

**Renewable Energy and Its Impact on Economic Development:  
Evidence from Bangladesh**

by

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## **Acknowledgement**

[All] praise is [due] to Allah, Lord of the World

[Al-Quran, Chapter 1:2]

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## Abstract

Energy is one of the indispensable inputs of modern civilization and prerequisite for sustainable development. A developing country like as Bangladesh, where socio economic development and energy crisis is a major issue in recent year, needs enormous supply of power. Although, the installed of electricity power generation capacity increased to 11,534 MW in 2015, this amount is inadequate to meet the current electricity demand of the country. In addition, limited power resources and inadequate power generation problem is the obstacle for socio-economic and industrial development. To generate the electricity, fossil fuel such as natural gas, furnace oil, coal and diesel are mostly used in Bangladesh which increases CO<sub>2</sub>, NO<sub>x</sub>, SO<sub>x</sub>. These greenhouse gases create negative impact on environment as well as climate change. Electricity shortage problem in Bangladesh and greenhouse effect can be solved by using renewable energy (Solar, Biomass, Hydro power, wind) into electricity generation. In recent times, technology of renewable energy is getting developed by different NGOs to meet the demand as well as reduce dependency on limited fossil fuel. Despite of huge potential of renewable energy sources, presently contribute only nearly 5% of total energy. BPDB estimated that, renewable energy consumption will be 10% by the year 2021. This paper reviews the relationship between renewable energy and GDP growth

and Extends existing knowledge of that relationship by providing new evidence from Bangladesh renewable energy sectors. Besides, it also deliver future research direction on renewable energy to meet the future energy demand as well as protect environment.



### **Some Important Abbreviation**

BBS	=	Bangladesh bureau of statistics
BPDB	=	Bangladesh Power Development Board
CSP	=	Concentrating Solar Power
EPA	=	Environmental Protection Agency
FDI	=	Foreign Direct Investment
FY	=	Fiscal Year
GDP	=	Gross Domestic Product
GOB	=	Government of Bangladesh
GWh	=	Gigawatt-hours
IDA	=	International Development Association
IEA	=	International Energy Agency
KWh	=	Kilo Watt Hours
MW	=	Megawatt
MWh	=	Mega Watt Hours
Mtoe	=	Million toe
NASA	=	National Aeronautics and Space Administration
PSMP	=	Power System Master Plan
PV	=	Photovoltaic
RET	=	Renewable Energy technology
RRP	=	the Rural Road Project
SHS	=	Solar Home System
TWh	=	Tera Watt-hours
WB	=	World Bank
WNA	=	World Nuclear Association

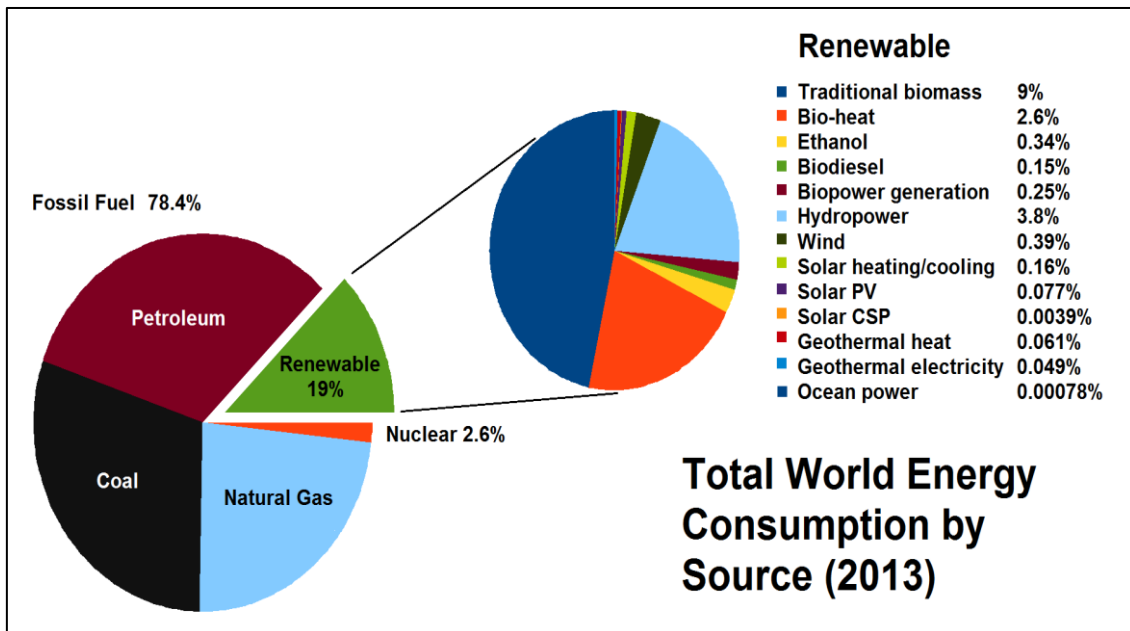
# 1 Chapter 1: Introduction

## 1.1 Background

Enough energy supply is the building block of modern civilization and precondition of sustainable socio and economic development of a country. The world primary energy consumption is increasing because of population growth, urbanization and rapid economic growth. The primary global energy consumption has increased average 5.6% from 1973 (Islam et al, 2014). Primary energy resources are fossil fuel such as oil, natural gas, coal and renewable energy. It is estimated that, fossil fuel will dominate primary energy supply mostly until 2020 (Islam et al, 2014). According to the Key World Energy Statistics in 2013, 78.4% of total world energy generated by fossil fuel where 19% from renewable sources. In the last couple of decades, the fossil fuel consumption has increased dramatically because of increasing electricity demand all over the world (World Energy, 2015). The world energy consumption shows approximately 6,131 TWh electricity was generated by fuel in 1973 and 23,322 TWh in 2013. For transportation and other industrial operation, Oil and other petroleum product are used which increased consumption 28.56% from 1991 to 2011 (Islam et. al, 2014). Below figure projected, coal and natural gas is the top position of global energy consumption. It is predictable that, primary global consumption will increase 34% until

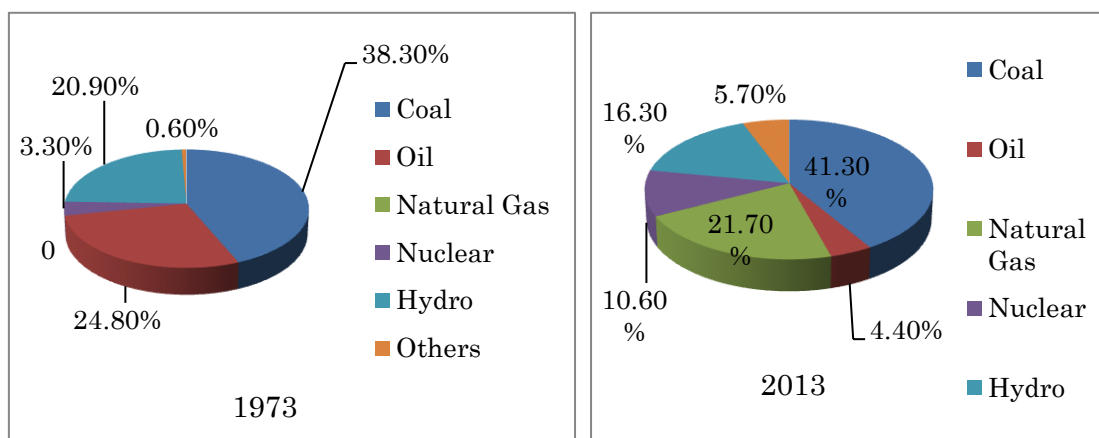
2035 with annual growth 1.6%. Fossil fuel will dominate 60% of increasing demand until 2035 (BP Energy Outlook, 2016). Figure 1-1 shows the individual contribution to world's energy in 2013. In addition, Figure 1-2 shows increasing demand from 1973 to 2013 and contribution of fossil fuel.

**Figure 1-1: World energy Consumption**



*Source: Key World Energy Statistics, 2015*

Figure 1-2: Fuel share for electricity generation in 1973 and 2013



Source: Key World Energy Statistics, 2015

However, the total primary energy supply is increasing 2.59% yearly where per capita energy consumption has increased 200% from 1992 to 2011 in Bangladesh (BPDB, 2016). In 2011, the total consumption of Bangladesh was 39,533 GWh, it is expected that in 2035 the total electricity demand will be 192.70 TWh (Halder et al, 2015). Halder et al, (2015) also mentioned that, the maximum electricity demand was 3,149 MW in 1999-2000 and 10,283 MW 2014-2015. The result reveals that, the maximum electricity demand has increased more than 3 times in last 15 years. Although electricity generation is increasing in every year, but it is not enough to meet increasing demand of electricity in Bangladesh. At present, to generate electricity nearly 98% use the fossil fuel such as gas, furnace oil, diesel and coal mostly. Based on the BPDB information (2016), natural gas 61.82%, furnace oil 21.68%, diesel 7.75%, coal 2.03% contributes to

generate the electricity. However, as per the current estimated, fossil fuel contribute 98% of total electricity power generation. Bangladesh will face serious problem in near future because of shortage electricity supply. On the other hand, global warming, greenhouse impact and climate change is the major obstacle for sustainable development. Explicit of fossil fuel consumption Bangladesh emitted 0.21 metric ton CO<sub>2</sub> in 2000 and reached to 0.37 metric ton in 2010 (World Bank, 2016). Moreover, to mitigate power crisis problems and reduce the dependency on fossil fuel the country stimulates energy policy towards renewable energy. The renewable energy sources are solar, biomass, biogas, wind and hydropower. Currently, renewable energy contributes nearly 5% of total energy supply and it will be 10% by 2021 respectively in Bangladesh (BPDB, 2016). Equally, now renewable energy contribute nearly 19% of total world's energy supply and it will be 60% by the year 2070 (World Energy, 2016).

Past few decades, the economy of Bangladesh has been transferring from agricultural to industrial. Equally, almost all emerging developing countries of the world, economy is transferring to industrial economy for high GDP growth. Energy demand is also increasing in Bangladesh for rapid urbanization and economic growth. But, in Bangladesh there is huge gap between power supply and demand which is great

obstacle for development. In 2014-15, the peak demand was 10,283 MW and peak generation was 7817 MW where only 62% people are connected with power grid (BPDB, 2015). From last few years both public and private sector try to minimize power crisis by increasing power generation of using indigenous natural gas, coal and oil. In addition, in recent time quick rental power plant has also used to lessen immediate power crisis in Bangladesh. Conversely more than 75% people live in rural area of Bangladesh where 42% people are access to the power grip and rest of them deprive from all electricity facilities (BBS, 2016)<sup>1</sup>. The mission statement of BPDB expresses that, quality electricity at reasonable price with professional services deliver to all citizen of the country by 2021 (BPDB, 2016). So, renewable energy can be alternative way to solve present shortage, future demand and environmental problems. This paper is organized as follows: Chapter 2 reviews different literature. Chapter 3 discusses about geographical location and energy related information such as renewable energy. Chapter 4 illustrate about time series analysis and regression equation. Chapter 5 presents econometrics result of renewable energy consumption and GDP growth in Bangladesh. Finally achievement and future target will be discussed in Chapter 6.

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<sup>1</sup> <http://www.bbs.gov.bd/PageWebMenuContent.aspx?MenuKey=230>

## 1.2 Problem Statement

According to Bangladesh Power development Board report in 2010 only half of the population has a full grid electricity access. Although electricity covers only half of the population but still supply side cannot able to fulfill the demand of the demand side. In 2010 it is shown on BPWD reports that in 2010 demand for electricity were around 6414MW but BPDB has an average production capacity of 5270MW but they can't able to utilize their full capacity (e.g. 5270MW) instead of that they are able to produce only 5060MW the rest are load shedding up to 1354MW. Before 2011 only public sectors was the monopoly producer of electricity and one analysis done by BPWD for forecasting the future demand of electricity and they found that the demand will increase about more than 10% in every year. By realizing this problem; government open this sector for private organization in 2012 by providing subsidies. That will add new electricity in the national grid. Although the private sectors produce huge electricity but still it's not sufficient for current demand. In 2016 the current demand is 11405 MW and it is estimated by World Bank that the demand in 2020 will be 17,304 MW.

When government including private sectors failed to supply the current demand of electricity; Different NGOs like BRAC, ASA and Grameen Bank encourage and promote alternative sources of electricity which is known as renewable energy in

Bangladesh. Researcher like Dutra, and Szklo (2008) provide an example how renewable energy reduce the current level of electricity demand. According to Farret, and Simões (2006) renewable energy includes Solar, Winds, Hydropower and Biomass and so on which have no direct impact on environment. Renewable energy has a positive impact on environment. Many scholar mentions that if we want to make a safe world for our future generation we should use less primary energy like gas, coal and crude oil because it produce greenhouse gas (GHG). Stern (2007) has already stated that “GHG emissions can be reduced to stabilization level that would cost merely one percent of the global gross domestic product (GDP) if actions are taken immediately”. However, maintaining the same level of stabilization would require around up to 20 percent of the global GDP in the case of delay.

Chien and Hu (2008) identify that renewable energy has a positive impact on GDP; on the other hand Tugcu et.al, (2012) and Pao and Fu (2013) finds no relationship between renewable energy and GDP growth. But there is no concrete evidence shows that the relationship between renewable energy and economic development and vis-a-vis.



### **1.3 Objective**

This study will investigate the relationship between renewable energy and GDP growth in Bangladesh. Therefor by contributing to the pool of knowledge we are trying to achieve the different objectives listed below.

1. To determine the relationship between renewable energy and economic growth.
2. To demonstrate whether renewable energy foster economic growth and vise-versa.
3. What is the direction of this causality between renewable energy and economic growth and vise-versa?

### **1.4 Rationality**

Energy is the key requirement of modern society and a prerequisite for sustainable development. With increasing population and modernization the per capita energy consumption and overall energy requirement has increased all over the world. The world energy consumption shows approximately 6,131 TWh electricity of total energy was generated by fuel in 1973 and 23,322 TWh in 2013. For transportation and other industrial operation, Oil and other petroleum product are used which increased consumption 28.56% from 1991 to 2011 (Islam et. al, 2014). Based on the Key World Energy Statistics 78.4% of total world energy generated by fossil fuel where 19% from

renewable sources in 2013. Equally in Bangladesh energy demand is increasing day by day for urbanization and economic development; in 1999 maximum demand was 3,140 which increased to 10,283 in 2015 (BPDB, 2015). Fossil fuel such as natural gas, furnace oil, coal and diesel are mostly used which is very limited in Bangladesh. At present, nearly 98% of total electricity generated from fossil fuel in Bangladesh which create greenhouse gases and very bad impact on environment. In this moment renewable energy can play a vital role to meet the increasing demand and protect the environment. Even though there are huge potential of renewable energy such as solar, mini hydro power, biomass, biogas and wind in Bangladesh. But renewable energy is still in a nascent stage because of not taking initiative step and lack of technology. Development of renewable energy can be one of the important strategies which reduce fossil fuel dependency, protect environment and support sustainable development. According to the renewable energy policy 2009, government is committed to encourage both public and private sector investment on renewable energy. However this research shows the relationship between renewable energy consumption and GDP growth in Bangladesh. It's also attempt to encourage both public and private sector for investment on renewable energy; to meet the increasing future energy demand as well as protect the environment.

## 2 Chapter 2: Literature Review

### 2.1 Literature Survey

Several numbers of studies in the literature reviews have tested the relationship between energy consumption and economic development in different countries. The result of these studies have no consensus with this paper because of different country, data, time period and methodological approach. Some of the studies show that causal relationship between energy consumption and economic growth. Some of literature explained the unidirectional / bidirectional relationship between renewable energy and economic growth.

Sari et al. (2008) showed that, the relationship between renewable energy consumption and industrial production. They estimate ARDL approach to disaggregated measure of U.S. renewable energy consumption and industry output. The study applied over the time period of 1969-2009 and finds negative impact with solar energy consumption and positive relationship with hydro electronic, waste, wind energy. Bowden and Payne (2010) examine unidirectional causal relationship from residential renewable energy consumption to output as well as GDP. In this sectorial analysis, use Toda-Yamamoto long run causality test where absence of relationship between renewable energy consumption in industries and real output. Payne (2011) use long range data from 1949

to 2007 to explore the casual relationship between biomass energy consumption and real GDP growth in U.S.A. The study shows that, the unidirectional casually from biomass energy consumption to real GDP growth by applying Toda- Yamamoto method. Pao and Fu (2013) utilize statistics data from 1980 to 2010 to examine the casual link between real GDP and four type of energy consumption. The energies are total primary energy, hydroelectric renewable energy, total renewable energy and nonrenewable energy. In this study, co integration test reveals long run equilibrium between four type of energy consumption and real GDP, capital labor in Brazil. The four types of energy consumption and real GDP growth have been fluctuating in the time period from 1980 to 2010. Khatun and Ahamad (2015) explained about current energy and power situation of Bangladesh in their study. After that, they tried to focus on causal relationship between foreign direct investment and economic growth for the time period (1972-2010). The paper also finds out a considerable gap between energy consumption and energy production during this period. Moreover, the FDI on energy also was fluctuating over the time period. Finally they confirmed that, there are strong positive and unidirectional a short run causal relationship from FDI to energy and energy to GDP growth in Bangladesh. Ahmed et al (2016) present a comparative and comprehensive renewable energy review and possible sharing opportunity of China, India and Pakistan.

They also discussed about abundant renewable resources like solar, wind, biogas, hydro power, nuclear, and geothermal of China, India and Pakistan. By sharing opportunities of energy, regional peace and security situation develop among the countries and might contribute to global peace and prosperity. It has also discussed about future energy demand and renewable energy sources and target among of China, India and Pakistan. Furthermore, the paper shows the present renewable energy situation and comparison by using recent data and analytical graph among the countries. Halder et al (2015) mentioned that, Bangladesh has inadequate of non-renewable energy and a very less amount of renewable energy which cannot survive the increasing demand. Although Bangladesh installed power generation 11,534 MW by the year 2015 to reduce the increasing demand. In conversely, this insufficient power generation is the obstacle to develop socio-economic and industrial development. This current power generation problems can be eliminate by implement new policy, proper use and technology innovation of renewable energy. It also discussed about geographical location and other related information of Bangladesh. The paper also outlines about present energy scenario of the country and mentioned renewable energy can achieve not only energy security but also reduce environmental pollution. Finally, potential of available renewable energy resources, achievement and future target in the renewable energy has

been mentioned in the paper. According to the Ahmed et al, (2014) in Bangladesh economic development with eco-friendly environment is one of the major issue where need a huge power supply. There is an imbalance between energy supplies and current demand in terms of current generation. Based on this paper, nearly 98% installed capacity cover of total electricity generation from fossil fuel where renewable energy contribute mere portion. It also mentioned about economic condition and present energy scenario of Bangladesh and neighboring countries like India, Nepal and Pakistan. Pakistan had 700 MW energy deficiency till 2011 and presently power generation mostly depend on fossil fuel, hydro power, nuclear and renewable energy. It is estimated that, remaining energy deficiency can be achieved by manipulating renewable energy. India is a highly populated country in Asia where 400 million people are not connected to electricity. In India is limited resources country but have a huge amount of poor quality coals. However, in research clearly mentioned that, it is not a good decision to import electricity from India for solving electricity problems in Bangladesh. To solve the energy problem, renewable energy can be one of alternatives which is came out from their research. Finally the research shows way to harness renewable energy and provide future direction to meet the future demand of Bangladesh. According to the Mondal et al (2010), Bangladesh has a enormous potential opportunity for harnessing

renewable sources such as solar, wind, mini hydropower and biomass. The research mentioned, renewable energy is the driving force for rural development where about 42% people are disconnected from the electricity grid. A few public sectors and some non-government organizations are involved with rural development and started to develop renewable energy technology project. The paper identified some barriers and obstacles that need to be overcome for effective development of RETs sector as well as rural development. It also addressed the gap between innovation system and appropriate technology, barriers and driving force to the implementation of renewable energy technology, policy implication and strategic direction for future work for development. Finally the paper mentioned, some barriers, driving forces, policies and strategies for implementation of renewable energy technology in rural areas of Bangladesh. Salim and Rafiq (2011) mention the casual relationship between renewable energy consumption and GDP of six emerging countries named Brazil, China, India, Indonesia, Philippines and Turkey. The article use Modified Ordinary Least Square (MOLS), Dynamic Ordinary Least Square (DOLS) and Granger causality test to define relationship between energy consumption and GDP of six emerging countries. Causal link also found in long run basis, among renewable energy consumption emission and income in China, India, Brazil and Indonesia. On the other hand, energy consumption in Philippine

and Turkey determine by income in short run basis. The result suggested that, appropriate step should be taken in emerging countries to reduce carbon emission by increasing energy efficiency and renewable energy in future. Yildirim et al (2012) apply Toda-Yamamoto and Hatemi J causality test to define firstly, the relation with renewable energy consumption and GDP growth. Secondly, renewable energy do not damage environment. The model consists of renewable energy consumption, real GDP, employment and investment. The empirical model results reveal that, there is no causal relationship with real GDP and total renewable energy consumption (hydropower energy consumption, geothermal energy consumption or biomass energy consumption). But there is one causal relationship between real GDP and waste derives energy consumption in US. Hossain et al (2016) examine the role of smart grid in the renewable energy. They conclude that, smart grid technology is not mature enough, and required further research.

## **2.2 Motivation from the literature**

The above survey reveals that most studies focus on the relation between renewable energy and GHG omission. However, the literature investigating the relation between



the renewable energy and economic growth is not much pronounced for developing countries. As such, it is worth knowing what will be is there any relation between renewable energy and economic growth and vise-versa, if so, in what direction?

## 3 Chapter 3: Country Background

### 3.1 Bangladesh

Bangladesh is one of the South Asian developing countries with nearly 160 million people on a landmass of 1, 47,570 square kilometers. According to the World Bank, Bangladesh is among the most densely populated country in Asia as well as in the world. Bangladesh is eighth densely populated country in the world with average 1222.1 people per kilometer (World Bank, 2015). However, when Bangladesh got independent from Pakistan in the year of 1971, it was only 75 million people respectively. Before 1947; Bangladesh, India, and Pakistan was only one country named as India<sup>2</sup>. In the year 1947 British India has divided into India and Pakistan from the religious perspective view. In that time, Pakistan belongs to two different name West Pakistan (currently Pakistan) and East Pakistan (currently Bangladesh) because of separated land. After that in 1971 Bangladesh has independent from Pakistan for the respect of mother tongue as well as political disputes. Bangladesh is a Muslim majority country where about 89.7% Muslim, 9.2% Hinduism, 0.7% Buddhist, 0.3% Christians and 0.1% Animists significantly (BBS, 2015).

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<sup>2</sup> <https://www.quora.com/What-was-India-Pakistan-and-Bangladesh-called-before-the-partition-of-1947>

Bangladesh is classified as a low income developing country even though it has continued impressive progress on economic growth and development. By 2021 Bangladesh expects to become a middle income country in south Asia with vision twenty-twenty made by present government. To reach the goal Bangladesh need to make continuous Gross Domestic Product (GDP) growth by the support of garments sector, agriculture sector, export and foreign direct investment. In addition, country needs political stability, strong microeconomic stability; female labor participation and private investment are present priorities to GDP growth and help to become middle income country. Since 1992, poverty declined one third, 15 million people have moved out from poverty and per capita food intake, life expectancy, literacy increased 2 times respectively. Despite political turmoil, global volatility and structural constraints country moving forward its continuous GDP growth 6.1% in 2014; but nearly 47 million people are still below the poverty line in Bangladesh (World Bank, 2016)<sup>3</sup>. By 2021 Bangladesh aspires to be a middle income country and it requires boosting GDP growth 7.5% to 8% per year. To accelerate GDP growth country need to increase both public and private investment as well as increase demand of domestic employment. Based on the Labor Force Survey 2013, in 2010 the total domestic employment

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<sup>3</sup> <http://databank.worldbank.org/data/reports.aspx?source=2&country=BGD&series=&period=>

increased 54.1 million and in 2013 increased 58.1 million. So, domestic economy enhances average 1.3 million jobs in every single year. It also needs to manage urbanization process more effectively and take preparation to adapt climate change and natural disasters. If government of Bangladesh speeds up decision making, labor intensive and service export can become an export power house and increase double digits of GDP growth. Table 3-1 shows the overall situation from 2010 to 2015 of Bangladesh.

**Table 3-1: Bangladesh Development indicators**

<b>Indicators</b>	<b>2010</b>	<b>2011</b>	<b>2012</b>	<b>2013</b>	<b>2014</b>	<b>2015</b>
Population, Total (million)	151.5	153.4	155.2	157.1	159	160
Population Growth (annual %)	1.1	1.2	1.2	1.2	1.2	1.2
Population density per sq. kilometer	1164.8	1178.5	1192.7	1207.3	1222.1	-
GNI per capita atlas method US\$	780	870	950	1010	1080	-
Life expectancy at Birth, total (year)	70.1	70.2	70.5	71.2	71.6	-
Gross enrolment ratio secondary (both sexes %)	50.1	50.9	53.5	58.3	-	-
Improve sanitation facilities (% population)	55.8	56.8	57.7	58.7	59.6	60.6
Electric Power Consumption per capita (kWh)	240.7	258.5	275.7	293.0	-	321

GDP growth annual %	5.6	6.5	6.5	6.0	6.1	6.1
Agriculture value added (% of GDP)	17.8	17.7	17.1	16.3	16.1	-
Industry value added (% of GDP)	26.1	26.4	26.7	27.6	27.6	-
Services etc. value added (% of GDP)	56.0	55.9	56.2	56.1	56.3	-
Export of goods and services (% of GDP)	16.0	19.9	20.2	19.5	19.0	-
Import of goods and services (% of GDP)	21.8	27.5	27.9	26.8	25.5	-
Mobile subscription (per 100 people)	44.9	55.2	62.8	74.4	80.0	-
Internet user (per 100 people)	3.7	4.5	5.0	6.6	9.6	-
Foreign direct investment net inflow billion US\$	123.2	126.4	158.4	190.5	249.6	-

*Source: World Data Bank, world development indicators*

The World Bank Data illustrate that, after independence of Bangladesh, the International Development Association (IDA) has been supporting to develop rural infrastructure, agriculture, energy, education, health, water supply and sanitation of Bangladesh. IDA provided more than \$19 billion to reduce the poverty and improve human development<sup>4</sup>.

IDA is the major partner in the development of road infrastructure to improve transportation and increase employment. Recently IDA completed Rural Road Project

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<sup>4</sup> <http://www.worldbank.org/en/country/bangladesh/overview>

of 2500 km rural roads in 21 districts to connect easily with schools, clinics as well as reduce transportation cost and better human life. The Rural Road Project (RRP) shows that, almost 47,000 employments have increased where 50% female employment and poverty reduced 1% of the total effect<sup>5</sup>. IDA is also focusing on agriculture by supporting Technology and Research and an active partner of agriculture sector in Bangladesh. In education sector, IDA has been contributing formal and informal education program which increased literacy rate especially in female education. Two decades ago, only one million girls attended in secondary school but today more than six million girls are attending in secondary school in Bangladesh. Not only developed the agriculture and education sector but also developed overall economic growth by supporting World Bank and IDA.

To reduce rapid poverty line and become a middle income country by 2021, Bangladesh needs a sustainable economic growth (World Bank, 2016). In recent, continuous GDP growth 6.1% has generated energy demand. Bangladesh is a country which is suffering shortage of electricity and gas service compare to demand. Even though production of electricity increased in both public and private sector, but unmanageable to meet the growing demand. Bangladesh is a country where 75% people live in rural areas and

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<sup>5</sup> <http://www.worldbank.org/en/country/bangladesh/overview#2>

only 42% access to the electricity grid (BBS, 2015). On the other hand, 90% people of urban area are connected with electricity (energypedia, 2013). The Bangladesh bureau of statistics mentioned 59.6% people of Bangladesh access with electricity grid in 2013 and about 62% in 2016 (energypedia, 2013). The mission statement of Bangladesh Power Development board (BPDB) mentioned that, country will make sure electricity available for all citizens in the country by 2021. Demand of electricity is increasing day by day because of enhance economic activities with economic growth. The key statistics of Bangladesh Power Development Board (BPDB) showed growth of electricity demand about 10% in 2016 which is estimated more in coming year. At present, the electricity maximum peak demand about 10,283 MW whereas maximum peak generation 7,817 MW based on nearly 7% GDP growth in FY 2015 (BPDB, 2015). Power System Master Plan (PSMP)-2010 forecast that, electricity peak demand will be 17,304 MW in FY 2020 and 25,199 MW in 2025 (BPDB, 2015). Table 3-2 illustrates yearly electricity peak demand in Bangladesh. It also forecast electricity peak demand until 2030.

**Table 3-2: Electricity Demand**

<b>Fiscal Year</b>	<b>Peak Demand (MW)</b>
<b>2010</b>	6,454
<b>2011</b>	6,765
<b>2012</b>	7,518

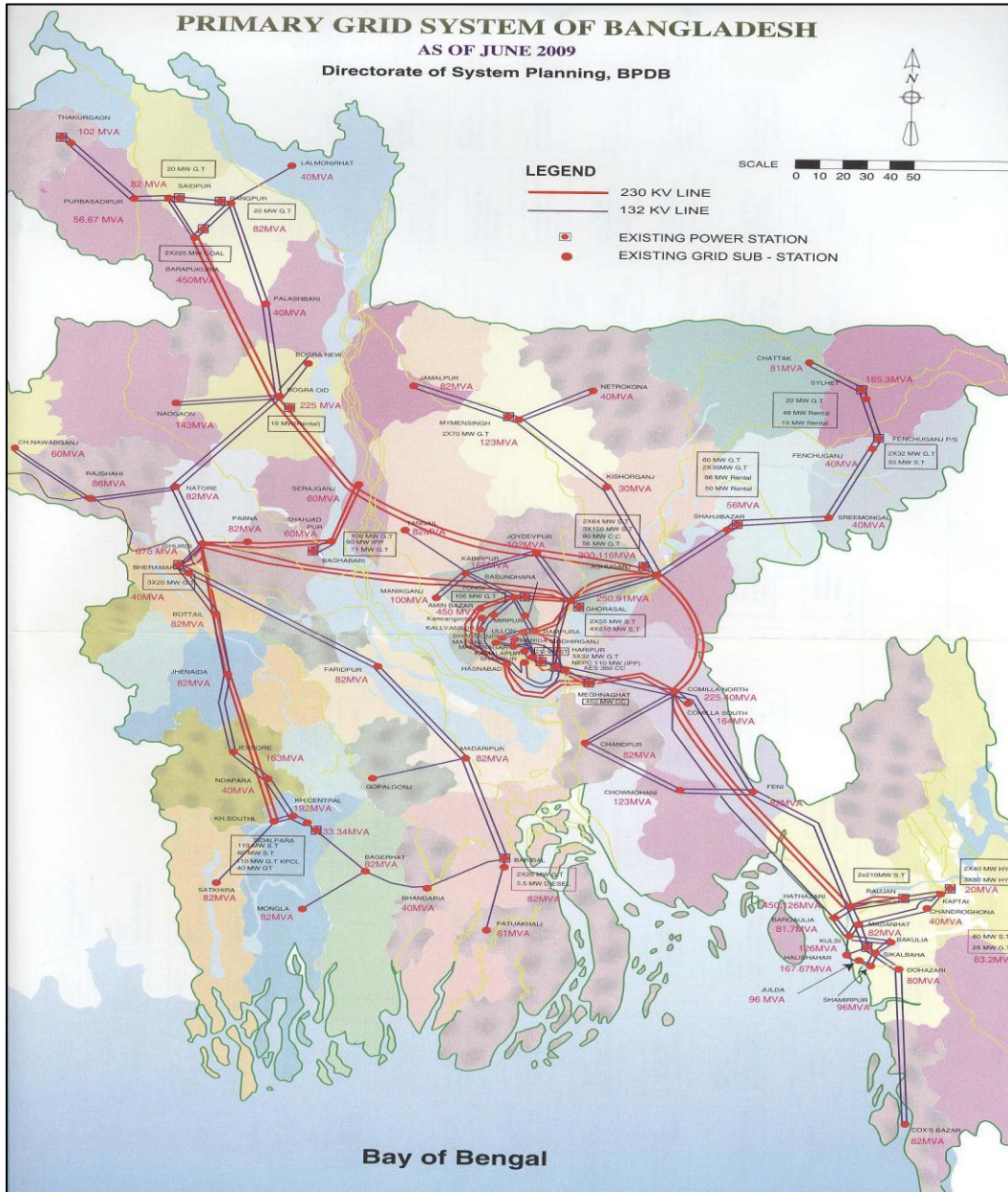
2013	8,349
2014	9,268
2015	10,283
2016	11,405
2017	12,644
2018	14,014
2019	15,527
2020	17,304
2021	18,838
2022	20,443
2023	21,993
2024	23,581
2025	25,199
2026	26,838
2027	28,487
2028	30,134
2029	31,873
2030	33,708

*Source: Bangladesh Power Development Board, Annual Report 2014-15*



### 3.2 Energy Scenario of Bangladesh

Figure 3-1: show the primary grid system of Bangladesh.



Source: Bangladesh Power Development Board, Annual Report 2014-15

Bangladesh is located in South Asia with nearly 160 million people and 6.1% GDP growth in 2015 (World Data Bank, 2016). As a developing country, Bangladesh needs to use its wealth and resources in proper way. In recent decade demand of energy increased

for economical, industrial and technological development. Moreover, rapid growth of population, urbanization, industrialization is the cause of increasing energy consumption in the country. To elevate the overall living standard and mitigate the energy demand, conventional and non-conventional energy is also necessary. According to the Islam et al (2014) in 2000 the primary energy consumption was 12.7 Mtoe and 2011 reached 24.3 Mtoe which is 47% increased within decade. By the year 2020, expected power demand will increase 185% and peak demand will be 17,304 MW (World Bank, 2016). Per capita electricity consumption is also very low in Bangladesh 321 kWh, comparing with other developing countries like India (644 kWh), Pakistan (457 kWh), Nepal (454 kWh) (Ahmed et al, 2016).

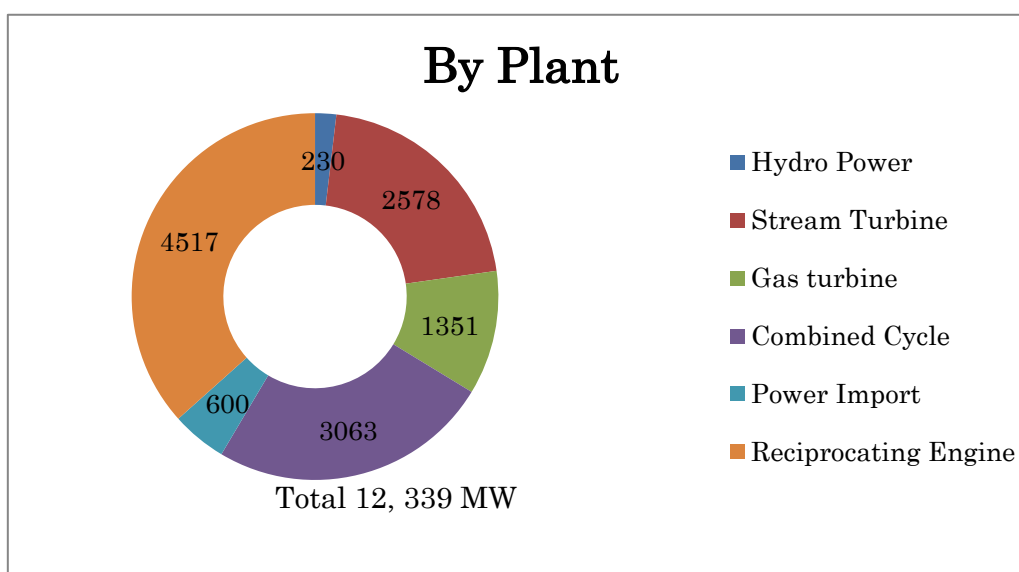
**Table 3-3: Electricity consumption in different countries.**

Country	Consumption per capita (MW)
USA	13,361
France	7756
Germany	7217
China	2942
Turkey	2474
India	644
Srilanka	636.3
Pakistan	457
Afghanistan	119.8
Bangladesh	321.1
Nepal	454.1

*Source: (Ahmed et al, 2016)*

The total primary energy supply is increasing 2.59% yearly where per capita energy consumption has increased 200% from 1992 to 2011 in Bangladesh. Present growth of electricity generation is not enough to meet increasing demand of electricity. At present, to generate electricity nearly 98% use the fossil fuel such as gas, furnace oil, diesel and coal mostly. Based on the BPDB information (2015), natural gas contribute 61.82%, furnace oil 21.68%, diesel 7.75%, coal 2.03% to generate the electricity<sup>6</sup>. The below figure 3-2, 3-3 shows electricity generation capacity by plant and fuel.

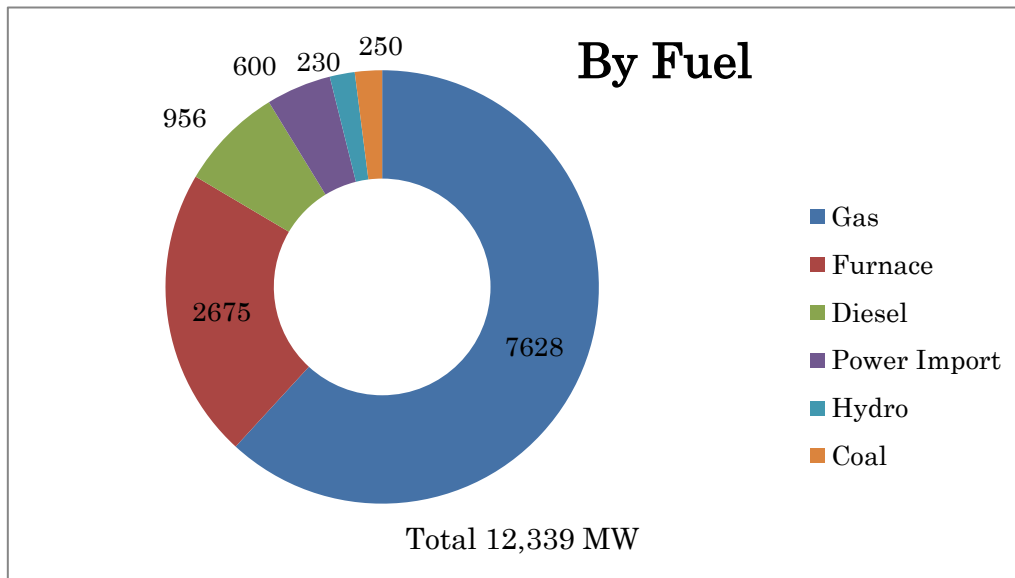
**Figure 3-2: Electricity generation capacity by plant**



Source: Bangladesh Power Development Board (annual report, 2014-15)

<sup>6</sup> [http://www.bpdb.gov.bd/bpdb/index.php?option=com\\_content&view=article&id=5&Itemid=6](http://www.bpdb.gov.bd/bpdb/index.php?option=com_content&view=article&id=5&Itemid=6)

**Figure 3-3: Electricity generation capacity by fuel**



*Source: Bangladesh Power Development Board (annual report, 2014-15)*

However, as per the current estimated, Bangladesh will face serious problem in near future because of shortage electricity supply compare to demand. At present, electricity problem is one of the critical issues in Bangladesh. Another thing is that, almost 47 million people of Bangladesh live below the poverty line. So, sufficient electricity is needed for economic growth, rapid urbanization and industrial development. By 2021 Bangladesh aspires to be a middle income country and it requires boosting GDP growth 7.5% to 8% per year. To accelerate GDP growth country need to increase both public and private investment as well as increase demand of domestic employment. Based on the paper Halder et al (2015), there is a casual relationship between GDP growth and

electricity generation growth in Bangladesh. The data show that, the consumer and beneficiaries of grid connection is increasing remarkably in the country. Both public and private sector are working together to increase electricity generation as well as minimize the gap between electricity demand and supply. In fiscal 2012, the total grid connection was 13.2 million and in 2009 was 10.80 million in entire country (BPDB, 2016). In 2011, the total consumption of Bangladesh was 39,533 GWh, it is expected that in 2035 the total electricity demand will be 192.70 TWh (Halder et al, 2015). The chart shows that, the maximum demand was 3,149 MW in (1999-2000) and 10,283 MW in (2014-2015). The result reveals that, the maximum electricity demand has increased more than 3 times in last 15 years.

**Table 3-4: Capacity, Demand, Generation, and Shedding in Bangladesh**

Year	Installed Capacity (MW)	Present Capacity (MW)	Maximum Demand (MW)	Maximum Peak Generation (MW)	Maximum Load Shedding (MW)
<b>1999-00</b>	3,711	3,549	3,149	2,665	536
<b>2000-01</b>	4,005	3,830	3,394	3,033	663
<b>2001-02</b>	4,234	3,883	3,659	3,218	367
<b>2002-03</b>	4,680	4,368	3,947	3,428	468
<b>2003-04</b>	4,680	4,315	4,259	3,592	694
<b>2004-05</b>	4,995	4,364	4,557	3,721	770
<b>2005-06</b>	5,245	4,614	4,693	3,782	1,312
<b>2006-07</b>	5,202	4,623	5,112	3,718	1,345
<b>2007-08</b>	5,305	4,776	5,569	4,130	1,049
<b>2008-09</b>	5,719	5,166	6,066	4,162	1,269
<b>2009-10</b>	5,823	5,271	6,454	4,606	1,459
<b>2010-11</b>	7,264	6,639	6,765	4,890	1,335
<b>2011-12</b>	8,716	8,100	7,518	6,066	1,058
<b>2012-13</b>	9,151	8,537	8,349	6,434	1,048
<b>2013-14</b>	10,416	9,821	9,268	7,356	932
<b>2014-15</b>	11,534	10,939	10,283	7,817	307

*Source: Bangladesh Power Development Board (BPDB), 2016*

So, the Government of Bangladesh and non-government agency need to think to increase electricity generation for upcoming demand and economic growth in future.

Power System Master Plan 2010 forecast that, electricity demand will be nearly 19,000 MW in 2021 and 34,000 MW in 2030 (World Nuclear Association, 2016). To meet the increasing electricity demand country was proposed for building a nuclear power plant in 1961. In 1963, site was selected in Ruppur at Pabna district which is 160 km north from Dhaka. After independence in 1980, 125 MW nuclear power plant was formally approved but not built. In 2001 Bangladesh adopted a national nuclear power action plan and in 2005 signed a nuclear agreement with China. In 2007, Bangladesh Atomic Energy Commission proposed another two 500 MW nuclear reactors for Ruppur by the year 2015 (World Nuclear Association, 2016). In 2008 the government reiterated to work with China and China offered funding for the project. The International Atomic Energy Agency (IAEA) approved to give technical support for the Ruppur nuclear power plant. In 2009, China Russian, South Korea offered financial and technical help to set up nuclear power plant and March, 2009 Russia made a formal agreement to build a power plant in the country (WNA, 2016) In May 2009, the government accept Russian formal proposal to build 1000 MW ASE-92 nuclear power plant in Ruppur which cost will be about \$2 billion. Finally intergovernmental agreement was signed with Russia in 2010. In 2012, the nuclear power plant bill introduced in parliament and set up to begin the work with Bangladesh Atomic Energy Regulatory Authority. In addition Bangladesh

parliament announced that, 5000 MW nuclear power plant will set up by the year 2030 (The daily Star, 2015). One agreement was signed for two 1000 MW class reactor at Ruppur in 2011 (World Nuclear Association, 2016).

**Table 3-5** Planned Nuclear Power Reactor

Type	Capacity	Construction Satrt	Operation
<b>Ruppur 1 AES-2006/V392M</b>	1200 MW	2017	2022
<b>Ruppur 2 AES-2006/V392M</b>	1200 MW	2018	2023

*Source: World Nuclear Association, 2015*

According to the finance minister 2015, total cost will be \$13.5 billion which \$12 billion finance by Russia with less than 4% interest. It is expected that, construction of the first unit will start from 2017 and second unit 2018; with commercial operation start from 2022 and 2023. However, nuclear power plan is a costly project for Bangladesh. Another important thing is that, consumption of conventional energy and nuclear energy has a negative impact on the environment and nature that is very important issue for Bangladesh as well as world. In Bangladesh, fossil fuel contributes more to generate electricity, nearly 98% electricity generation by fossil fuel. Consumption of fossil fuel raises the greenhouse effect; increase CO<sub>2</sub>, SO<sub>x</sub>, NO<sub>x</sub>, and SO<sub>2</sub> emission and change the climate (Ahmed et al, 2016). To resolve the huge environment and energy problem in Bangladesh, it must look for other alternatives way. Develop the technology of



renewable energy and proper use can be one of the alternative ways to mitigate the energy crisis up to the certain level (Ahmed et. al, 2014). That is why, this paper will try to find out alternative way (Renewable Energy) and increase production to meet the increasing demand and protect the environment.

**Table 3-6 present Installed Generation Capacity both public and private**

Public Sector	Installed Generation Capacity (MW)
BPDB	4,320
APSCL	904
EGCB	622
NWPGCL	368
RPCL	77
PDDDB- RPCL JV	149
Subtotal	6,440
<hr/>	
Private Sector	
IPPs	2,820
SIPPs (BPDB)	99
SIPPs (REB)	251
Rental (15 year)	167
Rental 3/5 years	1,962
Import	600
Subtotal	5,899
<b>Grand Total</b>	<b>12,339</b>

*Source: Bangladesh Power Development Board (BPDB), 2016*

### 3.3 Renewable Energy in Bangladesh

Past few decades indicated that, agriculture economy is shifting to industrial economy in the developing countries (Islam et al, 2014). As an emerging developing country of south Asia, Bangladesh is also moving from agriculture economy to industrial economy with high GDP growth 6.1%. According to the World Data Bank, in 2014 the agriculture sector contributed 16.1% and industrial sector 27.6% to the GDP in Bangladesh. It is expected that, demand of electricity will intensification up to the 18,838 MW and total demand will be 33,708 Mw by the year 2030. Indeed, electricity demand is rising by leaps and bounds. Furthermore, efficiency of existing power plant is fraught and inefficient to meet the demand. For sustainable economic growth and become a middle income country by the year 2021, Bangladesh needs to generate more energy. Recently, BPDB mentioned that, total installed capacity 12, 339 MW which natural gas generate 7628 MW, furnace oil 2675 MW, diesel 956 MW, coal 250 MW, power import 600 MW and hydro 230MW respectively (BPDB, 2016)<sup>7</sup>. But generate electricity by fossil fuel; there is a long-term negative effect on sustainable development and climate because of global warming. By end of the year 2012, the total capacity of global power generation was 22,668TWh where fossil fuel contributed 67.9%, nuclear 10.9% hydro power

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<sup>7</sup> [http://www.bpdb.gov.bd/bpdb/index.php?option=com\\_content&view=article&id=12&Itemid=126](http://www.bpdb.gov.bd/bpdb/index.php?option=com_content&view=article&id=12&Itemid=126)

16.2% and other renewable sources near to 5% (Ahmed et al, 2016). Consumption of fossil fuel raises the greenhouse effect; increase CO<sub>2</sub>, SO<sub>x</sub>, NO<sub>x</sub>, and SO<sub>2</sub> emission and change the climate. China is the leading country of greenhouse gases with 8205.86 million tons and India holds the third position with 1954.02 million tons (Ahmed et al, 2016). Increasing these gases in the atmosphere has caused some serious environmental issues such as environmental pollution and climate change on the planet. According to the Environmental Protection Agency (EPA), a serious climate change occurred and increased 42% greenhouse gases from 1992 to 2012 (Ahmed et al, 2016). Through the electricity generation, the fossil fuel is the leading contributor to emission greenhouses gases. To minimize the greenhouse gases and meet growing energy demand renewable energy is the best possible solution in 21<sup>st</sup> century. The statistics of Global Energy shows, renewable energy generation contributed nearly 19% of total electricity generation in 2014 (Global Energy, 2015)<sup>8</sup>. However, to reduce the CO<sub>2</sub> emission and sustainable economic development Bangladesh needs alternative way to generate electricity. In addition the people of rural area in Bangladesh are seriously deprived of electricity and modern facilities where 75% people live in (World Bank, 2015). For

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<https://www.iea.org/publications/freepublications/publication/WEO2015SpecialReportonEnergyandClimateChange.pdf>

these reasons, several attempts have been taken to develop the life expectancy of rural people as well as overall economic development of Bangladesh. The government of Bangladesh, both public and private sector has already taken several initiatives step to develop technology and promote investment on renewable energy to mitigate energy problems and negative environment impacts (Halder et al, 2015).

Table 3-7: Present achievement of power generation from renewable energy

<b>Present achievement of power generation from renewable energy</b>	
<b>Category</b>	<b>Achievement</b>
<b>SHS</b>	150 MW
<b>Solar Irrigation</b>	1 MW
<b>Roof top solar PV</b>	14 MW
<b>Wind Energy</b>	2 MW
<b>Biomass based electricity</b>	<1 MW
<b>Biogas based electricity</b>	5 MW
<b>Hydropower</b>	230 MW
<b>Total</b>	403 MW

Source: (Halder et al, 2015)

There is no alternatives way for accelerating sustainable development and economic development except to increase power generation by supplement of fossil fuel. From that point of view, renewable energy can be deliberated as the most realistic solution to meet present crisis as well as future demand towards sustainable economic development

in Bangladesh (Islam et al, 2014). Renewable energy sources are defined which are abundant in nature and derived from the nature to electricity. Bangladesh is a country of several renewable energy sources such as solar, wind, biomass and small scale hydropower energy<sup>9</sup>. Among the renewable energy of Bangladesh, solar and biomass biogas are considered the most favorable and effective resources compare with others. But we are still at nascent stage in the use of renewable energies whereas developed countries have already become prevalent. End of year, the renewable energy will contribute 5% of total energy of the country. According to the policy of renewable energy 2009, the renewable energy will contribute 10% by the year 2021 (BPDB, 2015)<sup>10</sup>. Directorate of Renewable energy and Research & development ensure that, the geographical location of the country is perfect for solar energy.

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<sup>9</sup> [http://www.iea.org/media/pams/bangladesh/Bangladesh\\_RenewableEnergyPolicy\\_2008.pdf](http://www.iea.org/media/pams/bangladesh/Bangladesh_RenewableEnergyPolicy_2008.pdf)

<sup>10</sup> [http://www.bpdb.gov.bd/bpdb/index.php?option=com\\_content&view=article&id=26](http://www.bpdb.gov.bd/bpdb/index.php?option=com_content&view=article&id=26)

**Table 3-8: Renewable energy potential in Bangladesh**

<b>Resources</b>	<b>Potential</b>	<b>Entities</b>
<b>Solar</b>	Enormous	Public and private
<b>Wind</b>	Resources mapping required	Public sector
<b>Hydro</b>	Estimated hydro potential 500MW	Mainly public sector
<b>Biogas Domestic</b>	8.6 million m <sup>3</sup> of biogas	Public and private sector
<b>Rice Husk based biomass</b>	300 MW consider 2 kg of husk	Mainly private sector
<b>Cattle waste based biomass</b>	350 MW consider 0.753 m <sup>3</sup> of biogas	Mainly private sector

The Government of Bangladesh (GOB) announced ambitious Renewable Energy Project to increase energy connection, reduce cost and make stronger its power sector.

The GOB has targeted to install 3,168 MW of renewable energy capacity by the year 2021 which is contribute 10% of total energy of the country (Mittal, 2015).

**Table 3-9: Renewable energy development in private sector.**

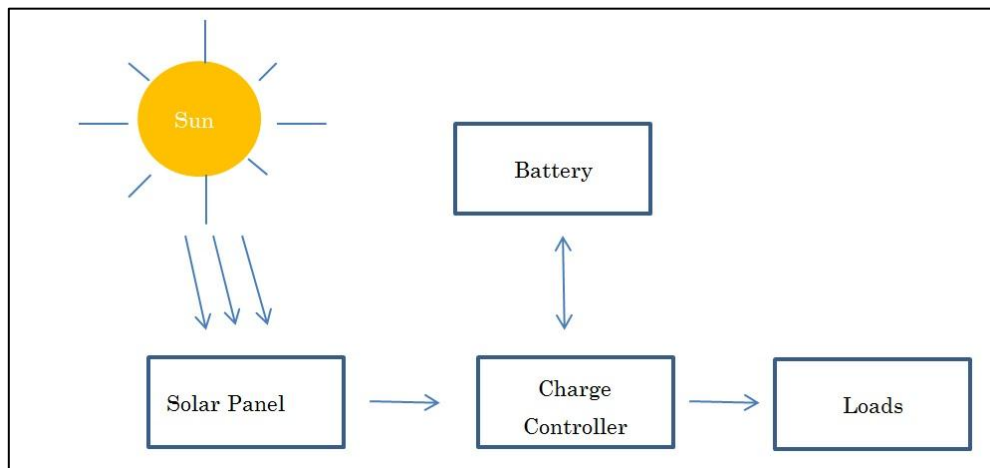
<b>Category</b>	<b>capacity</b>
<b>SHS</b>	234 MW
<b>Biogas plant for cooking</b>	40 MW
<b>solar mini grid</b>	7.5 MW
<b>soalar irrigation pump</b>	15.5 MW
<b>biogas based power plant</b>	7 MW
<b>biomass based power plant</b>	1.5 MW
<b>Total</b>	305.5 MW

*Source: (Halder et al, 2015)*

### 3.3.1 Solar Energy

Solar energy is the most prominent and sustainable renewable resource of energy all over the world. Basically solar energy comes from sun light as a conservation way then converted into photovoltaic direct energy. The photovoltaic systems, receive a large amount of sunlight by mirror, lenses or tracing system. After that, the photovoltaic system use to generate electricity from sunlight (Hossain et. al, 2016).

**Figure 3-4: Schematic illustration of solar energy utilization**



*Source: Halder et al (2015, p.1642)*

Solar photovoltaic (PV) technology is becoming popular especially in off grid rural and isolated areas like hill tracks, coastal area in Bangladesh. Bangladesh also has huge scope of utilizing sunlight radiation because of her suitable geographical location. Bangladesh is situated in an appropriate location where easy to tap huge solar radiation. Investigation shows that, 94% area of Bangladesh can receive average solar radiation, from March to April receive maximum radiation and from December to January receive

minimum radiation (Ahmed, 2014). Based on solar radiation data of National Aeronautics and Space Administration (NASA) illustrated along with Surface Metrology; average solar radiation should be range of 4-5 kWh/m<sup>2</sup> for solar energy which is absolutely perfect for geographical location of Bangladesh (Ahmed, 2014). She receives average 4-6.5kWh/m<sup>2</sup> solar radiation that can produce (1018\*10<sup>8</sup>) EJ energy. For this reason solar energy is measured as a most favorable renewable energy sources to mitigate the electricity demand all over the world. Approximately 3,400, 000 exajoule solar radiations come on the earth in a year, which could generate about 1700 TW electricity power. Theoretically proved that, 1% of this energy can solve world's electricity demand (Islam et. al, 2014). Solar PV and CSP play a vital role in global electricity generation. Halder et al, (2015) mention that, in Italy nearly 7.8%, in Greece 6% and in Germany 5% electricity generation from solar system. Then Asian leading country China and Japan also are generating electricity from solar power approximately 20 GW and 13.6 GW respectively. Bangladesh also considered being an ideal place of solar energy utilization where about 1900 kWh/m<sup>2</sup> solar radiation is available in a year. Theoretically she receives approximately 69,751 TWh in a year which is 3000 times higher than present generated electricity in Bangladesh (Erakhrumen, 2013). However, sustainable investment from both governments of Bangladesh (GOB) and private sector



are required to step up the potential of solar energy in Bangladesh. Beside Concentrating Solar Power (CSP) technology, some solar technologies are quite successful in Bangladesh such as solar PV, solar cooker and SHS (solar home system). About 260 hot boxes cooker and 61,500 solar PV system has been installed in rural, coastal and hill tracts areas of Bangladesh (Islam et al, 2014). At present, GOB has approved to construct a huge solar power project which plays a vital role to achieve the renewable energy target. About, 200 MW solar power project to be constructed by Bangladesh government and developed by SunEdison Energy Holdings (Singapore)<sup>11</sup>. It is expected that, this will be the largest solar power project in the country. In total, GOB has targeted 3,168 MW of renewable energy project which 1,740 MW will contribute by solar power project by 2021 (Mahapatra, 2015).

**Table 3-10: Expected 500 MW solar program by public sector**

<b>Project</b>	<b>Capacity (MW)</b>
Solar electrification in health center	50
Solar electrification in remote education institutioun	40
Solar electrification at union e-center	7
Solar electrification at religious establishment	12
Solar electrification at railway station	10
PV system in government offices	41
<b>Total</b>	<b>160</b>

Source: (Halder et al, 2015)

<sup>11</sup> <http://cleantechnica.com/2015/11/26/bangladesh-approves-200-mw-solar-power-project-sunedison/>

**Table 3-11: Expected 500 MW solar program by private sector**

<b>Project</b>	<b>Capacity (MW)</b>
<b>Solar mini grid</b>	25
<b>Solar irrigation pump</b>	150
<b>Solar park</b>	135
<b>Solar roof top residential and commercial building</b>	10
<b>Industrial building</b>	20
<b>Total</b>	340

*Source: (Halder et al, 2015)*

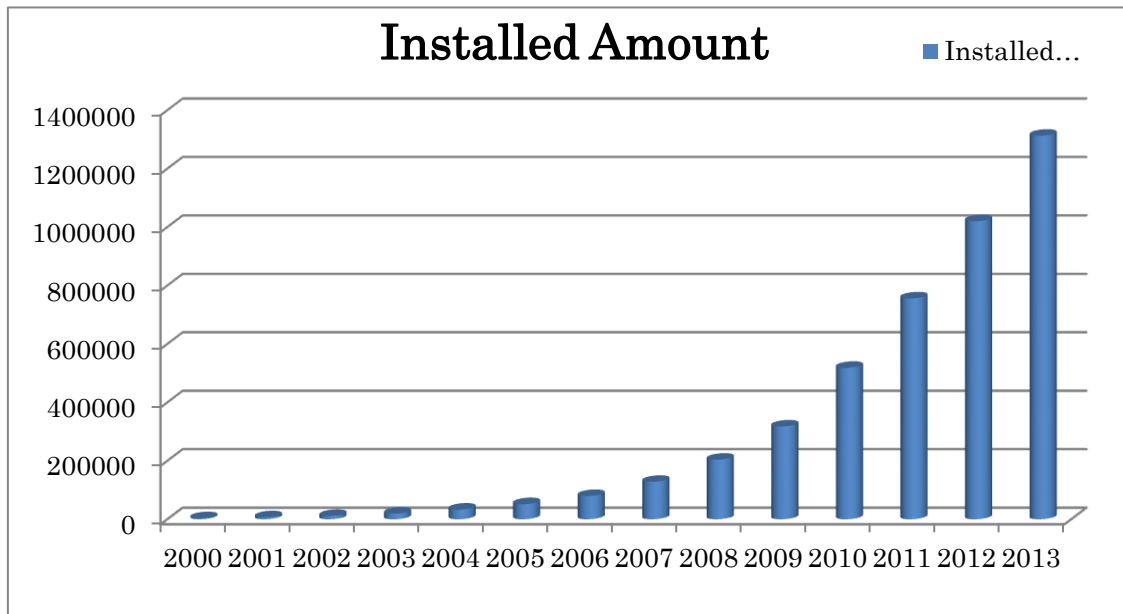
However, Bangladesh only 62% people of total population have connected with electricity supply (BPDB, 2016). Compare to other developing countries, Bangladesh is still at the nascent stage of renewable energy technique as well as total power generation. Even there is no large commercial industry and coordinating authority of renewable energy as well as solar energy sector. It is estimated that there is potentiality 50,174 MW electricity can generate by grid connected PV system in Bangladesh. It also notices that 500 kWh grid connected solar system can decline 658 tons greenhouse gas which is very friendly for environment (Reza et.al, 2012). Capital of Bangladesh, Dhaka is the most densely populated megacity in the world, where 2000 MW electricity need in peak hour for 14 million people. Theoretically proved that, more than 1000 MW electricity can produce by PV solar power system in Dhaka city (Kabir, 2013). Energy crisis has become tremendous issue in Bangladesh, particularly in urban area. Proper policy

should be taken to promote PV solar system, it possible to meet future demand in urban area. On the other hand, rural area of Bangladesh, infrastructure, health system, and education system is not well organized because of power crisis (Reza et.al, 2012). Modern health care and education services cannot run without power of electricity. Solar PV system can play a vital role to mitigating such power crisis for developing modern health and education services.

### **3.3.2 Solar Home System (SHS) and SCP**

From off grid power generation perspective, Solar Home System (SHS) achieved remarkable success in remote and isolated areas of Bangladesh. In 2012, government and non-government organizations installed more than 1,320,965 SHSs entire the country. The installed capacity of SHS with 36.5 MW in remote area is increasing to meet the power demand (Jahan et.,al, 2013). Infrastructure Development Company Limited (IDCOL), has been started it solar program in 2003 to encourage the people those are living in remote area without electricity. In 2014, the total SHS has increased up to 3357609 all over the country by 47 organizations. Grameen Shakti is the pioneer organization, installed almost 56% of total SHSs in different part of the country (Halder et al, 2015). The total install capacity in the year 2013-2014 was nearly 150 MW which is 185.185% increase compare with previous year.

**Figure 3-5: Grameen Shakti installation of SHS by the year**



*Source: Halder et al, 2015*

At present, in Bangladesh almost 234MW electricity is generating from SHSs (Halder et al 2015). Furthermore, grid connected solar PV system is another solar technology for generating electricity from sun light. Mini grid concept and grid connected solar PV system would bring new dimension to produce electricity as well as decline power crisis in Bangladesh. It is now considerate as an important socioeconomic development such as children education, health in remote and isolated area (Ahmed et al, 2014). However, Bangladesh is producing 3MW electricity from roof top solar plant and has a great potential of 50,174 MW Grid connected solar PV system (Halder et al 2015). The Rural Electrification Board (REB) took several initiative steps under the Renewable Energy Development program to promote and increase the install SHS. It also has taken step to

promote generation capacity up to 50 MW and installing 4,000,000 SHSs by the year 2015 (Islam et. al, 2014). SHS is also supporting to decline CO<sub>2</sub> and greenhouse gas emission. It is estimated that, nearly 84,000 tons carbon and GHG emission to be declined compare with other primary energy resources (Islam et. al, 2014). However, SHS should not be considered as a poverty decline instrument, but it can be noticeable socioeconomic benefits and change lifestyle in rural area of Bangladesh (Islam et. al, 2014).

### **3.3.3 Wind Energy**

At this time, Wind energy is one of the fastest growing eco-friendly resources of renewable energy in the world. Wind energy is converting into electricity by using wind turbine. In early 1980s the wind energy production was nearly zero in the world. Based on the information halder et al, (2015), wind power energy contributes almost 2.9% of total world's energy in 2013. In the year 2013, wind power energy increased 35 GW and reached 318 GW in the world. For maintaining the rapid economic growth, the wind energy grew nearly 16.2% and total energy reach to 373 by end of the year 2014GW (World Energy, 2015). China is the biggest wind power generation country in the world where total install capacity was 91.4 GW in 2013 (Halder et al 2015). India is the second largest wind power Asian country where installed capacity was 20.2 GW in 2013.

However, for wind power generation Bangladesh also has some potential sites with 724 km long coastal line. As per the GOB, the total generation capacity from wind energy is 235 MW. Nevertheless, wind power technology is still in nascent level and marketable power generation from wind; require more investment and technology development in Bangladesh. International wind blow data and research represent that, more than 7m/s wind speed is needed for large scale grid connection to generate electricity. Bangladesh Metrological Department (BMD) and Local Government Engineering Development (LGED) revealed that, the speed of wind varies from 2.96 to 4.54 m/s at the height of 25 m and 50 m in different place in Bangladesh. To harness wind energy potential, ground data and a well-constructed wind map is essential. BMD and LGED also found the average wind speed is 3-6m/s from March to September in different sites in Bangladesh. BPDB installed first wind power generation plant at Muhuri in Feni district of installed capacity 0.90 MW with four units. Then in 2008, BPDB installed another wind battery hybrid power plant at Kutubdia of installed capacity 1 MW. According to the BPDB, steps have been taken to install 15 MW wind power generation plant at the coastal areas of Bangladesh. Recently, Bangladesh signed agreement with DK green energy of US for installing capacity 60MW wind power plant which will largest wind power plant in the country (Hossain, 2016). At this moment Bangladesh is on footstep to utilize wind

energy potential. Technology innovation, wind mapping in whole country and proper ground data should be necessary to access the full potential of wind power generation plant. Wind power generation can be provided off grid power in remote and isolated areas. More research, development should be conducted on wind mapping based on the geographical context and comprehensive analysis to identify full potential of the resources in Bangladesh.

### **3.3.4 Hydropower**

Hydro power is a form of renewable energy generated from water flow. It is depending on the water head and varied from watt to megawatt. There are many types of hydropower plant; mini hydropower plant is one of them. Mini hydropower plant can produce electricity up to 100 kW (Hossain, 2016). It can be used for small community, industry; especially in remote and isolated off grid areas. Due to geographical location and structure, Bangladesh has limited opportunity for hydropower. In 1962 the first remarkable hydro power plant established in Bangladesh named Kaptai hydropower plant<sup>12</sup>. Currently the plant is generating 220MW electricity, which is 2.3% of total

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<sup>12</sup>

[http://www.smallhydroworld.org/fileadmin/user\\_upload/pdf/Asia\\_Southern/WSHPDR\\_2013\\_Bangladesh.pdf](http://www.smallhydroworld.org/fileadmin/user_upload/pdf/Asia_Southern/WSHPDR_2013_Bangladesh.pdf)

power generation in Bangladesh<sup>13</sup>. LGED mentioned in its report, there are several prospective sites for mini hydropower plant in Bangladesh. In addition, Water Development Board and BDB have been looking for large scale hydro power plant since 1981. Especially in Chittagong Hill Tracts areas there are several potential sites for mini hydro power plant. To generate electricity from hydro power plant is considered low cost and socio economic development. It also plays a vital to reduce GHG emission and economic development as developing country in Bangladesh.

Globally electricity production from hydropower is rapidly increasing day by day. In 2010 the total electricity production from hydropower was 3427TWh which is 16% of world production (global Energy, 2016). China is the largest hydro power production country in the world where produce about 721TWh. More than 32% hydro power electricity is generated by 150 countries those are located in Asia Pacific Region (Islam et al, 2014). Hydro power electricity is also the main stream in Brazil, Canada, New Zealand, Norway, Australia, Switzerland and some other countries. However, Bangladesh is a country where numerous canals and branch of rivers. Bangladesh water development board and BPDB already discovered some sites which has great potential

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<sup>13</sup> <http://mirrorofbd2012.blogspot.jp/2012/06/kaptai-dam-karnafuli-hydro-power.html#.V0lyjjV97cs>



for micro hydropower generation. In future, it will contribute to ensure power supply in rural isolated off grid areas and overall socio-economic development of Bangladesh.

**Table 3-12: Ten largest Hydro power producer countries in the world**

Country	Annual Hydroelectric production
China	721.00
Canada	369.50
Brazil	363.80
United States	250.60
Russia	167.00
Norway	140.50
India	115.60
Venezuela	85.96
Japan	69.20
Sweden	65.50

*Sources: key world energy statistics, 2015*

**Table 3-13: Potential micro-hydropower sites in Bangladesh (Kilowatts)**

Location	Power Potential (kW)
Nuchari tholi khal in Khagrachari	5
Sealock khal in Bandarban	30
Taracha khal in bandarban	20
Rowangchari khal in Bandarban	10
Hnara khal in Ranggamathi	10
Hnara khal in chara much Ranggamathi	30
Monjaipara micro Hydro power unit	10
Bamer Chara Irrigation Project	10

*Source: Local Government Engineering Department LGED, 2015*

### 3.3.5 Biomass Energy

Biomass energy is one of the most important sources of energy among the all source of

energy (Hossain et al, 2016). Biomass is a kind of energy renewable energy where biomass is to produce energy. Biomass is anything that has once been alive. Logs, cows, trees, crops, cotton shirts, leaves and its residues and even people are examples of biomass. Rocks, air, windows and water are not. Biomass is arranged in an ecosystem (Huda et al, 2013). The biomass we use for fuel includes wood, wood waste, straw, manure, sugar cane, and many other byproducts from a variety of agricultural processes. When burned, the chemical energy is released as heat. If you have a fireplace, the wood you burn in it is a biomass fuel.

Biomass was the first form of energy that was harnessed by humans in the form of wood being burned (Islam et al, 2014). Biomass is not only used by humans, but all other animals use biomass to get their energy for living. There are many advantage and disadvantages of biomass energy in all over the world. Many energy sources used today struggle to control their carbon dioxide emissions, as these can cause harm to the ozone layer and increase the effects of greenhouse gases, potentially warming the planet<sup>14</sup>. It is completely natural, has no such carbon dioxide side effects in its use. So there is no harmful emission. It is a kind of clean energy. It does release carbon dioxide but captures carbon dioxide for its own growth. Carbon dioxide released by fossil fuel is

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<sup>14</sup> [http://www.eia.gov/energyexplained/?page=biomass\\_environment](http://www.eia.gov/energyexplained/?page=biomass_environment)

released into the atmosphere and are harmful. Biomass energy is abundant and renewable. In biomass energy can reduce dependency on fossil fuels. It has developed as an alternate source of fuel for many homeowners and has helped them to reduce their dependency on fossil fuels so there are many application of biomass energy in all over the world. So the advantages of biomass energy are very applicable in the world.

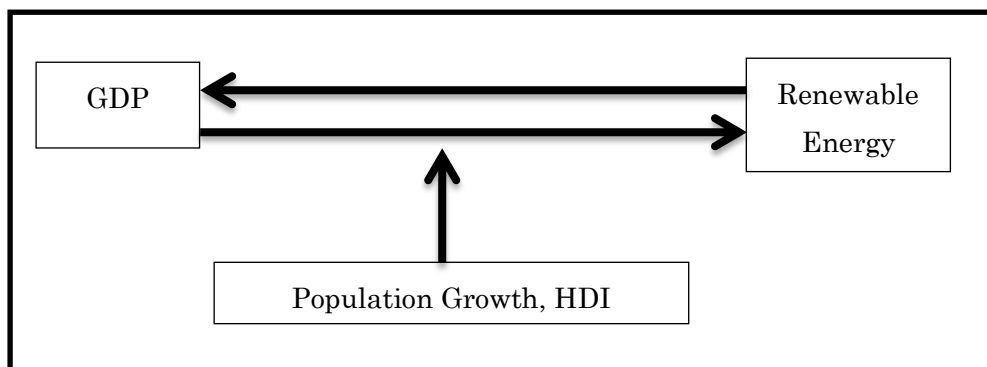
Bangladesh is a country with over population. Source of energy is too much essential in Bangladesh. Bangladesh is endowed with an enormous amount of renewable energy resources. Biomass energy is the most favorable and effective renewable energy in Bangladesh (Halder et al, 2015). Bangladesh has been experiencing several problems over the past few decades. Over population is one of the biggest problems in Bangladesh.in order to meet up the demand of energy which is used in different purposes. Biomass is one of the potential renewable energy sources in Bangladesh. Agricultural crop residues, animal manure and municipal solid waste are the major sources of biomass energy in the country (Ahmed et al, 2014).

## 4 Chapter 4: Methodology

### 4.1 Conceptual Framework

The conceptual framework of this study is presented in Figure 4-1. As we mentioned earlier that the relationship between renewable energy and economic development is controversial therefor this research, researcher can sense a relation between and among renewable energy and economic development. The main objective of this study is to understand the potential relationship between renewable energy and economic growth. In order to evaluate the role of economic growth in renewable energy, this study employs GDP growth rate as a proxy economic growth and total renewable energy consumption will be used as an independent variable. Other variable population growth and Human Development Index (HDI) will be used as a control variable.

**Figure 4-1: Conceptual Framework**



*Source: Author Creation Based on Literature*

## 4.2 Hypothesis

**Hypothesis#1:** Renewable energy enhance Economic growth

**Hypothesis # 2:** Economic Growth encourage consume more renewable energy.

## 4.3 Regression Equation

Different regression analysis can be used to see the relationship between GDP growth and Renewable energy consumption. Researcher have used the following Static Models multiple regression equation which is as follows

$$y_i = \alpha_i + \sum_{i=0}^n \beta_i X_i + \varepsilon_i \dots \dots \dots (1)$$

Where,

$y_i$  = Dependent Variable

$\alpha_i$  = Intercept of the Equation

$\beta_i$  = coefficient of  $X_i$  variables

$X_i$  = Different Independent variables

$\varepsilon_i$  = error terms

To see the relationship between GDP growth and renewable energy; researcher

Calibration the variables into the model yield the following equation:

$$GDP_t = \alpha + \beta_1 REC_t + \beta_2 PG_t + \beta_3 HDI_t + \mu_t \dots \dots \dots \text{EQ-1}$$

$$REC_t = \alpha + \beta_1 GDP_t + \mu_t \dots \dots \dots \text{EQ-2}$$

Where,

$GDP$ =GDP growth at time  $t$

$REC$ = Renewable energy consumption at time  $t$

$PG$ =Population growth rate at time  $t$

$HDI$ =Human development index at time  $t$

In the EQ-1 researcher consider the effect of control variable but in EQ-2 researcher assume that there is no effect on control variable in EQ-2.

#### 4.4 Sampling and Data collection

This study is focusing only on Bangladesh. The reason for selection Bangladesh is that it is a developing country in south East Asia. Mostly densely populated country among Southeast Asia near 160 million populations where half of the population doesn't have access formal full grid electricity supply. Among them who do not have a formal full grid electricity supply, few people use renewable energy for their daily necessary. And as Bangladeshi citizen it is easy to get data from Bangladesh.

This research researcher considers 13 years' time series data from 2000 to 2012. Required data are collected from World Bank dataset; International energy statistics; Bangladesh bureau of statistics and UNDP (Table 4-1).

**Table 4-1: Data sources**

<b>Data</b>	<b>Data sources</b>
<b>Renewable energy</b>	International energy statistics
<b>Population growth</b>	Bangladesh Bureau of Statistics
<b>Human Development Index</b>	UNDP
<b>GDP</b>	World Bank Database.

#### 4.5 Unit root test

This study use a standard time series data to analysis the relationships between dependent and independent variables. To see the unit root between interest variable this research employed Augmented Dickey-Fuller unit root test in constant and trend method.

## 5 Chapter 5: Findings

### 5.1 Demographic profile

Table 5-1 shows the summary of selected variable. The mean value of GDP growth is 5.70% where standard deviation is 0.9%. The deviation is really too high. That means GDP growth is little bit stable over the year. Renewable energy mean value is 1377.523 million MWh and standard deviation is 319.26 which means the renewable energy is not stable over the period. Population average growth rate is 1.4% over the period with a standard deviation 0.3%. The HDI average 0.477 and standard deviation is 0.27 over the period.

**Table 5-1: Descriptive Statistics for time series of concern (2000-2012)**

Variable	Mean	Std. Dev.	Min	Max
GDP	.0569737	.0093385	.0383312	.0705864
REC	1377.523	319.2637	937.5	1942.8
PG	.0144031	.0031712	.0110906	.0194945
HDI	.4776154	.0276247	.433	.515

### 5.2 Unit root test

To see the unit root test researcher employed Augmented Dickey-Fuller on all individual variables (Table 5-2) shows that test strongly reject the null hypothesis at any level (e.g. 1%,5% and 10%) of significant of a unit root. Therefor researcher can run regression without taking any further data modification.

**Table 5-2: Dickey-Fuller unit root Test**

Variable (t)	Specification	Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
REC(t)	constant and trend	9.541	-2.66	-1.95	-1.60
GDP(t)	constant and trend	6.113	-2.66	-1.95	-1.60
PG(t)	constant and trend	-4.018	-2.66	-1.95	-1.60
HDI(t)	constant and trend	12.409	-2.66	-1.95	-1.60

### 5.3 Econometrics Result

For the first equation EQ-1 there results shows that F-statistics 0.0207 which means that the F-statistics is less than 5% which means that the test is significant at 5% level. The R-squared value 0.6448 and Adjusted R-squared 0.5264 which means the independent variables can explain of 52.64% of dependent variables (Table 5-3). From the table 5-3 it is shown that there renewable energy beta coefficient is .0001508 and P-value is 0.032 which means renewable energy is positively related with GDP at 5% significant level. There beta coefficient of Population growth is -11.56811 and P-value is 0.017 that means that the population growth negatively related with GDP and significantly related at 5% level. And Human Development Index Beta coefficient -2.79068 and P-value 0.029 which means that Human Development is negatively related and its significant at 5% level.



**Table 5-3: Basis Econometrics Results (EQ-1)**

Source	SS	df	MS	Number of obs	=	13
				F( 3, 9)	=	5.45
<b>Model</b>	.000674737	3	.000224912	Prob > F	=	0.0207
<b>Residual</b>	.000371743	9	.000041305	R-squared	=	0.6448
				Adj R-squared	=	0.5264
<b>Total</b>	.00104648	12	.000087207	Root MSE	=	.00643

<b>GDP</b>	<b>Coef.</b>	<b>Std. Err.</b>	<b>t</b>	<b>P&gt;t</b>	<b>[95% Conf.</b>	<b>Interval]</b>
<b>REC</b>	.0001508	.0000593	2.54	0.032	.0000166	.000285
<b>PG</b>	-11.56811	3.98113	-2.91	0.017	-20.57406	-2.562173
<b>HDI</b>	-2.79068	1.075136	-2.60	0.029	-5.222807	-.3585528
<b>_cons</b>	1.34876	.4892265	2.76	0.022	.2420526	2.455467

For the second equation EQ-2 there results shows that F-statistics 0.0517 which means that the F-statistics is more than 5% which means that the test is not significant at 5% level but significant at 10% level. The R-squared value 0.3021 and Adjusted R-squared 0.2387 which means the independent variables can explain of 23.87% of dependent variables (Table 5-4). From the table 5-4 it is shown that there GDP growth beta coefficient is 18791.64 and P-value is 0.052 which means GDP growth is positively related with Renewable energy at 10% significant level.

**Table 5-4: Basis Econometrics Results (EQ-2)**

Source	SS	df	MS	Number of obs	=	13
				F( 1, 11)	=	4.76
<b>Model</b>	369539.008	1	369539.008	Prob > F	=	0.0417
<b>Residual</b>	853612.855	11	77601.1686	R-squared	=	0.3021
				Adj R-squared	=	0.2387
<b>Total</b>	1223151.86	12	101929.322	Root MSE	=	278.57

REC	Coef.	Std. Err.	t	P>t	[95% Conf.	Interval]
<b>GDP</b>	18791.64	8611.299	2.18	0.052	-161.7014	37744.98
<b>_cons</b>	306.8941	496.6637	0.62	0.549	-786.2553	1400.043

## **6 Chapter 6: Recommendation and Conclusion**

### **6.1 Conclusion**

Energy sector of Bangladesh comprehensively depend on conventional energy resources such as coal, natural gas, imported crude oil and refined petroleum product where natural gas contributes 61.82% of total electricity generation (BPDB, 2016). So currently natural gas is the major energy resource which is utilizing highest level in power generation. Although, coal and hydro power contributes limited percentage of total power generation but there is a huge prospective of small scale micro hydro power energy in Bangladesh. On the other hand, renewable energy shares nearly 5% of total energy which very nascent stage compare with global energy generation. But Bangladesh is a country where numerous potentiality of renewable energy such as solar, small scale hydro power, wind and biomass. Moreover GOB has a plan to set up 5000 MW nuclear power plant by 2030 to meet future demand. But still it would not be sufficient to meet the future demand (BPDB, 2016). Therefore, for the assurance of the energy security, protect the environment; reduce the dependency on fossil fuel initial step must be taken to stimulate alternative and sustainable energy solution in Bangladesh. In this paper examined the positive relationship between renewable energy consumption and GDP growth in Bangladesh using time series data for the period

2000-2012. This result also supported by Bowden and Payne (2010), Payne (2011), Pao and Fu (2013), Ahmed et al (2014), Mondal et al (2010) and Salim and Rafiq (2011).

More research is needed on renewable energy for the development of Bangladesh energy sector. Sustainable energy services can play a vital role for socio economic development of Bangladesh. Government of Bangladesh should work with public and private organizations including international donor agencies and concern authorities to build attentiveness among the people.

According to Glatthorn and Joyner (2005, p.19) a research can contribute in the following ways; Test a Theory, Contributes to the Development of Theory, Extends Existing Knowledge, Changes Prevailing Beliefs, Suggests Relationship between Phenomena, Extends a Research Methodology or Instrument, and Provides Greater Depth of Knowledge about Previously Studied Phenomena. From this research researcher hopes that this research contribute in the following two section. Firstly, it's suggests the relationship between renewable energy consumption and GDP growth, population growth, HDI. Secondly, extend existing knowledge of that relationship by providing new evidence from Bangladesh renewable energy sectors. This research will also help for many people those are working in BPDB, company and government offices related to renewable energy by extending their knowledge and making new

future plan. Government policy makers can take initiative steps and make new policy on renewable energy by getting knowledge from this research. Private sectors and NGOs can change their future planning and activities to get more positive result and solve the energy problems in a country.

## 6.2 Recommendation

Energy is the key element for modernization and sustainable development of a country. Bangladesh is a developing country where energy crisis is one of the burning issues in current time. After reviewing the energy scenario of Bangladesh especially renewable energy; needs some recommendation to improve the current situation as given below:

- Based on the renewable energy sources such a solar, wind, hydro power biomass; whole country mapping is very important which will improve the current situation.
- New policy should be made on renewable energy and proper implementation can be solve energy problem in Bangladesh
- Need an umbrella organization with information communication technology for monitoring and regulating.
- Should install new technology to increase efficiency of existing power plant.
- Government should work together with both public and private sectors and

encourage them to invest more on renewable energy.

### **6.3 Limitation of Research and Direction of future Research**

This paper examined that, renewable energy consumption is positively related with GDP growth and negatively related with population growth. On the other hand, human development index is negatively related renewable energy consumption. This research cannot explain why the relationship between human development index and GDP growth is negatively related?

This problem will be highlighted in future research.

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