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Attaining Nationally Determined Contributions of Bangladesh through Greenhouse Gas Emission Reduction: Role of Solar PV Systems

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ABSTRACT

The paper analyzes as to how Bangladesh can secure its future demand of electricity and mitigate greenhouse gas emission to meet the targets of Nationally Determined Contributions (NDCs). The overall objective of the study is to assess the possible mitigation of greenhouse gases emission for achieving NDCs from power sector of Bangladesh through solar photovoltaic systems. A quantitative analysis was done to project future power consumptions and greenhouse gas emissions up to 2030. A scenario analysis was also done to see the effects of different primary energy mix in power on the emissions. It is found that the total consumption in different sectors will increase with an increasing population and the GDP. Industrial and residential sectors are the main consumers of power. The scenario result shows that there is relationship between the energy mix and greenhouse gas emissions. The fossil fuels have higher emissions in the scenarios where they are thought to be main contributor to the energy mix. In case of high renewables, the emissions can be mitigated to meet the targets of NDCs. As Bangladesh receives high solar radiation, grid-connected solar photovoltaic systems can be the main source of renewable energy in such case. Therefore, solar photovoltaic technology is essentially required not only for achieving the targets of NDCs but also for the development of a low carbon power sector in Bangladesh for a sustainable future.

Introduction

Global temperature is reported to gradually rise, while the year 2016 was the warmest year since preindustrial time and the temperature was 1.2 ℃ above preindustrial level (WMO, 2019). The reasons for such a rise are a blend of both natural variability and human activity. However, there are ample evidences to indicate that human activities are mostly responsible for such rising (NASA, 2020). In addition, caring about this change is very important for a balanced ecosystem. Because change in world average temperature is not just the thermometer reading which may vary daily, annually or seasonally, it represents an amount of energy required to change the temperature of oceans, ice sheets and lands of the earth, which of course not a small change. A great amount of change is required in absorptive and radiative energy of the earth surface features. Human induced greenhouse gas emissions associated with aerosols and their precursors are likely to be the main impediment of such changes and resulting imbalances (IPCC, 2018). The atmospheric concentration of greenhouse gases is increasing continuously as the extensive use of fossil fuels (UNFCCC, 2019). The annual emissions of GHGs has increased to more than 36 billion tonnes in 2017 from only .01 billion tonnes in 1751. GHGs are mainly emitted from energy sector, industrial processes, waste, agriculture sector and land use change and forestry sector. Of total emitted GHGs in 2018, more than 70% came from energy sector alone (CAIT, 2019). At the same time, electricity and heat generation subsector in energy sector emits most of the energy sector. In response to the situations, the world leaders in September 2015 had pledge to reduce anthropogenic emission of greenhouse gases to keep global rise of temperature within 2°C compared with pre-industrial level and pursuing a limit of 1.5^0C by 2100 (Gao et al., 2017). This is known as the historic Paris Agreement. Earlier, through Kyoto Protocol there was also an attempt to reduce global emissions where only the developed nations were involved on taking actions and supporting to developing nations in transferring technology and financial supports. Thus, through Paris Agreement, the developing nations also get a chance to participate in emission mitigation.

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Bangladesh contributes only less than 0.35% of emission of greenhouse gases in the atmosphere Most of the emission comes from the energy sector, which is about to 70% of total emission (MoEFCC, 2015). The power sector contributes a major part of it. The power sector of Bangladesh is highly dependent of fossil fuels. Gas is the main source of fuels in electricity generation. But Bangladesh has limited gas reserve. Therefore, the country is turning toward coal as an alternative source of fuels in power generation. But coal is the highest emitter of GHGs than any other fuels. So, replacing gas by coal will result in higher emissions in the future. On the other hand, the government is committed to decrease the emission as part of international agreement, Paris Agreement (MoEFCC, 2015). Bangladesh has intended to reduce its greenhouse gas emission in power, transport and industrial sector by 5% unconditionally and 15% conditionally from Business as Usual (BAU) level by 2030 (MoEFCC, 2015). Intended emission reduction from the power sector alone will be by 5% also unconditionally and 18% conditionally. However, the country is thriving in economy and the GDP is growing at faster rate, 7.86 percent in FY 2017-18 (Economic Advisor's Wing, 2018). Therefore, there will be huge demand of energy in forthcoming years. A question of energy security will be raised in the context of reducing emission on the one hand and fulfilling growing demand for electricity on the other. The solar PV system has already been recognized as a viable option to supplement electricity and to substantially reduce GHG emission as Bangladesh receives high average daily solar radiation ranging from 4-6.5 kWh/m^2 (Kabir et al., 2010; Marzia et al., 2018). The present study attempts to evaluate the role of solar photovoltaic (PV) systems in achieving the targets of NDCs for the overall low carbon energy development in Bangladesh.

Conceptual Background of the Study

Power Sector of Bangladesh and Greenhouse Gas Emission

Installed Capacity, Demand and Peak Generation: Figure 1 shows the installed capacity, derated capacity, maximum demand and peak generation of electricity of Bangladesh for years 2001-2019.

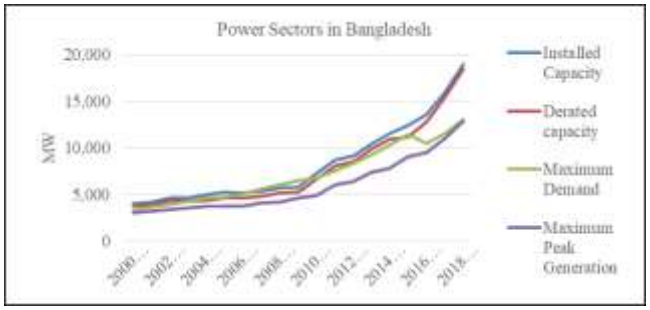

Figure 1: Current Electricity Generation in Bangladesh
Source: BPDB, 2019

In 2001, the installed capacity of electricity was only about 4000 MW. It has gradually increased to reach the present capacity of about 18900 MW in 2018-19, so there is almost five times increase in the installed capacity. The maximum demand of electricity has also increased through time. The maximum demand of electricity in 2001 was about 3394 MW in 2000-01, which reached to 13044 MW in 2018-19. Again, from Figure 1, it can be described that there is an increase in the peak generation with time. But the peak generation is still below the maximum demand. So, there was gap between the maximum demand and the peak generation and the gap was about 2000 MW in 2019 which is the source of deficiency in supply of fuel. The peak generation in year 2000-01 was about 3033MW and it was 12893 MW in 2018-19.

Historical Generation and Primary Energy Mix

Figure 2 shows the yearly actual power generation in TWh. It shows the actual generation than capacity. From 2000 to 2019, the power generation of the country has increased by about 350% from about 16 TWh to about 70.5TWh. The total generation of electricity for FY2009-10, 2014-15 was about 29TWh and 52 TWh respectively. Half of the generation comes from private sector, which was very low in FY2000-2001 (BPDB, 2019). Primary energy sources in Bangladesh are gas, oil, coal and renewables. Bangladesh produces the natural gas from its own gas fields and recently the country is buying the LNG from abroad (HC Unit, 2020). In recent years, it has been producing nearly 1000 BCF of the natural gas annually (Petrobangla, 2019). Most of the gas produced is used in power generation in both on-grid and captive, which is about 75% of total production (Petrobangla, 2019). By the end of FY2018-19, the cumulative production of natural gas is about 16.93 Tcf and remaining reserve (Proven + Probable) is about 11.76 Tcf (HC Unit, 2020).

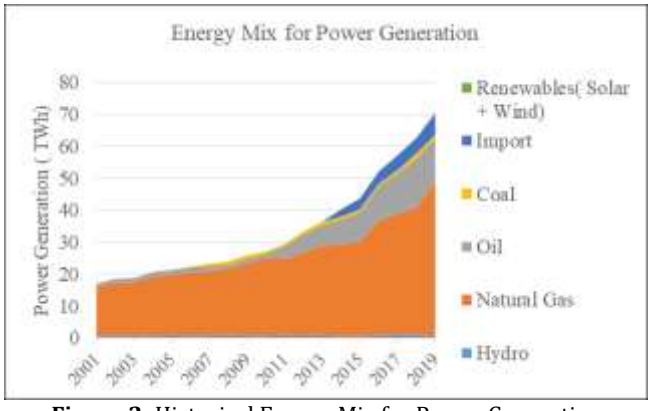

Figure 2: Historical Energy Mix for Power Generation
Source: BPDB, 2019

Thus more than half of the reserve has already been depleted. The remaining portion cannot ministry last long if the growing demand of gas is fulfilled by only the

domestic sources of gas. At the same time, most of the total power generation of the country is generated from the natural gas. Therefore, it is essential to find other sources through fuel diversification. In this situation, coal seems to be the alternative source of primary energy for power generation and is considered to be the key source to supply in the power stations in future (Power Division, 2016) Bangladesh has 5 coal fields with a reserves of about 5.565 billion metric tons.

Recent studies suggest that the Jamalganj basin may alone have more than five billion metric tons resulting in total sum of more than seven billion metric tons. Only the Barapukuria coal filed alone produce coal commercially and produce about 1 million metric ton of coal per year, which is used in the Barapukuria thermal 525 MW power station. Bangladesh has only one hydroelectric power plant at Kaptai, which has a generation capacity of about 230 MW. The total power generation of year 2001-2019 is shown in Figure 2. The historical power generation curve shows that natural gas has contributed to nearly 90% of the power generation in the period of 2001-2011. After 2011, the share of oil, which includes both, has increased gradually and contribution of gas started to decease. In 2019, the contribution of gas and oil was about 69% and 19% summing up 88% of the total generation. Other 12% generation comes from Hydro, coal and imported power. Imported power contributed more than 9% of total generation. Renewable energy contributes only small portion to the total generation.

Renewable Energy Sources of Bangladesh

Today the main sources of renewable in power generation are solar followed by hydroelectricity. A small amount of electricity is produced from biomass and biogas. Energy consumption from renewable sources of Bangladesh has been summarized in Table 1.

Table 1: Power Generation from Renewable Energy Sources in Bangladesh

Renewable Energy Sources	Off-grid (MW)	On-grid (MW)	Total (MW)
Solar	332.79	82.21	415.01
Wind	2.00	0.90	2.90
Hydro	0.00	230.00	230.00
Biogas	0.63	0.00	0.63
Biomass	0.40	0.00	0.00
Total	335.82	313.11	648.94

Source: SREDA, 2020

Bangladesh has a solar capacity of about 332.79MW off-grid and about 82.21 MW on-grid summing to total about 415 MW, which is about 64% of total renewable energy sources. Bangladesh has a peak generation capacity of about 251, 58, 42.5, 38.4 MW of electricity from SHS, Solar Rooftop, Solar Irrigation and Solar Park. They comprise 61, 14, 10, 9% of total capacity, which is 94% of the total peak generation capacity. At present the total number of installed SHS in the country is about 5.8 million, which have the capacity of 251.64 MW. Hydro-electricity contributes another 35.4% of total renewable energy leaving only less than one percent to other sources like wind, biogas and biomass electricity.

Sector-wise Power Consumption

The main sectors of power consumption in Bangladesh are agriculture, industrial, commercial and public and residential sector. Of them, the industrial sector is the most power consuming sector followed by the residential sector. Figure 3 shows the sector wise power consumption in Bangladesh. Of 2900GWh of the total consumption, about 17000 GWh has been consumed in this sector, which is more than 58% of total consumption. The consumption in the residential sector was about 9300 GWh, which is about 32% of the total consumption. The rest, only 10% came from others sectors combined. This figure has changed in small amount in 2019. In 2019, almost 50% of the total consumption occurred in industrial sector while the residential sector consumed about 40% adding to 90% of the total consumption. Another 10% of the total consumption is consumed in agriculture, commercial, and public sectors.

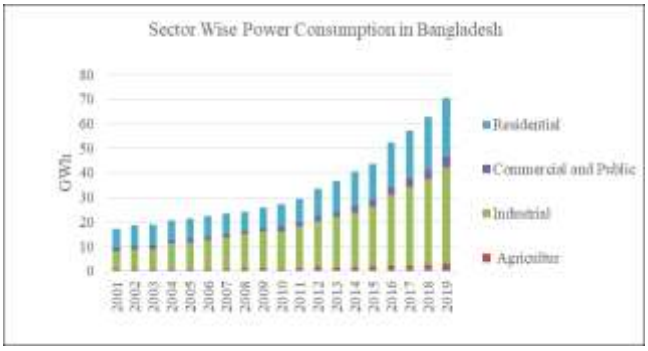

Figure 3: Historical Sector Wise Power Consumption
Source: IEA, 2020

Emissions from Power Sector of Bangladesh

Historically, the emission from power generation has increased gradually. The annual emission of GHG from power generation was about 9 $MtCO_2e$ in 2001 which increased to 17 $MtCO_2e$ in 2011 and 38.69 $MtCO_2e$ in 2019. So there is an increase of annual emission by about 2 and 4 times in 2011 and 2019 relative to 2001 level. Thus, emission has doubled roughly in every ten years. This is shown in Figure 4.

The main source of fuel in power generation is natural gas so, most of the emissions is related to the combustion of natural gas in power plants, followed by emissions from oil. Little amount of emissions comes from the coal fired plants. Though coal contributes a small portion of the total power

generation, it is high in emissions. With the increasing coal consumption will increase the emissions in the country in future. Figure 4 shows the emissions of Bangladesh from electricity generation for years 2011-2019. In 2011, of total emissions of 17.24 $MtCO_2e$, 13.5 $MtCO_2e$ and 3 $MtCO_2e$ produced from the consumption of natural and oil respectively, which is about 95% of total emissions. If we examine the emissions of 2019, we can see that of total 38.69 $MtCO_2e$, 27.3 $MtCO_2e$ and 10.2 $MtCO_2e$ emitted from the consumption of natural and oil respectively, which is about 96% of total emissions.

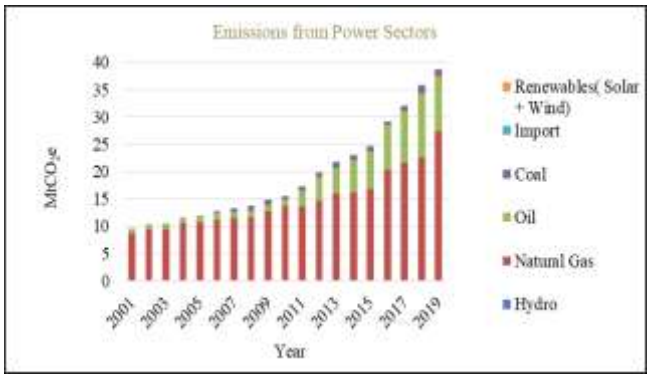

Figure 4: Greenhouse Gas Emission from Power Sector of Bangladesh

Source: Based on BPDB, 2019

NDCs of Bangladesh

Though Bangladesh's GHG emission share is insignificant, the country has pledge to reduce its production. The country is committed to setting ambitious goal to reduce emission and to fighting against the impacts of climate change and it has gained in a great economic growth in the last decade, but climate change induced frequent natural hazards are seriously affecting development of the country. Bangladesh is most vulnerable to sea-level rise and associated hazards of cyclone, floods and salinity. If the proper measures to combat the climate change are not taken, then it will be very for the country to sustain the development. As part of global community, the country must support the global efforts to reduce GHG emission and combat climate change.

Mitigation

Bangladesh puts emphasis on the mitigation of emission in both unconditionally and conditionally. The unconditional mitigation action is set to reduce the emission by the ability of the country of its own. But the conditional mitigation only implies if the country get enough international support to develop lower carbon resilient society. The country is committed to reducing the emission in three major emitting sector, power, transport and industry. At the same time, Bangladesh also intends to carry out mitigation efforts in others sectors (MoEFCC, 2015). The mitigation target of INDCs of Bangladesh is summarized in Table 2. Bangladesh has a mitigation target of reducing emissions by 5% unconditionally and 15% conditionally from Business as Usual by 2030.

Table 2: Sectoral Mitigation Pledges of Bangladesh

Sectors	Unconditional Commitment (%)	Conditional commitment (%)
Power	05	18
Transport	09	24
Industry (energy)	04	10
Total	05	15

Source: Nationally Determined Contributions (INDCs); MoEFCC, 2015

Bangladesh is also committed to continuing to consider mitigation actions in others sectors like Households, Commercial buildings, Non-energy agriculture, waste and Land Use, land use change and forestry. Activities will be taken place in these sectors includes: increasing the number of households with improved cook stoves to 70% by 2030; reducing commercial sector energy consumption by 25% below BAU; and diverting 50% of landfill waste to composting by 2030.

Adaptation

The key area for adaptation in Bangladesh is the climate change and the country has taken initiatives to adapt to the changing climate. Agriculture, forestry, water, health and infrastructure sectors are the main areas where the government has already given importance for the sustainable development of the country. National Adaptation Plan (NAP) and Bangladesh Climate Change Strategy and Action Plan (BCCSAP) are the documents that compiled the adaptation approach of the country where climate resilient development through climate adaptation is given highest priority. The country has established Bangladesh Climate Change Trust Fund and the Bangladesh Climate Change Resilient Fund to fund adaptation projects.

Cost of Implementation of NDCs of Bangladesh

Estimation shows that Bangladesh needs US$27 billion for mitigation and US$42 billion for adaptation between 2015 and 2030 (MoEFCC, 2015). The INDC states that "effective access to international climate finances is critical for implementation of the Bangladesh INDC."

Methodology

The entire methodological approaches of the study include two steps. The first step is the calculation of final sector wise energy consumption up to 2030 while the

second one is the secondly scenario analysis to predict the impacts of energy mix on GHG emission.

Projection of Final Power Consumptions

Socio-economic conditions control the power consumption. Future power consumption of the country is calculated from past consumption pattern. To do so, the historical power consumption in different sectors are used to predict future sectoral consumptions and then aggregated to get the final consumption in the whole power system. To predict the sectoral consumptions, the microeconomic dimensions are considered. In broader sense, the sectors of power consumptions are agriculture, industrial, commercial and public (service) and Household. In this study, it is assumed that the corresponding drivers of these sectoral power consumptions are agricultural Value Added, Industrial Value Added, Service Sector Value Added and Household income per capita respectively. A regression analysis is done to examine whether there is a relationship between the sectors of power consumption and microeconomic conditions. The sectoral value added has been calculated as function GDP per capita. The GDP per capita has been calculated by dividing GDP by total population. It is assumed that the population and the GDP will continue to grow at a stable rate and the growth rate of the population and the GDP used in the calculation is 1.36 per hundreds of population per year and 6.8 respectively.

Total Final Power Consumption=Power Consumption of sector i* Driving Force of sector i ..... (01)

The regression result shows that there is a statistical significance between the variables involved in each regression.

Data Sources

Data have been collected from different sources based on types of data required. Data for items population, GDP, GDP value added are collected from Bangladesh Bureau of Statistics (BBS) and different reports. Data on GDP per capita have been collected from World Bank online database. Data on primary energy mix in power generation were collected from Bangladesh Power Development Board (BPDB). Data regarding sectoral consumption of power have been collected from International Energy Agency (IEA).

Scenario Building and Emission Calculation

After calculating the final power consumption, different scenarios have been developed to see the effects of different primary energy mix on emissions of GHGs. These scenarios contain different energy consumption. Scenarios are presented in Table 3.

Table 3: Energy Scenarios in Power Production

Scenario	Description
Business as Usual	Based on present trends of economic development and Government plan
High Coal	Coal will contribute most to power generation. About 45% of Energy generation will be from coal combustion in 2030 and gas consumption assumed to be decreased
Equal Coal and Gas	Gas will continue to contribute more in power generation and coal consumption will increase. Each of these two sources will contribute 35% of total generation.
High Renewable	At least 10% power will come from Renewables mainly from Solar. More emphasis on cross-border renewable import and increasing nuclear energy consumption

Emissions from each scenario had been calculated based on the following equation.

Total GHG emission = Production Using Fuel i * Equivalent CO_2 Emission per unit of Power Production Using Fuel i)

Equivalent CO_2 emission per unit of power of fuel (Carbon Emission Factor) varies across countries. The emission factor is the function of type of fuel, fuel efficiency and the heat producing technology. To find the emission factors of power generation per fuel, full life cycle assessment of power producing plant is necessary. Karmaker et al. (2020) analyzed the emission for different technologies and fuels in Bangladesh. The calculated emission factor for coal, oil and natural gas are 0.90 Kg, 0.76 kg and 0.566 Kg of CO_2 per kWh of electricity production. Sovacool (2008) screened 103 lifecycle studies of greenhouse gas-equivalent emissions for nuclear power plants and found a emissions of 0.066kg of CO_2 per kWh of power production from nuclear source. The value for hydropower is 0.024 kg (Schlömer, 2014). These values are used in above formula for calculating total emissions.

Results

Projected Final Power Consumption

The aggregated final power consumption of the country will be about 125 TWh in 2030, which is more than 75% increase relative to 2019 level. The consumption in 2019 was 70.5 TWh and it was 16 TWh in 2001. Most of the consumption in 2030 is expected to occur in industrial and residential sector. Day by day, the agriculture sector is becoming energy intensive. The main area of power consumption in agriculture is irrigation. The agriculture share of GDP is estimated to be decreased in the coming years, but due to the overall increase in the population and GDP of the country, there will be a growth in the total consumption in this sector. The consumption in agriculture sector in 2020 is projected to be about 1.8 TWh, which is expected to

increase by it in 2030 and resulting in a final consumption of about 3.3 TWh in 11 years.

Industrial sector is the highest consumer of electricity in the country and it will continue to be most electricity-consuming sector in coming days also. Again, from Figure 5, we can see that the total consumption from this sector will be about 40.6 TWh in 2020 and in 2030 it is projected to be 72.09 TWh. So there will be an overall increase of about 31.5 TWh in these 11 years, which is 77% increase relative to 2020 level. The total consumption in the commercial and public sector will be about 4.3 TWh and 5.3 TWh in 2020 and 2030 respectively. The residential sector is the second highest power consuming sector. The government is determined to give the whole population access to electricity by 2021 (GED, 2012). After following the historical growth rate and GDP growth, there will be increasing electricity demand in this sector. Figure 5 shows that the consumption of electricity in residential sector will be about 24,300 TWh, 33,100 TWh and 42,000 TWh in years 2020, 2025 and 2030 respectively.

Figure 5: Projected Final Power Consumption

Projected Power Generation in Different Scenario

Business as Usual Scenario: In business as usual scenario, power generation from different sources reflects the existing sources of generation and government's plan for committed and candidate projects in coming years.

In this scenario, the natural gas consumption in power generation reduces from 68% (48.36 TWh) in 2019 to 34% (34 TWh) and 22% (28 TWh) in 20125 and 2030, whereas the coal consumption will increase from 2% (1.25 TWh) in 2019 to 33% (40.94 TWh) in 2030 (Figure 6). Nuclear and Import has considerable role in total generation which will expected to contribute 12% and 17% of total generation in 2030. As in 2019, Bangladesh has imported 600 MW of electricity from India, which has a total supply of 6.7 TWh and a 9.62% of the total consumption in the country. Bangladesh is planning to import 5000 MW of cross-border electricity from neighboring countries by 2030. On the other hand, Bangladesh has committed to generating 3432 MW of nuclear based electricity by 2030.

Figure 6: Fuel Wise Power Generation in BAU Scenario

High Coal Scenario: In 2020, the proportion of power generation from natural gas will be about 50% which will decrease to about 27% in 2025 and farther decrease to 15 % in 2030. On the other hand, coal consumption will increase from about 21% in 2020 to 45% in 2030. Therefore, there is a drop in gas consumption in power of about 35% and an increase in coal consumption of about 25% in ten years. Oil based and imported power will be about 20% and 7 % respectively. The proportion of generation from nuclear source will be about 10% in 2030 (Figure 7).

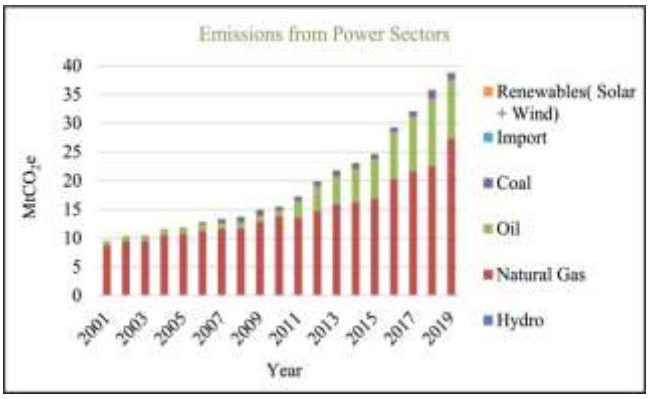

Figure 7: Power Generation in High Coal Scenario from Different Sources

Equal Coal Gas Scenario: In the equal coal and gas scenario, coal and gas will equally contribute to the total generation in 2030. In this scenario, the proportion of power generation from natural gas will be about 40% in 2025 and 35% in 2030. On the other hand, coal consumption will increase to about 31% in 2020 and 35% in 2030 (Figure 8). As a result, there is a drop in gas consumption in power of about 15% and an increase in coal consumption of about 15% in ten years.

Figure 8: Power Generation in Equal Coal and Gas Scenario

High Renewable Scenario: In this scenario, power from conventional fossil fuels are assumed to decrease and natural gas, oil and coal fired plants will generated 62% of total generation in 2030 (Figure 9). An emphasis is given on imported power and about 15% (18.6 TWh) of total power will come from this source. Nuclear energy is also expected to provide a share of 10% (12.5 TWh) of total generation. Hydro and renewable (solar+wind) will contribute about 13% with 3% coming from hydroelectricity and the rest (10%) comes from solar and wind energy sources.

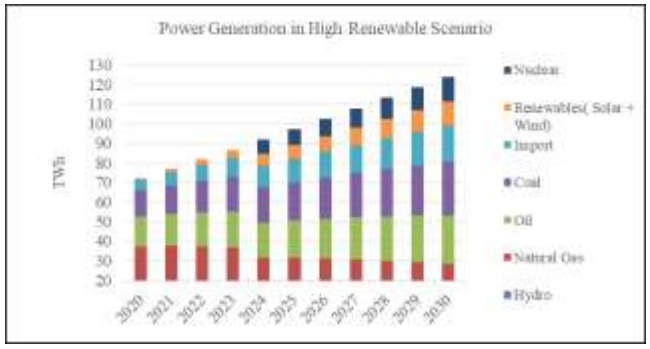

Figure 9: Power Generation in High Renewable Scenario

GHG Emission in All Scenarios

Figure 10 shows the GHGH emission in all scenarios. In BAU, total GHG emission will be 66 million tons CO_2 equivalent. Overall increase in emission relative to 2011 will be 283%. On the other hand, total emission from High Coal scenario and Equal Coal and Gas scenario is 80.6 and 76 Million tonnes CO_2e, which is higher than the BAU case. Only in High Renewable scenario, the emission is less than the BAU. The emission in this scenario is 59 million tonnes CO2 e. Therefore, there will be only 11% of emission reduction relative to BAU emission of 2030. Therefore, the unconditional mitigation pledges (5%) could be fulfilled through this energy mix. But Bangladesh has also a conditional target of 18% reduction from power sector. For a reduction of 18% emissions, the emissions should not exceed 54 million tonnes of CO_2 e in 2030.

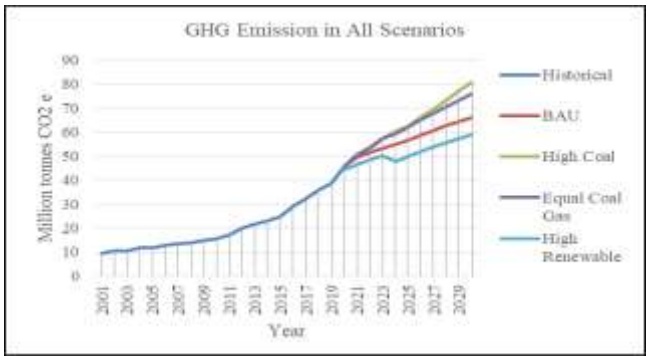

Figure 10: Emission of Greenhouse Gases in All Scenarios

Scaling up Solar PV Applications

Solar photovoltaic system is a sustainable source of energy. At the same time, solar energy is non-pollutant and has no emissions during electricity generation. However, pollutants and emissions can be emitted during the production of solar PV based electricity capturing cells and batteries, which is very low compared to conventional fossil fuels. Bangladesh being a tropical country receives a daily solar radiation of more than 4.0 kWh/m^2 (Sovacool and Drupady, 2012). Shiraishi et al. (2019) assessed the potentiality of solar and wind energy using GIS and RS techniques. They have shown the possible areas of the country where there are environmental favorability to install solar PV, concentrating solar thermal power (CSP) or rooftop PV. A 10% of identified areas have the potentiality of generation capacity of 53 GW, 2 GW and 30 GW from solar PV, rooftop (only urban areas) and CSP without storage respectively. The yearly generation possible from these technologies is about 84 TWh, 13 TWh and 98 TWh. Mondal and Islam (2011) has calculated the technical potential of 50GW from solar PV while Noor and Munner (2010) assessed the potentiality of CSP of the country to 0.1 GW (Table 4).

The cost of electricity from solar is higher than the cost from conventional fossil fuel sources. But there is an increasing trend in the markets of solar energy. In 2019, there was a growth of 12% of solar market (REN21, 2019). The cost of electricity from this source is also falling. The cost of electricity form utility scale solar PV and CSP was USD 0.068/kWh and USD 0.182/kWh in 2019. There was an early fall of 13% and 1% respectively, while a fall of 82% and 47% in ten years from 2010-2019 (IRENA, 2020). Apart from that, the price of electricity is quantified in market price where the external costs have been excluded. But, from environmental point of view, using fossil fuels poses threat to the sustainability of development and the external costs are high. ADB report suggests that Bangladesh may lose 2 percent of GDP by 2050 due to the impacts of climate change (Ahmed and Suphachalasai, 2014).

Table 4: Solar Energy Potential of Bangladesh

	Potential Generation Capacity (GW)				Yearly Generation Capacity (TWh)			
	Solar PV	Rooftop	CSP without Storage	CSP with Storage	Solar PV	Rooftop	CSP without Storage	CSP with Storage
Shiraishi et al. 2019	53	2	30	53	84	13	98	17.3
IEEFA, 2016	10				17.520(utility scale)			
Mondal and Islam, 2011	50							
Noor and Munner, 2010			0.1					

Conclusion and Recommendations

Conclusion

To assess the role of solar PVs in achieving the targets of NDCs of Bangladesh, two different analyses have been done. At first the impacts of population and GDP on total power consumption by sector has determined. It is found that there is positive correlation between them. After that, a scenario analysis has been done to see impacts of energy mix on emissions and thus the role of solar PVs could be analyzed. It is found that there is relation between energy mix and emission. At the same time, solar PVs can be good options for reducing emissions by introducing more solar PVs in power generation. Though the country has planned to increase installed capacity from renewable sources, more is required for achieving the targets of NDCs of Bangladesh. It is because only certain amount of installed capacity from renewables does not reduce the targeted mitigations as emissions depend upon the actual generation not upon the capacity. The main source of renewables should be solar PVs as Bangladesh has high potentiality of generation power from this technology.

Recommendations

The specific recommendations to achieve the target of NDCs of Bangladesh are as follows:

- For fulfilling the mitigation pledge of NDCs, Bangladesh needs more renewable energy in energy mix. Due to its geographic location, the country has less potential of harnessing large hydro and wind based power generation but substantial potential from solar photovoltaic systems.
- Though Bangladesh has succeeded in penetrating solar home systems, it has lower contributions to total power generation (currently less than 1%). The application of different technologies needs be made to enhance its contribution. Grid connected PVs can also be good options for the country.
- Need an updated policy for market penetration of more solar PV.
- Like SHS, the government needs to formulate policy to engage private sector in PV micro and mini grids.
- Appropriate policy for PV micro utility should also be in place. Moreover, proper monitoring and dedicated maintenance support is required. In the same way, supports to research and development in the application of SPVs is extremely required to exploit its optimum potentials.

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