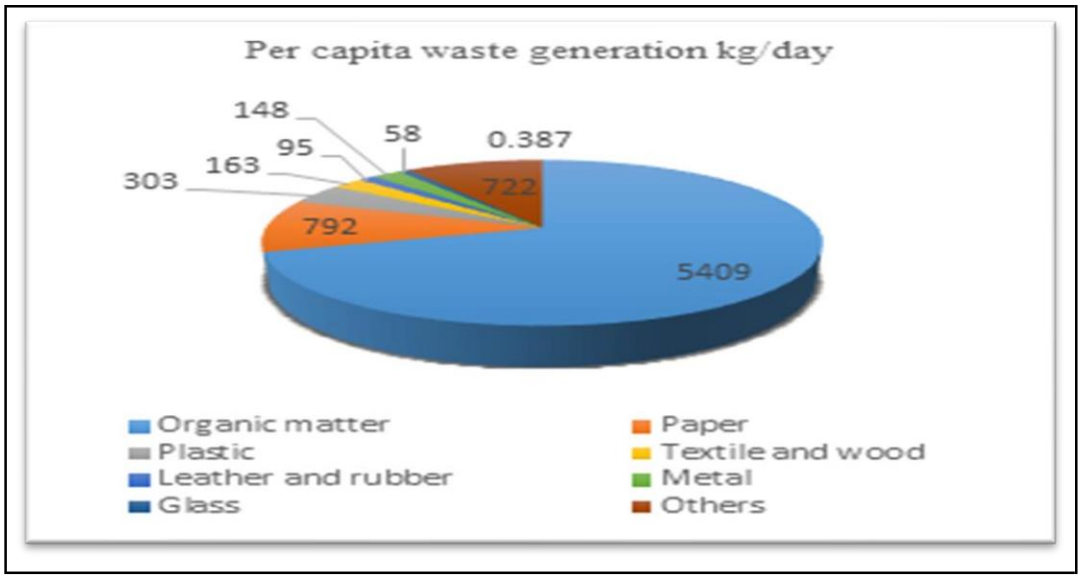

Figure 3.7: *Generation of different kinds of wastes for six major cities of Bangladesh [23].*

The number of different types of solid waste produced in six major cities is presented in Figure 3.7. The total amount of waste in Bangladesh right now is 20000 tons per day. By using this it is possible to generate more than 1000 MW of electricity. SREDA is going to install a 100kW municipality solid waste-based electricity generation project at Kushtia. According to ADBI, within 2025 total waste generation of Bangladesh will be 47064 tons per day. (220kg/cap/year) (0.6kg/cap/day).

3.4 Estimated Power Generation from Tidal

Tidal energy is considered as the important reliable energy source in Bangladesh. Bangladesh is a land of the river with sufficient tides much or little throughout the whole year.

Bangladesh has the huge possibility in the sector of tidal energy for the generation of electricity. The seaside region is suitable for tidal power generation. To generate tidal power the main conditions are the availability of tidal waves of more than 3 m in height and suitable for the embankment. Before choosing a tidal power station some key points also need to be considered like a stable tidal wave, low possibilities of natural disaster, away from the locality and should have an easy transmission system. Tide with heights of approximately 3-5 m is available in many coastal areas of Bangladesh. Tidal power is

possible to generate around the whole year and 24 hours in each day with an efficiency of 80%. Bangladesh has only one hydropower plant which generates 230 MW of electricity.

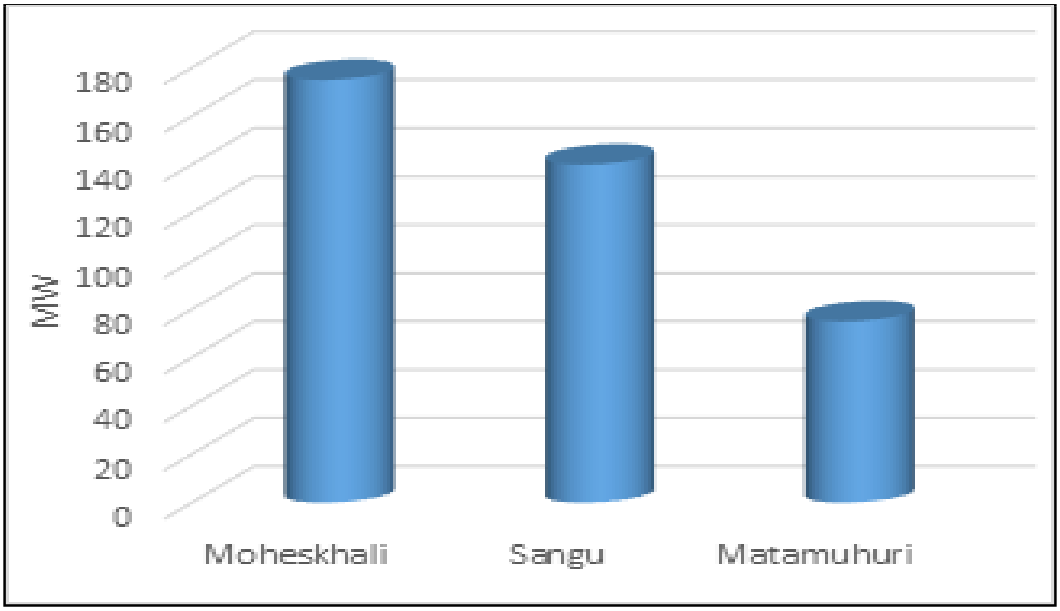

Figure 3.8: *Large Hydro Power Potential (MW).*

There is a high potential to set up three large hydropower plants in Bangladesh which is highlighted in figure 3.8. Those are Moheskhali, Sangu, and Matamuhuri and they will combinedly generate electricity of approximately 390MW [25], [26].

Figure 3.9 represents that there is huge scope to install different types of hydropower plants in Bangladesh like small, mini, micro. Evaluating the possibilities of the generation of each hydropower plant it is expected that there will be around 124702 kW [26] of electricity.

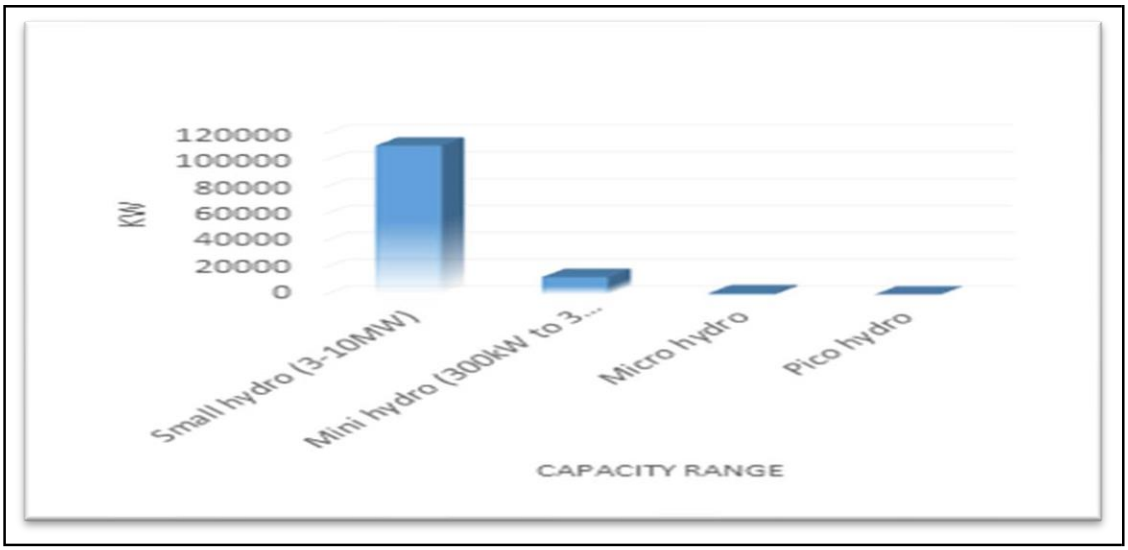

Figure 3.9: *Small hydro power plant (kW) [26].*

Several potential spots with tidal range and desired output power are presented in Figure 3.10. The total amount of potential tidal power is possible to generate 390(large hydro potential) + 124.702(others hydropower potential) = 514.702 MW. This is a significant amount for the power development of Bangladesh.

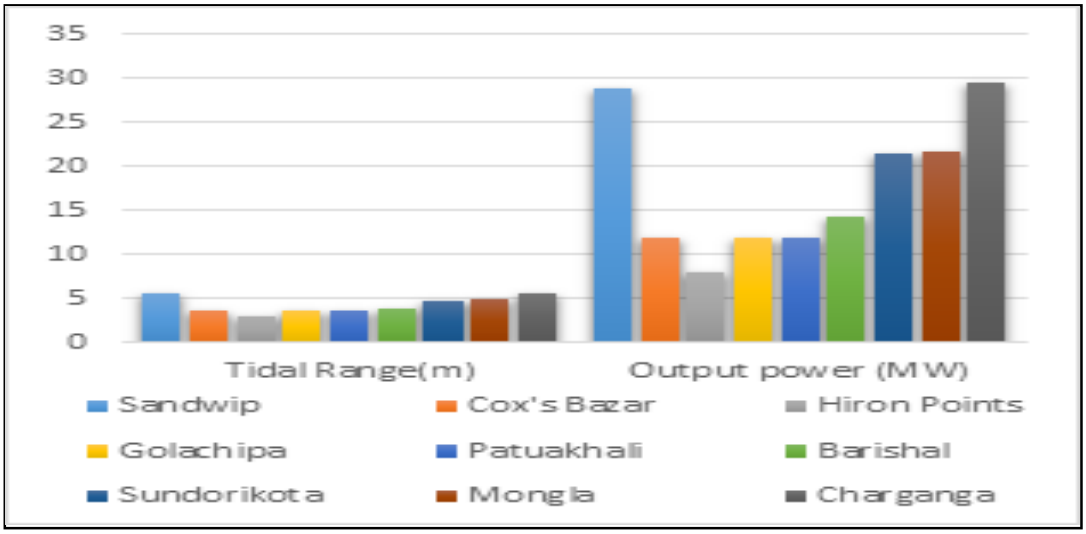

Figure 3.10: *Tidal range and Output power of most potential hydro power plants in Bangladesh [27].*

3.5 Estimated Power Generation from Biomass and Bioenergy

Biomass is actually biological material that comes from living organisms. Bioenergy is a type of renewable energy derived from biomass to produce electricity. Biomass energy is

considered as the first energy source which human beings used at an early time. All kinds of organic matters are under the coverage of biomass. Among all energy sources biomass is the fourth largest source of energy across the globe [28]. Biomass energy is generally used in case of the household purposes like cooking, warming and also used in generating electric energy. Biomass energy can be used to produce electric energy in many ways. Among them, direct combustion and gasification are the most popular and efficient to produce electric energy. In the case of direct combustion, the hot flue gas is produced which later turns to produce steam and this produced steam is used to generate electricity. Another one is gasification where the biomass produces medium or low calorific gas and this gas is used as gas in the case of a combined cycle power-producing plant. Agriculture is the main occupation for the people of Bangladesh. Most of the people depend on agriculture. So, biomass energy will be more productive here. Bangladesh produces around 35000000 MT (1MT=1000kg) of Paddy per year on an average [29].

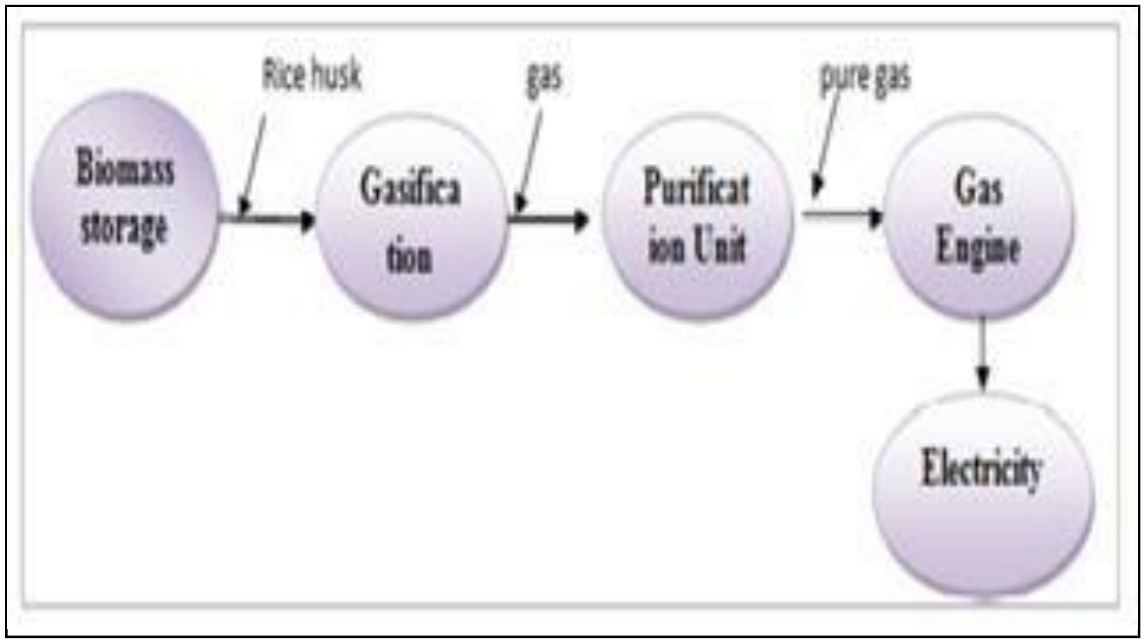

Figure 3.11: *Generation of Electricity by rice husk gasification [29].*

A schematic arrangement of husk gasification process for the electricity generation is presented in Figure 3.11. Approximately 364 MW of electricity is possible to generate by using only 20% of total husk in Bangladesh using gasification technique [29].

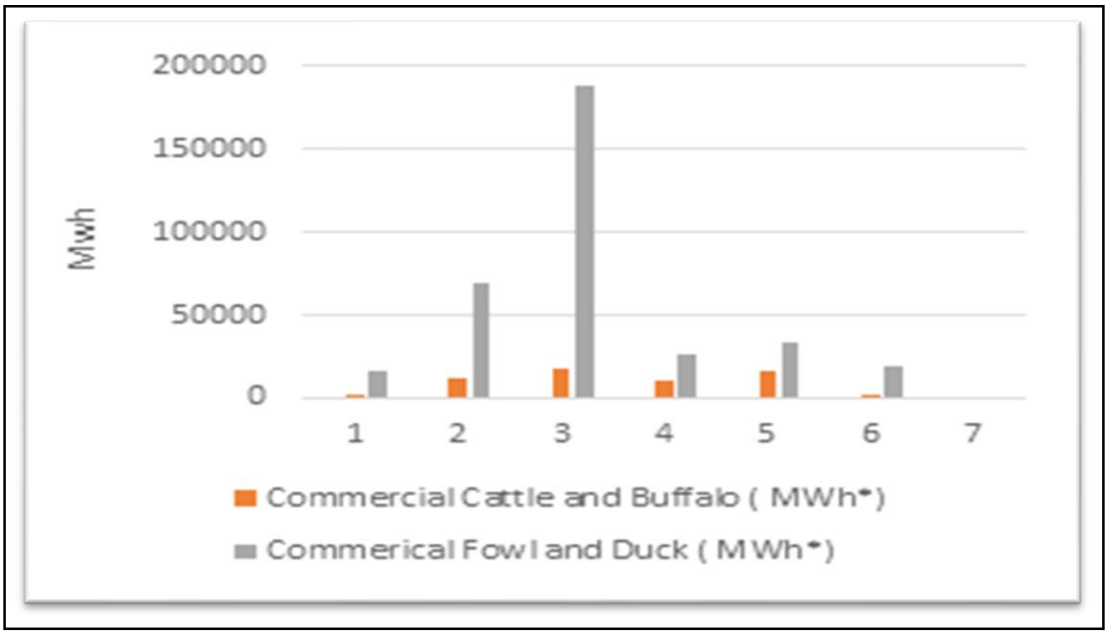

Figure 3.12: *Technical Potential of Commercial Cattle and Buffalos also Commercial Fowl and Duck [12]*

Several technical potential sectors for the electricity generation from biomass are presented in Figure 3.12.

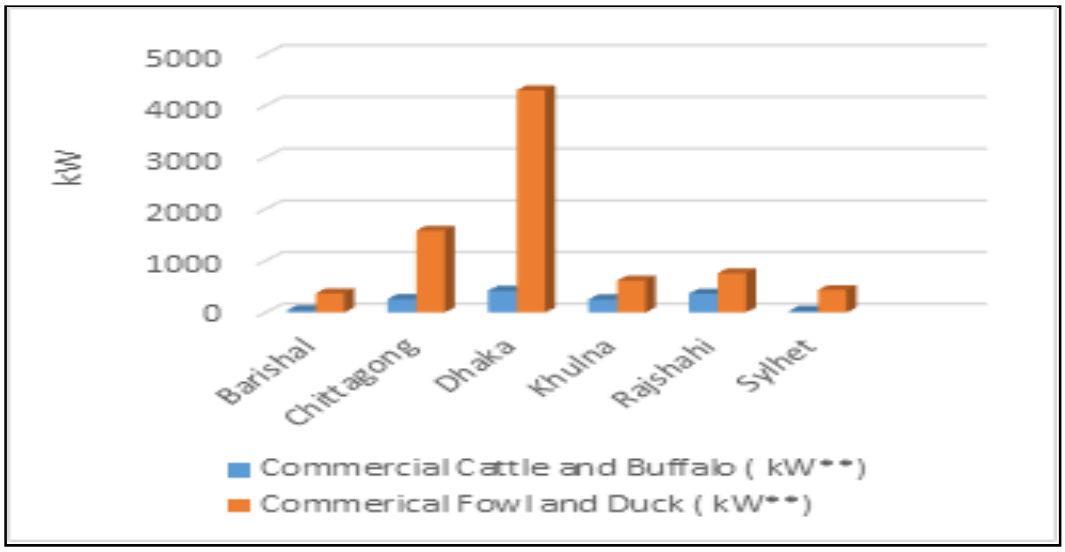

Figure 3.13: *Estimated Potential of Commercial Cattle and Buffalos also Commercial Fowl and Duck [12].*

The amount of potential electricity is possible to generate from six cities considering commercial cattle and buffalo; also, commercial Fowl and Duck is presented in figure 3.13.

Table. 3.2 *Potential industry to generate electricity from biomass energy [26].*

Factory	Mill Number	Amount	Generation Capacity (MW)
Sugar Cane Factory	15	267750	191.25
Rice Industry	540	18900	172
Poultry Farm	-	-	197
Waste Low Calorific Value	-	5000	20

There are some good potential sectors of biomass for the electricity generation as mentioned in detail with meal number and generation capacity in Table 3.2.

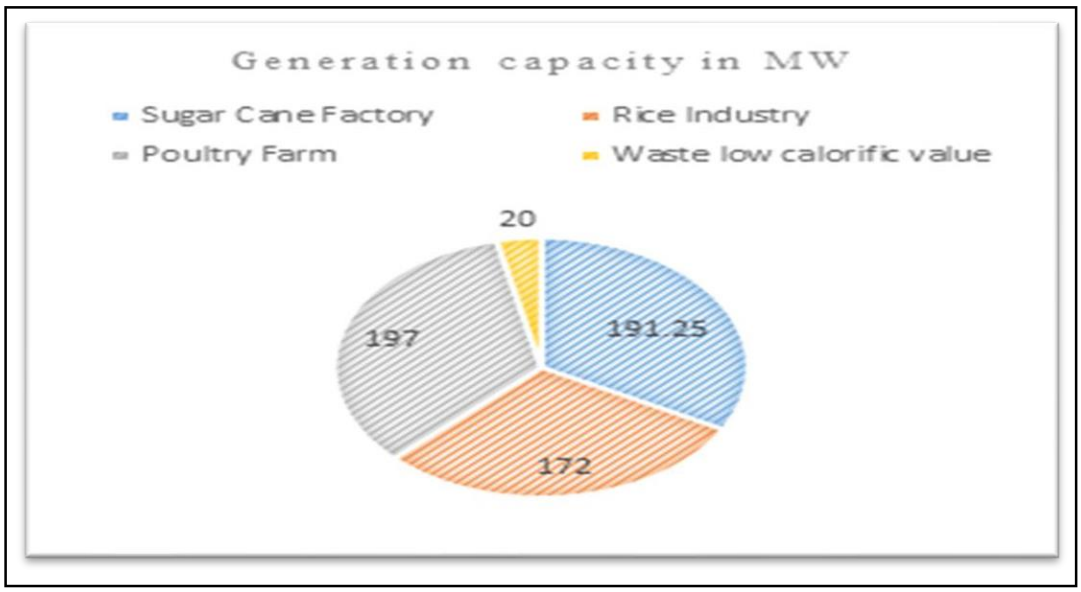

Figure 3.14: *Potential sector to generate electricity from biomass energy.*

The pie chart in Figure 3.14 presents the generation capacity of four different potential sectors of biomass for the electricity generation. Taking into account all the potential biomass energy the electricity production will be approximately 772.25 MW.

3.6 Estimated Power Generation from Geothermal

There are some geothermal potential spots in Bangladesh where it is possible to get geothermal energy. Those are Rangpur Saddle with 700m, Kuchma and Bogra with the kilometer range from 60 to 125 [30]. Warm water of Thakurgaon can be the main source of geothermal energy in this country. The Government of Bangladesh has a plan to install

a geothermal energy of 200 megawatt in Thakurgaon with the cooperation of Anglo MGH [31].

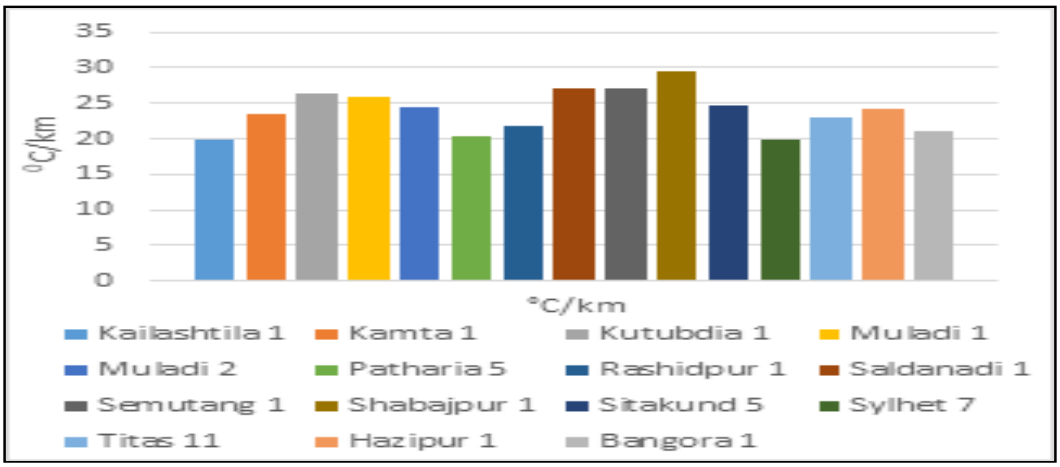

Figure 3.15: *Geothermal Gradients [32].*

Figures 3.15 and 3.16 represent the geothermal gradients for the deep wells along the Bengal Foredeep Region.

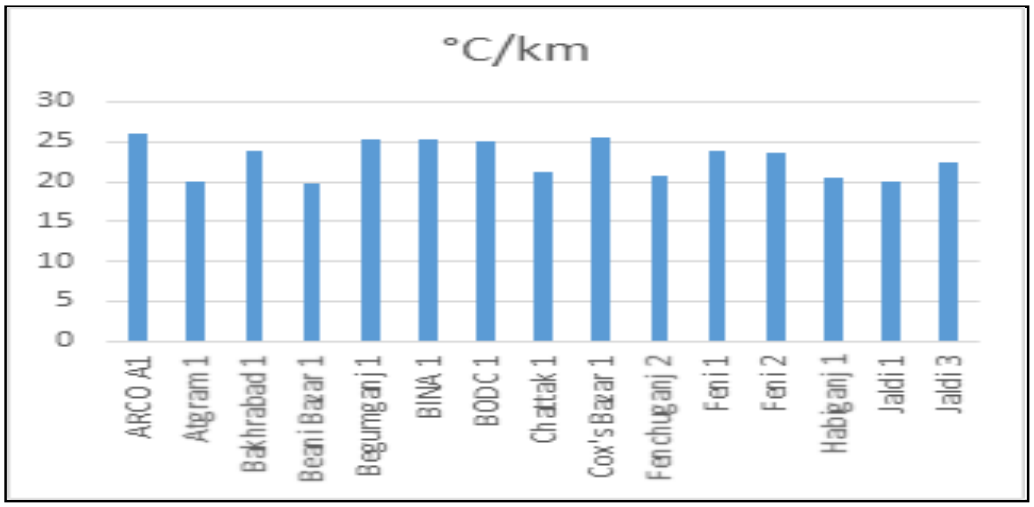

Figure 3.16: *Geothermal Gradients [32].*

The bar chart of Figure 3.16 shows geothermal gradients for the deep wells along the Bengal Foredeep Region. There is an approach by the Ministry of New and Renewable Energy (MNRE) from the government's that is to install 1000 MW of geothermal power plant in the first stage till 2022 and as well as there is an extended target to install 10000 MW by 2030 with the collaboration of the US, Philippines, Mexico, and New Zealand [33].

3.7 Estimated Power Generation from Wind

Bangladesh has some suitable locations to generate electricity from wind energy. A strong wind is available in the south/south-western region and it originated from the Indian ocean. This strong wind comes into Asia through the seaside area of Bangladesh. Normally this wind passes during the time between March and September that has an average speed ranging from $3ms^{-1}$ to $6ms^{-1}$. During the time of June and July the speed of wind is maximum and lowest in October to February [34]. Bangladesh has the coastal belt which is likely to be 724 kilometer that is the longest in the world [13]. A realistic and timely project is ongoing which has a generation capacity 50-200 MW and will be built in Chittagong. An amount of around 15 megawatts power plants is planned to be installed in Muhuri dam of Feni , Mognamaghat, Parky Beach, Kuakata and Kepupara [12].

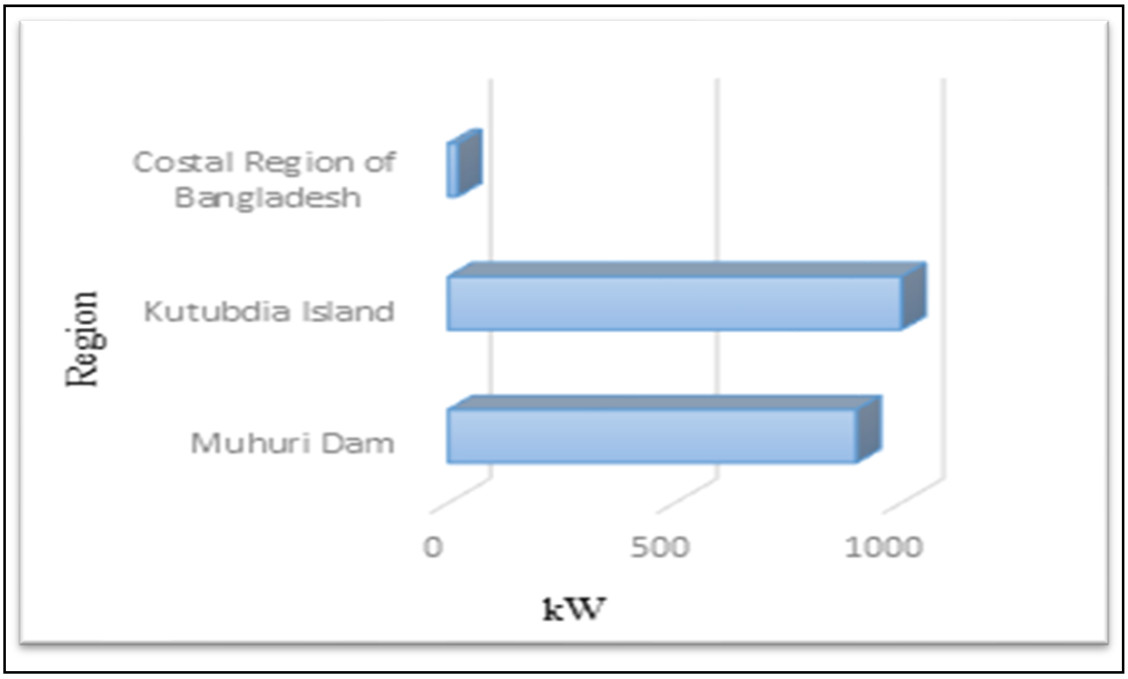

Figure 3.17: *Current Wind power situation of Bangladesh [12].*

In Figure 3.17, the current scenario of the electricity generation from wind power in Bangladesh is presented.

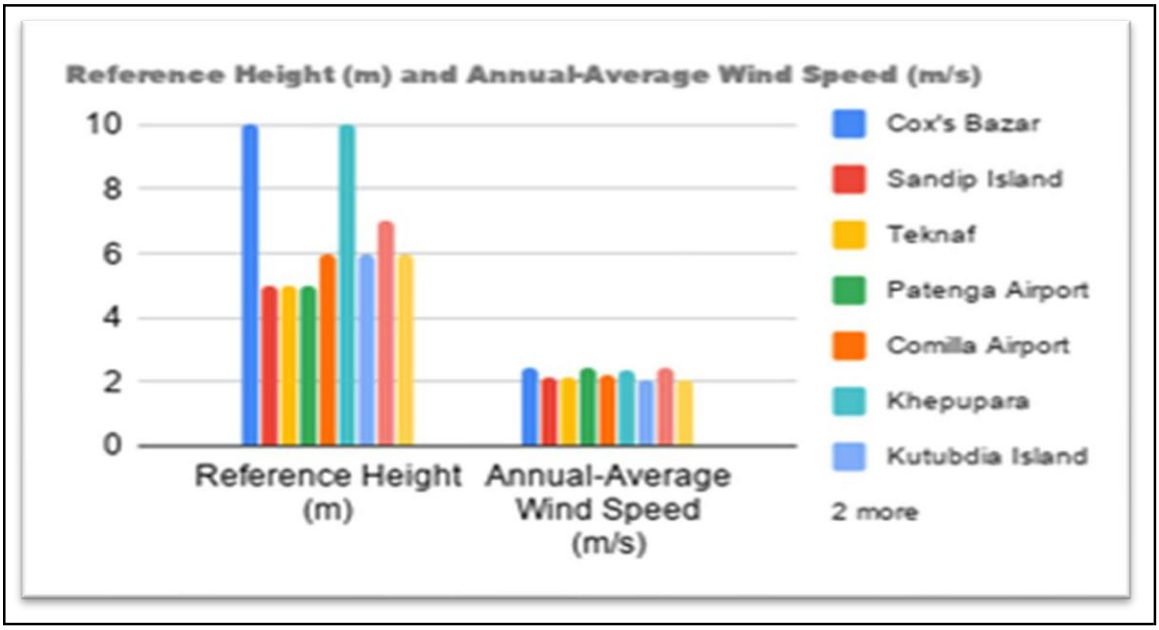

Figure 3.18: *Potential location for electricity generation from wind power at different locations of Bangladesh [12].*

The bar chart in Figure 3.18 describes the annual wind speed with annual reference height for different potential locations of wind power for the electricity generation.

CHAPTER – 4: Approximate Cost Calculation

4.1 Introduction

Bangladesh is a developing country, so it will have to make sure the energy generation project can be feasible and cost-effective. Cost analysis can make a good impact for the future power generation project.

Table 4.1 *Current generation capacity and future requirement [35]*

Current Generation Capacity	16046
Access to Electricity	83%
2021 requirement	24,000 MW
2030 requirement	39000 MW

Table 4.1 demonstrates the current power generation capacity, percentage of access to the electricity and future requirement of energy demand for Bangladesh. As of September 2019, Bangladesh has one national grid with an installed capacity of 21,419 MW and the total installed capacity is 20,000 MW. To meet the upcoming energy demand and energy security, renewable energy generation can play a crucial role.

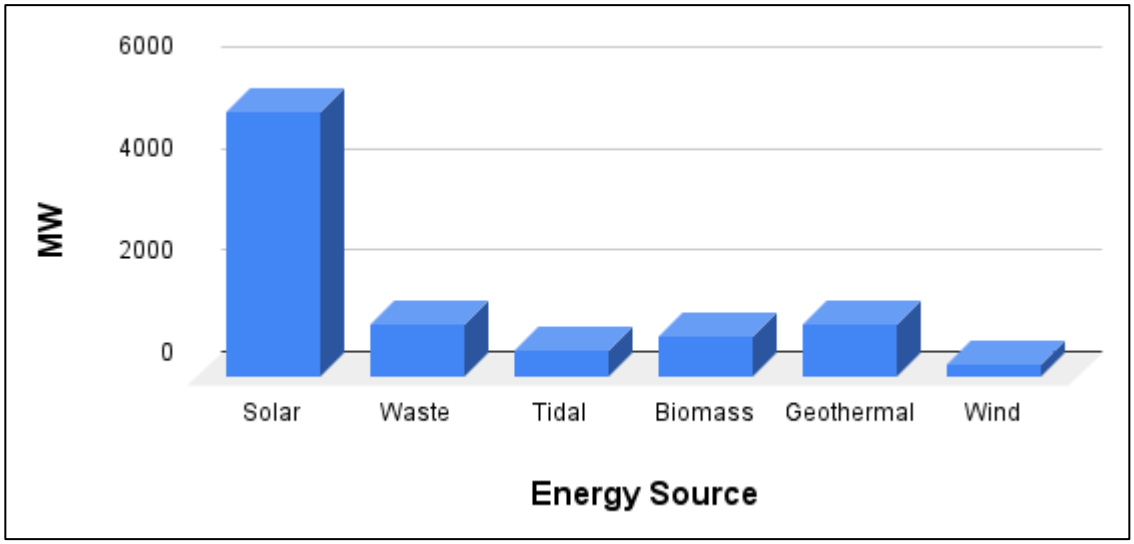

Figure 4.1: *Expected Renewable Energy Generation [36]*

Figure 4.1 represents the expected power generation from the solar, waste, tidal, biomass, geothermal and wind. Solar has the potential for energy generation. These potential sectors can help to meet the next energy demand for Bangladesh.

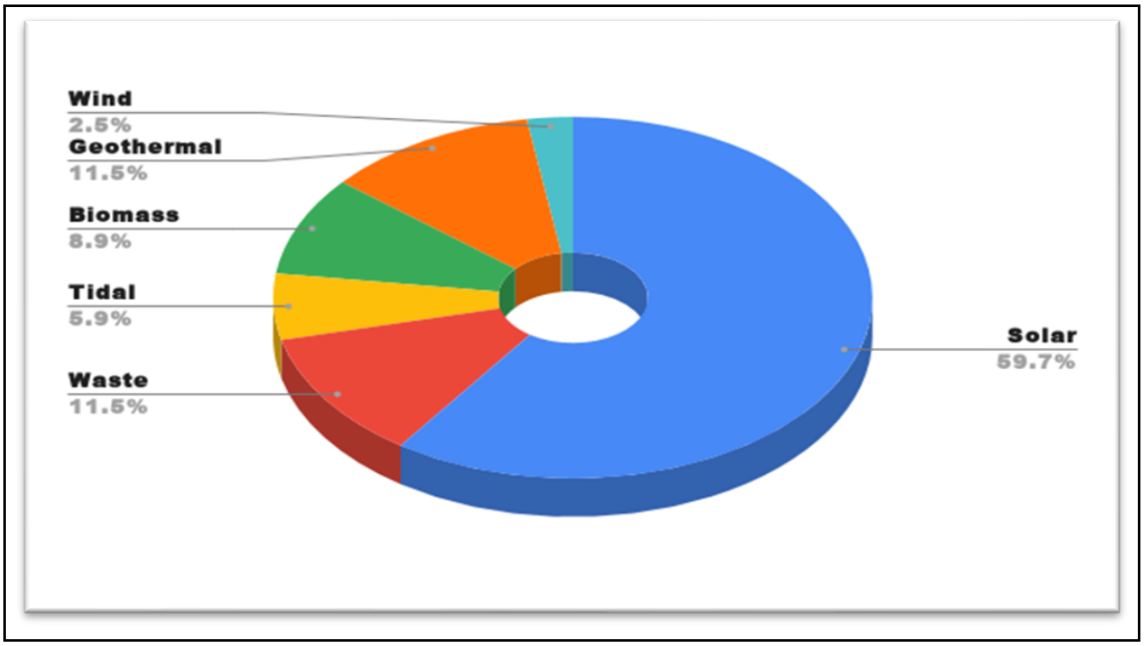

Figure 4.2: *Renewable Energy Generation share in percentage*

In figure 4.2, it is clearly understood that solar is the most potent source of energy for power generation among the renewable sources right now, and waste has also good potential for the megacities in Bangladesh. Renewable energy is the only approach for the energy security solution. Calculating the approximate cost and returning year have a goodimpact to make the decision, as well as to guess the potential and it will help to guess the real implementation of the projects. This paper represents a calculation to find out the costof the plant and it's return year.

4.2 Cost Calculation of Solar Power

The cost of 50 MW solar PV power plant is $95 million [37]

The potential solar power generation will be around 5197.42 MW.

Plant cost calculation:

So, taking 50MW as standard,

5197.42 /50 MW = 103.94 * 95 million dollar = 9875.098 million dollars

1 million dollar = 84620000.00 takas

9875.098 million dollar = 9875.098 * 84620000.00 takas = 835,630,792,760 takas

835,630,792,760 / 10000000 crore taka = 83,563.079276 crore taka

So, the total cost of the solar power plant will be around 83,563.08 crore taka.

Return Cost Calculation:

In the case of the dry season, Bangladesh gets 7.6-hour sunlight and for the monsoon it is 4.7 hours per day [38]. So, considering 7 hours a day, it will be around 2500 hours in a year. Therefore, Solar hours available for the electricity generation in Bangladesh is around 2500 hours in a year.

5197.42 MW * 2,500 hours = 12,993,550 MW

12,993,550 MW * 1000 = 12,993,550,000 kW

12,993,550,000 kW * 11 takas = 142,929,050,000 taka/ year

So, returning year = power plant cost/ per year return

=835,630,792,760 / 142,929,050,000

= 5.858218181818182 year or approx. 6 years.

4.3 Cost Calculation for the power from Waste

A power plant with the capability of producing 20 MW of electricity could cost up to $20M (twenty million US$) [39].

The potential waste power generation will be around 1000 MW

Plant cost calculation:

20 MW for 20 million dollars

So, taking 20MW as standard,

1000 MW/20 MW = 50 * 20 million dollar = 1000 million dollars

1 million = 1,000,000 US Dollar = 84620000.00 taka

84620000.00 taka * 1000 = 84,620,000,000 taka = 84,620,000,000 / 10000000 crore taka = 8,462 crore takas.

So, the total cost of the waste power plant will be around 8,462 crore takas.

Return Cost Calculation

The waste generation possible hour in a year is about 8760 [40].

Waste Electricity generation hour in a year = 8,760 hours in a year

1000 MW * 8,760 hours = 8,760,000 MW /year

8,760,000 MW /year * 1000 = 8,760,000,000 kW/year

8,760,000,000 kW/year * 11 taka = 96,360,000,000 takas

So,

returning year = power plant cost/ per year return

= 84,620,000,000 / 96,360,000,000

= 0.8799294312992943 years or approximately 0.88 years.

4.4 Cost Calculation of Tidal Power

A power plant with the capability of producing 16.49 MW of electricity costs around 10.37 million dollars [41].

The potential tidal power generation will be around 1000 MW.

Plant cost calculation:

16.49 MW for 10.37 million dollars

So, taking 10.37 MW as standard,

1 million = 1,000,000 US Dollar = 84620000.00 taka

514.702 / 16.49 MW = 31.23 MW * 10.37 million dollar = 323.8551 million dollars * 84620000.00 takas

= 27,404,618,562 takas =

27,404,618,562 / 10000000 crore taka

= 2,740.4618562 crore taka or approx. 2,740.46 crore taka.

Return Cost Calculation:

Tidal power generation hour in a day is around 6 hours [42].

Tidal Electricity generation hour in a year = 6* 365 = 2,190 hours in a year

514.702 MW * 2190 hours = 1,127,197.38 MW /year

1,127,197.38 MW /year * 1000 = 1,127,197,380 kW/year

1,127,197,380 kW/year * 11 taka = 12,399,171,180 takas.

So,

returning year = power plant cost / per year return

= 27,404,618,562 / 12,399,171,180

= 2.210197614353768 years or approx. 2.21 years

4.5 Cost Calculation for the Biomass and Bioenergy Power

A power plant with the capability of producing 30 MW cost 250 million yuan [43].

The potential Biomass and Bioenergy power generation will be around 772.25 MW.

Plant cost calculation:

30 MW = 250 million yuan

So, taking 30 MW as standard,

772.25 / 30 = 25.7416 Mw * 250 million yuan

= 6435.4167 million yuan

1 million yuan = 13,070,000 takas

6435.4167 million yuan = 6435.4167 million yuan * 13,070,000 takas

= 84,110,896,269 takas

= 84,110,896,269 / 10000000 crore taka

= 8,411 crore takas.

Return Cost Calculation:

Waste power generation is possible to run 24 hours a day if sufficient waste is supplied to the power plant over the period of 24 hours.

Biomass Electricity generation hour in a year = 24* 365 = 8,760 hours in a year

772.25 MW * 8760 hours = 6,764,910 MW /year

6,764,910 MW /year * 1000 = 6,764,910,000 kW/year

6,764,910,000 kW/year * 11 taka = 74,414,010,000 takas

So,

returning year = power plant cost/ per year cost

= 84,110,896,269 / 74,414,010,000

= 1.130309954657732 year or approx. 1.13 years.

4.6 Cost Calculation of Geothermal Power

A power plant with the capability of producing 40 MW cost 50.7 million USD [44].

The potential geothermal power generation will be around 1000 MW.

Plant cost calculation:

40 MW for 50.7 million USD

So, taking 40 MW as standard,

= 1000/40 MW = 25 MW

= 25 MW * 50.7 million USD = 1267.5 million

USD1 million USD = 84620000.00 takas

1267.5 million USD = 1267.5 * 84620000.00 takas = 107,255,850,000 takas

= 107,255,850,000 / 10000000 = 10,725.585 crore taka or approx. 10,725.58 crore taka

Return Cost Calculation:

Geothermal Electricity generation hour in a year = 24* 365 = 8,760 hours in a year

1000 MW * 8760 hours = 8,760,000 MW/ per year

8,760,000 MW/ per year * 1000 = 8,760,000,000 kW/per year

8,760,000,000 kW/per year * 11 taka = 96,360,000,000 taka / year

So, returning year = power plant cost/ per year cost

= 107,255,850,000 / 96,360,000,000 year

= 1.113074408468244 year or approx. 1.13 years

4.7 Cost Calculation of Wind Power

A wind power plant with the capability of producing 1 kW cost 1,227.00 Euro =125,421.85 Bangladeshi Taka [45].

The potential wind power generation will be around 215 MW.

Plant cost calculation:

For 1 1kW = 1,227.00 Euro =125,421.85 Bangladeshi Taka

Wind 215 MW,

215*1000=215000 kw

215000*125,421.85 = 26,965,697,750 taka = 2,696.569775 crore taka

Return Cost Calculation:

Wind Electricity generation hour in a year = 2,500 hours in a year

215 MW * 2,500 hours = 537,500 MW /year

537,500 MW /year * 1000 = 537,500,000 kW/year

537,500,000 kW/year * 11 taka = 5,912,500,000 takas

So,

returning year = power plant cost/ per year cost

= 26,965,697,750 / 5,912,500,000

= 4.560794545454545 years or approx. 4.56 years.

4.8 Observations

According to Figure 4.3 it's clear that solar power plants require higher cost among all of the sources, whereas, the wind has the lowest cost.

In case of solar the return year is approximately 6.

Power plant cost per MW is = 160,778,000 Taka

In case of waste, the return year is approximately 0.88.

Power plant cost per MW is = 4,620,000 taka.

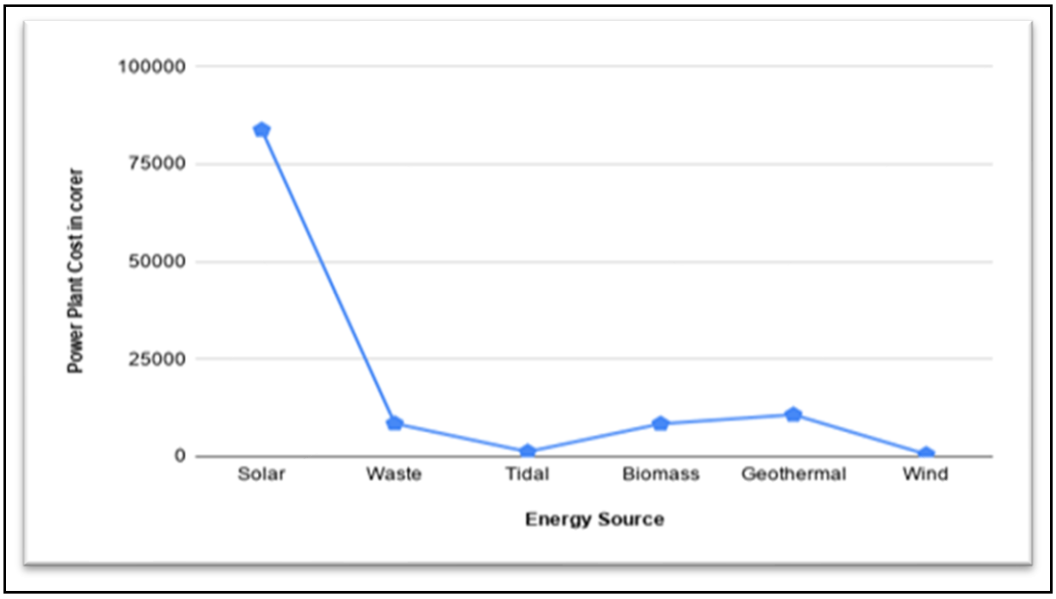

Figure 4.3: *Power plant estimated cost*

In case of biomass the return year is approximately 1.13.

Power plant cost per MW is =108,916,666 Taka

In case of geothermal the return year is approximately 1.13.

Power plant cost per MW is =108,916,666 Taka

In case of wind, the return year is approximately 4.56.

Power plant cost per MW is =125,421,850 Taka

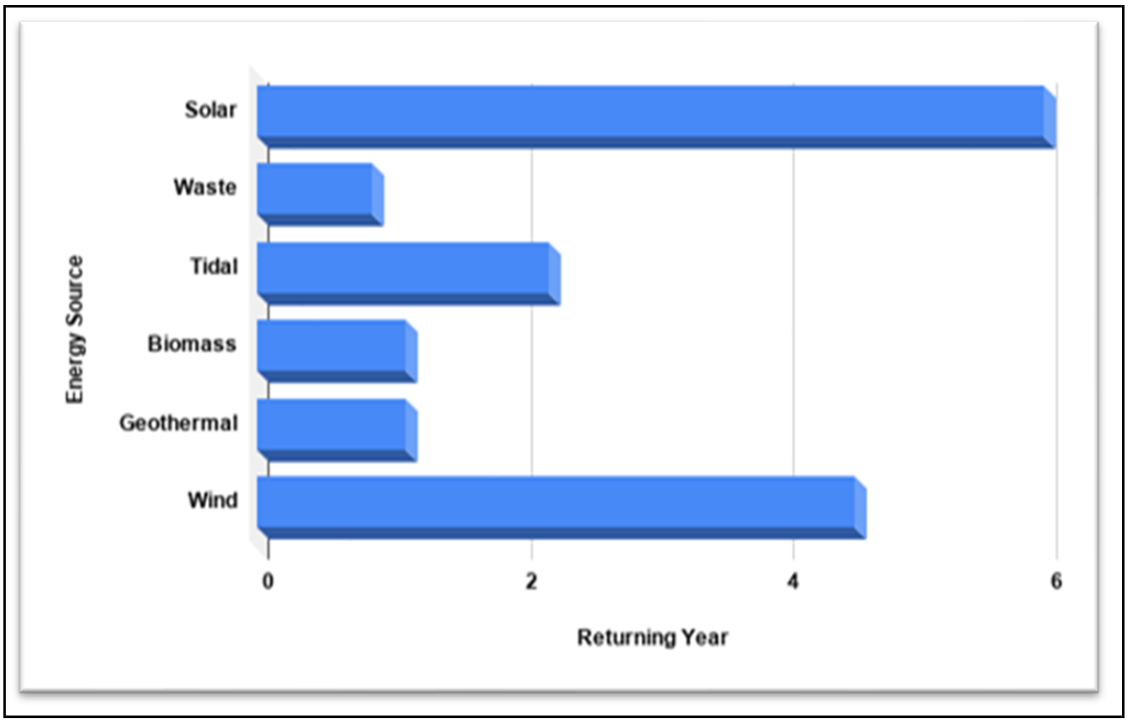

Figure 4.4: *Estimated returning year of the power plant*

As solar has the highest power plant cost, it will be long for the return and the returning year of wind will also take sometimes longer than other sources, not more than solar.

Considering waste power generation, it has good potential and is easy to generate and economical and quick returning year.

CHAPTER – 5: Conclusion

5.1 Conclusion

Bangladesh is now on the edge of traditional electricity generation from non-renewable energy sources. All projects like importing electricity or using non-renewable energy can be for short term solutions but for the future energy security there is no alternative way of shifting electricity generation from non-renewable to renewable energy sources. Bangladesh has good potential with different sectors of renewable energy sources that might open a new window for the electricity generation and ensure the energy security of Bangladesh. There are some resources of renewable energy that have good potential to generate electricity like solar, waste, tidal, biomass, geothermal, and wind. In this thesis , the final estimated amount of renewable energy is quite impressive to dive into renewable power generation. The most important sector is solar power generation which can generate approximately 5197.42 MW. Other sectors like waste, tidal, biomass,geothermal, and wind also have good potential and they can generate power around 1000 MW, 514.70 MW, 772.25 MW, 1000 MW, and 215 MW respectively. Considering the share in a percentage of renewable energy power generation, solar is the maximum with59.7% and the least sector is 2.6% for wind power generation. Renewable energy is becoming the most cost-efficient than other non-renewable energy. Renewable energy willplay a vital role in reducing carbon gas emissions and it will help to meet the future energydemand. Cost analysis is important to implement the project. Cost management is an important parameter for the power generation sector. Bangladesh has to give more importance on power plant cost implementation. Cost analysis regarding power plants willhelp to take the decision for the governments. This thesis presents the expected renewablepower generation possibilities and the cost analysis of the estimated power plant for the sixsources of renewable energies and observed the most and least cost and return year of thosepower plants.

5.2 Recommendation for the future Research

This study revealed the possibility of renewable energy generation with the cost analysis to meet the energy security of Bangladesh. Based on the findings and conclusions presented, the following recommendations are suggested:

1. Calculation of solar power generation possibilities has been done by considering Dhaka city only. Further research can be done by calculating solar power generation possibilities considering other cities.
2. More methodological work is needed for the exact calculation of solar power generation possibilities by doing field surveys and data analysis.
3. More research can be done in cost analysis by using real cost data of Bangladesh's existing power plants.
4. More field survey is required to make decision about whether it is efficient or not in the perspective of Bangladesh.

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