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Analysis of Energy Sector of Bangladesh's to Ensure the Route of Vision 2041

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Abstract: Energy is a major driving force for economic and socio-economic development of a country. Throughout the last decade Power & Energy Sector of Bangladesh has been undergone unprecedented transition towards realizing its targets set for achieving Visions (2021 & 2041). Keeping pace with the economic growth, all out efforts have been undertaken in Power & Energy Sector. As Per successful implementation of PP 2021 and MDGs, the power and energy sector targets of PP2041 and SDG7 are reasonably expected to be realized in due course. The sector is moving towards achieving long term targets to ensure energy sustainability 33,000 MW plant generation capacity, maximum peak demand 29,300 MW (in 2030), and 56,734 MW plant generation capacity, maximum peak demand 51,300 MW (in 2041). This is an appropriate time to review the achievements so far. The main objective of this research paper is to analyze the performance of the energy sector over the last decade in order to identify the areas of weaknesses and challenges and to present a set of recommendations on long term sustainability. From methodological point of view, the current practice is to analyze a gap in the sector aimed at identifying weaknesses. Therefore, this study focuses on the following issues in the energy sector of Bangladesh's to ensure the route of vision 2041: (i) Perspective Plan 2041 for Energy Sector in Bangladesh; (ii) Present status of Electricity Generation in energy sector of Bangladesh (iii) Energy Pricing and Policy in Bangladesh (iv) Major Initiatives in Energy Sectors of Bangladesh (v) Challenges faced by vision 2041 in energy sector of Bangladesh. Energy plays an important role in the development and security of any country, poverty eradication, economic growth and sustainable infrastructure. Therefore, future economic growth will depend significantly on the availability of electricity.

Keywords: Primary Energy, Electricity, Energy Pricing, Energy Policy, Economic Growth

1. Introduction

Energy is a foundation stone of the modern industrial economy. Modern energy services are a powerful engine for economic and social development of a country. Soon after achievement of political independence of the nation under the leadership of the Father of the Nation, Bangabandhu Sheikh Mujibur Rahman, he dreamed for achievement of economic independence of the country by realizing the vision Sonar Bangla. He thought that without a self-reliant power and energy sector, it would not be possible to uplift the fate of the nation. He put the issue of harnessing Bangladesh's own mineral resources on the top of the priority. On 9 August 1975 he took a revolutionary decision to purchase Bakhrabad, Tatias, Rashidpur. Kailashtila and Habiganj gas fields with only 4.5-million-pound sterling from British Shell Oil Company. In addition, his Government took over the ownership of ESSO Eastern Inc, a United States' company, by "The ESSO Undertakings Acquisition Ordinance, 1975" issued on 14 March 1975 for storage. supply, distribution and sales of petroleum products with smooth operation under the state supervision. His initiative facilitated supply of energy at cheaper price as compared to most of the countries. This year 2021 is the centennial birth anniversary of the Father of Nation and is the Golden Jubilee year of Bangladesh 's independence. One of

the main programs of the government in "Mujib Year is ensuring access Electricity to all.

The 7th goal of SDG is to "Clean energy for everyone: Secure access to affordable, reliable, sustainable and modem energy for everyone, ensuring adequate energy supply and energy security is one of the priorities of the current Government to achieve the desired economic growth and maintaining the speed of the country's economic activity. Bangladesh achieved a decade of 7% average GDP growth, crossing the Lower Middle-Income threshold in 2015.

Accordingly, the government has adopted Vision 2041 that is a continuation of Vision 2021 and seeks to take the nation to the development path dreamt by Bangabandhu. Specifically, Vision 2041 seeks to eliminate extreme poverty and reach Upper Middle-income Country status by 2031, and High-income Country status by 2041 with poverty approaching extinction.

2. Perspective Plan 2041 for Energy Sector

Perspective Plan 2041 (PP2041) 1 for power energy seeks to build on the successes Perspective Plan 2021 (PP2021) 2 and put Bangladesh forward on to the path of a high-income economy. The targets for the power and energy sector indicators as stipulated in PP2041 are shown in Tables 1 and 2. Projections show that the demand for power will grow by 9.3% during FY 2021-2041 [8]. This large demand for power and energy will require considerable investment based on least-cost options, while also paying attention to minimizing the carbon impact. Accordingly, the fuel mix will need to change from excessive reliance on fossil fuel towards a combination of low-cost fuel and renewable energy. More use of imported power from neighboring countries will help mitigate the domestic pressure on power production while also lowering carbon emission. On the financing side, a core objective is to ensure the financial sustainability of the power sector.

Table 1. *Performance Indicators and Target 2031 for Energy Sector [8].*

Performance Indicators	FY 2031
Make power sector financially viable	-
Total grid based generation capacity of electricity	33,000 MW
Maximum Peak Demand Based on PSMP 2016 base case	29,300 MW
Increase efficiency of energy use as well as reducing the system loss (T&D loss)	-
Diversify fuel use in power generation capacity to balance use of low-cost fuel with low carbon content of the fuel mix	29% gas; 30% coal; 14% nuclear; 9% liquid fuel, 17% power import, 1% hydro
Increase private sector investments in electricity, gas, and other energy supply	55%
Encourage energy trade	5,000 MW
Access to electricity	100%
Installation of petroleum pipeline	1077 km
Installed processing capacity of refinery	19.5 million tons

Table 2. *Performance Indicators and Target 2041 for Energy Sector [8].*

Performance Indicators	FY 2041
Make power sector financially viable	-
Total grid based generation capacity of electricity	56,734 MW
Maximum Peak Demand Based on PSMP 2016 base case	51,300 MW
Increase efficiency of energy use as well as reducing the system loss (T&D loss)	T&D loss single digit
Diversify fuel use in power generation capacity to balance use of low-cost fuel with low carbon content of the fuel mix	35% gas; 35% coal; 12% nuclear; 16% power import; 1% liquid fuel; 1% hydro
Increase private sector investments in electricity, gas, and other energy supply	-
Encourage energy trade	9000 MW
Access to electricity	100%
Installation of petroleum pipeline	1177 km
Installed processing capacity of refinery	19.5 million tons

3. Achieving the Energy Sector in 2019 and 2021 Against Performance Indicators

Table 3. *Achieving Energy Sector in 2019 against Performance Indicators [8].*

Performance Indicators	FY 2019
Make power sector financially viable	Losses amounting Tk. 75 billion
Total grid based generation capacity of electricity	18,961 MW
Maximum Peak Demand	12,893 MW
Increase efficiency of energy use as well as reducing the system loss (T&D loss)	11.96% (T&D losses)
Diversify fuel use in power generation capacity to balance use of low-cost fuel with low carbon content of the fuel mix	57.37% Gas; 32.38% Liquid fuel; 2.76% Coal; 6.12% Power import; 1.21% Hydro 0.16% Renewables
Increase private sector investments in electricity, gas, and other energy supply	50% including imports
Encourage energy trade	1160 MW
Access to electricity	72%
Installation of petroleum pipeline	0 km
Installed processing Capacity of Refinery	1.5 million tons

Table 4. *Achieving Energy Sector in 2021 against Performance Indicators [4].*

Performance Indicators	FY 2021
Make power sector financially viable	-
Total grid based generation capacity of electricity	22,031 MW
Maximum Peak Demand	13,792 MW
Increase efficiency of energy use as well as reducing the system loss (T&D loss)	-
Diversify fuel use in power generation capacity to balance use of low-cost fuel with low carbon content of the fuel mix	51.97% Gas; 33.11% Liquid fuel; 8.02% Coal; 5.27% Power import; 1.04% Hydro 0.59% Renewables
Increase private sector investments in electricity, gas, and other energy supply	50%
Encourage energy trade	1160 MW
Access to electricity	97%
Installation of petroleum pipeline	107 km
Installed processing Capacity of Refinery	1.5 million tons

3.1. Status of Electricity Generation of Bangladesh

Demand of electricity is increasing rapidly due to enhanced economic activities in the country with sustained GDP growth. At present, growth of demand is about 9-10% which is expected to be more in coming years.

Demand of electricity in the system varies throughout the day and night. The maximum demand is occurred during 5 pm to 11 pm which is termed as 'peak hour' and other part of the time is termed as off-peak hour. The extent of this variation is measured in terms of Load Factor, which is the ratio of average and maximum demand. For economic reasons, it is desirable to have a higher Load Factor, as this would permit better utilization of plant capacity. Moreover, the cost of energy supply during peak hour is higher, because some relatively costlier liquid fuel based power plants are required to put in operation during the peak hour. For these reasons, load management is essential throughout the year for better capacity utilization of power plants and minimum generation cost.

There are some loads in the system which can be avoided or minimized by consumers during peak hour. In order to shift these kinds of loads from peak hour to off-peak hour by introducing some mechanism is termed as load management. From the view point of load management, (i) two-part tariff is introduced for 3-phase consumers (LT & HT) where peak hour price is much higher than the off-peak hour that motivates consumers to avoid or use less in the peak hour; (ii) holiday staggering is implemented to keep industries, markets & shopping malls close on area basis holiday marked day; (iii) consumers are encouraged to use energy efficient bulb, electric appliances, pumps, etc; (iv) consumers are encouraged to keep their air-conditioner's temperature at 25 degree and so on.

Total installed capacity was 22,031 MW which includes 10,146 MW Public, 9,481 MW Private, 1244 MW PPP (BCPCL) and 1,160 MW Power Import from India. The maximum peak generation was 13,792 MW which was 8.27% higher than that in the previous year [4]. The Generation Capacity mix is shown below.

Table 5. *Installed Capacity and Present Production Capacity by type of Fuel of 2020-2021 [4],*

	Installed Capacity (MW)		Present Production Capacity (MW)	
Hydro	230	1.04%	230	1.08%
Gas	11,450	51.97%	11,100	52.16%
Furnace Oil	6,004	27.24%	5,687	26.73%
Diesel	1,290	5.86%	1,286	6.04%
Coal	1,768	8.03%	1,688	7.93%
Solar PV	129	0.59%	129	0.61%
Power Import	1160	5.27%	1160	5.45%
Total	22,031	100%	21,280	100%

Table 6. *Installed Capacity by type of Plant of 2019-2020 and 2018-2019 [5, 6].*

	By type of Plant 2019-20 (MW)		2018-19 (MW)	
Hydro	230	1.13%	230	1.21%
Steam Turbine	2966	14.55%	2,344	12.36%
Gas Turbine	851	4.18%	1,607	8.48%
Combined Cycle	7330	35.96%	6,364	33.56%
Reciprocating Engine	7808	38.31%	7,226	38.11%
Solar PV	38	0.19%	30	0.16%
Power Import	1160	5.69%	1,160	6.12%
Total	20,338	100%	18961	100%

Table 7. *Installed Capacity by type of Fuel of 2019-2020 and 2018-2019 [5, 6].*

	By type of Fuel 2019-20 (MW)		2018-19 (MW)	
Hydro	230	1.13%	230	1.21%
Gas	10,979	53.86%	10,877	57.37%
Furnace Oil	5,540	27.18%	4,770	25.15%
Diesel	1,290	6.33%	1,370	7.23%
Coal	1,146	5.62%	524	2.76%
Solar PV	38	0.19%	30	0.16%
Power Import	1160	5.69%	1,160	6.12%
Total	20,338	100%	18,961	100%

Total net energy generation in FY 2020-21 was 80,423 Ghr, which was about 12.61% higher than previous year's net generation of 71,419 Ghr. Net energy generation in the public sector was 31,916 Ghr, 3812 Ghr from Joint Venture and 36,592 Ghr in the private sector (including REB). Another 8,103 Ghr was imported from India through the interconnection in Bheramara and Tripur [4]. Total net energy generated in public and private sector power plants by type of fuel are as follows.

Table 8. *Total net energy generated in public and private sector power plants by type of fuel [4-6].*

Item	2020-2021 (Ghr)	2019-2020 (Ghr)	2018-19 (Ghr)
Hydro	655	825	725
Gas	48,403	51,290	48306
Furnace Oil	17,497	9,461	11426
Diesel	609	139	2022
Coal	4997	2968	1230
Renewable Energy	158	62	39
Power Import	8103	6674	6786
Total	80,423	71,419	70,533

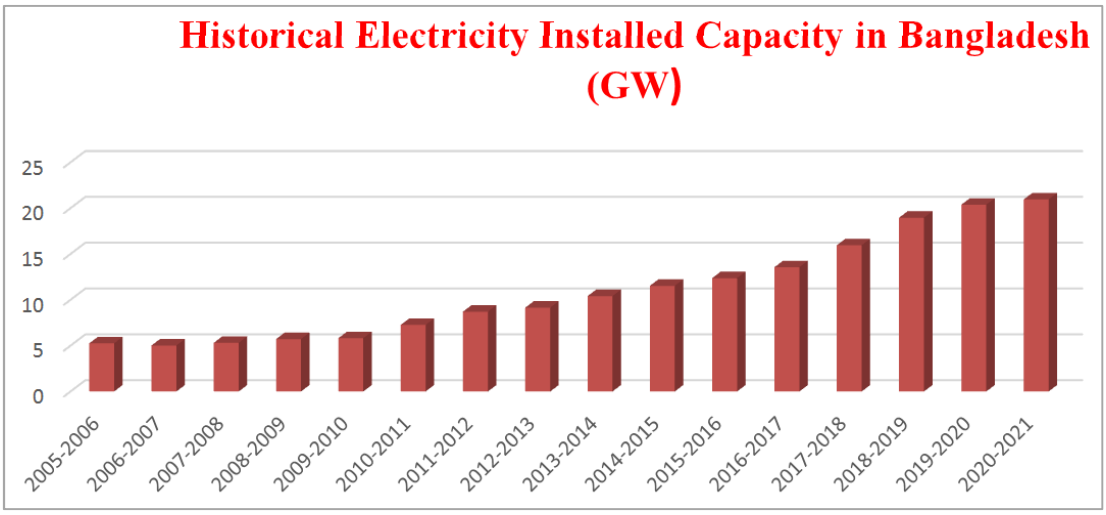


Figure 1. *Historical electricity installed capacity in Bangladesh [4].*

3.2. Electricity Installed Capacity in Bangladesh

The present installed electricity generation capacity in the country is just meeting the demand which is in ever growing mode. This has happened after the strong efforts of the Government to raise the generation capacity through installing new power stations through both public and private sectors.

Figure 1 shows the increase in installed capacity from 2005-2006 to 202-21. It is evident from the figure that the capacity has grown rapidly over the last few years. Favorable Government policies have attracted private investment and Independent Power Producers (IPP). They are now producing 49% of total power in Bangladesh [7]. The country is also importing power from India 5% of the total power [7].

3.3. Maximum Demand in Bangladesh

The maximum power demand for electricity in the country is always increasing and the rate has increased over the last years. About one hundred percent of the total population has access to electricity. The quality of electricity cannot be maintained due to shortage of production and insufficient capacity and low quality of transmission and distribution network.

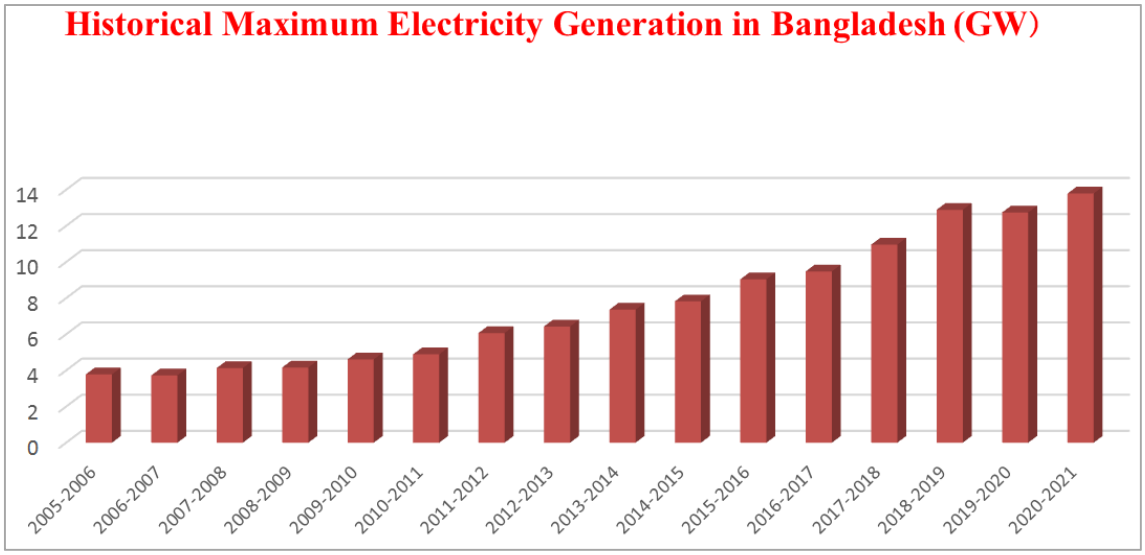


Figure 2. *Historical Maximum electricity generation in Bangladesh [4].*

The maximum demand growth from 2005-2006 to 2020-21 is shown in Figure 2. From the figure it is clear that demand has increased rapidly 2007-2008 to 2020-2021. This is because this demand actually represents the demand for the connected loads of the grid.

3.4. Coal Based Power Plant

The international price of coal is relatively more stable and has less volatility than oil and natural gas. Coal is widely available around the world and can provide a more diversified and stable supply. The Government's Perspective Plan 2041 to setting up a large coal based power plants. The plan is to generate about 9,900 MW from total coal based power plant by 2031 and 19,857 MW from total coal based power plant by 2041 [8].

3.5. Nuclear Power Plant

To meet the growing demand for electrical energy in Bangladesh it has become essential to think about Nuclear power plants (NPP). Nuclear power is characterized by very large up-front investments, technical complexity, and significant technical, market and regulatory risks, but have very low operating costs and can deliver large amount of based load electricity while producing almost no CO_2 emissions. Typical construction times are between five and eight years from first concrete poured. Government of Bangladesh has signed a general contract with Russia on December 25, 2015 for the construction and commissioning of the country's first nuclear power plant (2*1200 MW) at Rooppur in Pabna at the cost of $12.65 billion [9].

Table 9. *Nuclear power Plant scenario in Bangladesh [9].*

Unit	Type	Capacity	Start	Operation
Rooppur-1	VVER-1200/V-523	1200 MW	2017	2024
Rooppur-2	VVER-1200/V-523	1200 MW	2018	2025

The life of the two new generation nuclear power plants will be 60 years. With these features and with stable low cost fuel availability, it is expected that the cost of electricity will be competitive though initial investment is very high. As nuclear power plant has no emission, it will help building low carbon society.

All fuel for Rooppur is being provided by Rosatom, and all used fuel is to be repatriated to Russia, in line with standard Russian practice for such countries. A draft agreement on used fuel was signed in March 2017, totaling about 22.5 ton/yr. from each reactor (42 fuel assemblies, each with 534 kg of fuel). A further agreement for repatriation of used fuel for reprocessing was signed in August 2017.

The Bangladesh Atomic Energy Commission (BAEC) has taken an initiative to conduct a survey in eight char areas of southern region to select one or two suitable sites to set up the country's second nuclear power plant, aiming to meet the future demand of huge electricity. The study will cover a demographic survey over a 5-km diameter, seismic stability, geological location, and power infrastructure and communication system. The Government's Perspective Plan 2041 to setting up a Nuclear power plants. The plan is to generate about 4,620 MW from total Nuclear power plant by 2031 and 6800 MW from total Nuclear power plant by 2041 [8].

3.6. Renewable Energy Program

Bangladesh Government has given strong drive to boost renewable electrical energy production. The government has established Sustainable and Renewable Energy Development Authority (SREDA) to promote renewable energy and energy efficiency in 2014. To strengthen international cooperation, Bangladesh became one of the initial members of the International Renewable Energy Agency (IRENA), the only inter-governmental agency working exclusively on renewable energy.

Renewable energy resources could assist in the energy security of Bangladesh and could help reduce the natural gas demand. Regions of the country without supply or access to natural gas or the electric grid use biomass for cooking and solar power and wind for drying different grains and clothes. Biomass is currently the largest renewable energy resource in use due to its extensive noncommercial use, mainly for cooking and heating. Biomass comprises 27 percent of the total primary energy use in Bangladesh [9]. The country has a huge potential for generating solar power. Moreover, the use of renewable energy has become popular worldwide in view of the depleting reserves of non-renewable fossil fuels. Renewable energy is environmentally friendly.

Renewable energy resources used in Bangladesh may be classified into three major types- (a) traditional biomass fuels, (b) conventional hydropower, (c) new-renewable resources (e.g. solar PV, wind, biogas etc.) of energy.

3.6.1. Traditional Biomass Fuels

In Bangladesh, three major types of biomass fuel resources are in use: wood fuels, agricultural residues and animal dung. Wood fuels are obtained from different types of forests and tree resources grown in rural areas. Agricultural residues and animal dung contribute a substantial portion of biomass fuel in Bangladesh. A part of the total agricultural residues available during harvesting of crops and a part of total animal dung produced by animal resources are used as fuel. Availability of these resources (agricultural residues, animal dung) as fuel depends on local situation and socio-economic condition of the owners.

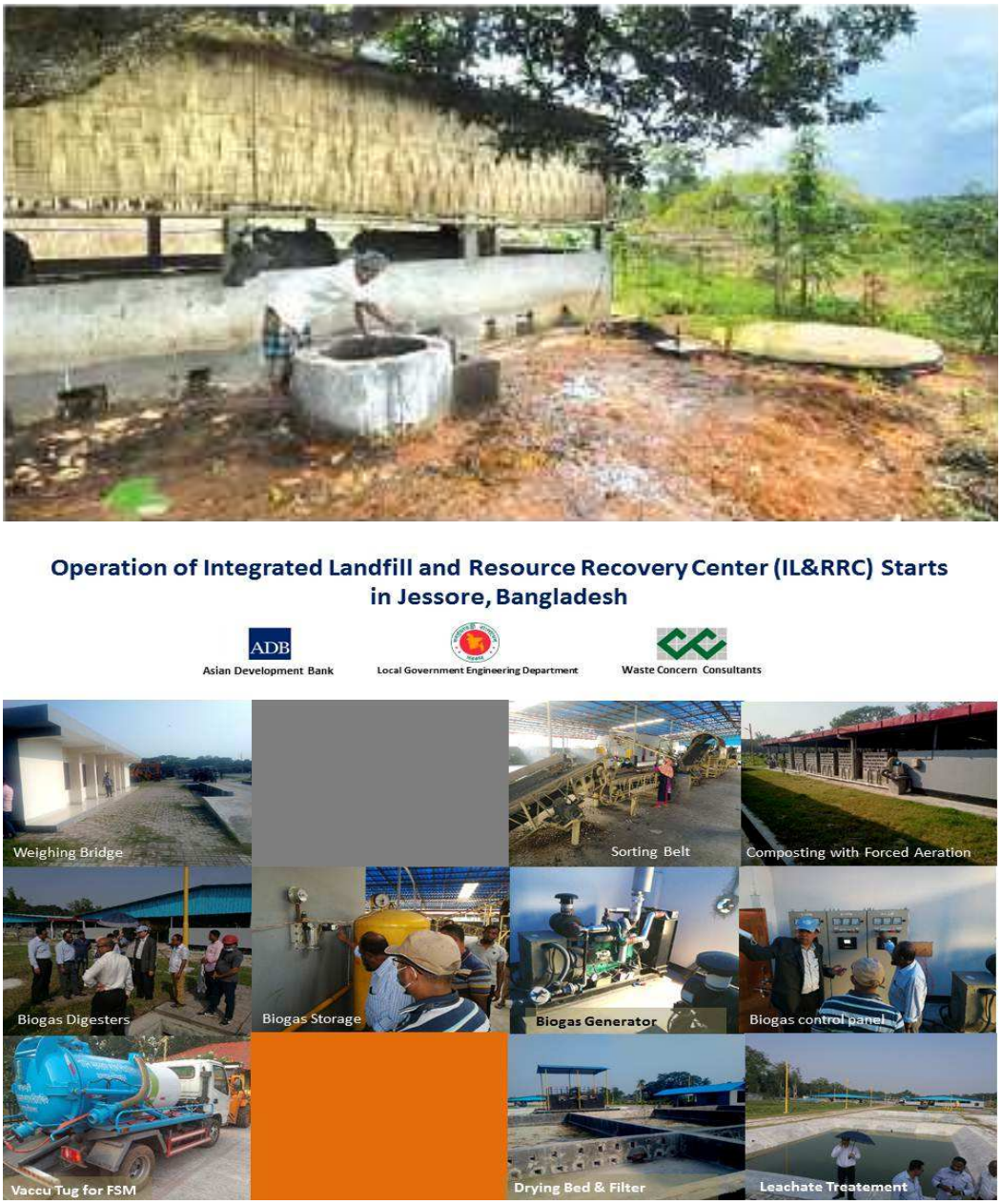


Figure 3. *Conventional Biomass plant and ILRRC (Jashore) Operation.*

Converting biomass into more energy efficient fuel is a means of upgrading the rural energy consumption pattern. Biogas is very suitable for cooking and lighting (Mantel/Hazak) and for running a small generator to produce electricity. Throughout Bangladesh, there are currently about 80,000 households and village-level biogas plants in place [10]. Around 50,000 domestic biogas plants already installed by IDCOL [10]. There is a real potential for harnessing basic biogas technology through rural electrification, village-level biogas production, and internal combustion (or even micro turbine) power generation.

3.6.2. Conventional Hydropower

Total hydropower potential of the country was reported as 1500 GWh/year at Kaptai (1000 GWh/year). Matamuhury (300GWh/year) and Sangu (200GWh/year) (GOB 1996). In 2019-2020 and 2020-21, total generation capacity of 5 hydropower units installed at Kaptai was 230 MW and electricity generated was 825 GWh [5] and 655 GWh [4]. Depending upon rainfall, yearly electricity generation capacity of hydro plants varies between 700 GWh to 1000 GWh. The Government's Perspective Plan 2041 to setting up a Hydro power plants. The plan is to generate about 330 MW from total Hydropower plant by 2031 and 568 MW from total Hydropower plant by 2041 [8].

Considering the energy scarcity of the country, the feasibility of harnessing additional electricity through conventional hydropower technologies and mini & micro hydropower technologies should be explored to meet a part of future energy needs.

3.6.3. New-renewable Resources

It was mentioned in the Renewable Energy Policy 2008 that 5% and 10% of total electricity would be generated using renewable energy by 2015 and 2020 respectively (GOB 2008). Total generation of electricity from renewable energy sources (e.g. solar PV, Wind, biomass, biogas etc.) up to June 2021 was 534 MW. Total generation from RE including hydropower (230 MW) was 774 MW which was 3.07% of total electricity generation capacity (25,235 MW) of the country including Installed Capacity (22,031 MW) off grid RE (404 MW) and Captive (2800 MW) in the FY 2020-21 [7]. In line with the policy, government has already taken different initiatives in renewable energy development, in which some projects/programs have been completed and some are under implementation.

i. Solar Energy

Bangladesh is geographically except for the three months of June-August when there is plenty of sunlight for most of the year and there is no excess rainfall. The amount of Solar Energy available in Bangladesh is high about 4 to 7 kWh/m^2/day, which is enough to meet the demand of the country. There is a fast-growing acceptance of rural people to solar photovoltaic (PV) systems to provide electricity to households and small businesses in rural off grid areas. Various projects have been undertaken to generate 1801 MW of electricity from solar energy by 2030. At present the projects are in the planning phase, these projects will be implemented by 2030 [11].

Table 10. *Solar energy scenario in Bangladesh [11].*

Solar Unit	Capacity
Majhipara Tetulia Solar pp (Sympa)	8.0 MW
Sirajgonj Solar Power Plant	6.0 MW
Sutiakhali Solar Power Plant	50.0 MW
Sarishabari Solar Power Plant	3.0 MW
Manikgonj Solar Power Plant	35.0 MW
Kaptai Solar Power Plant	7.0 MW
Teknaf Solartech Power Plant	20.0 MW
Total	129 MW

The country's largest solar power plant at Mymensingh has the capacity to generate 50 MW of electricity, which will help meet the government's target of generating 10% of the country's total electricity through using renewable energy by 2021. With a 173K solar panel and 332 inverters, the solar power plant is being fully installed with Huawei Smart photovoltaic (PV) solution to connect to the national grid.

Figure 4. *50 MW Solar Power Plant at Mymensingh in Bangladesh.*

a. Solar Home System (SHS)

Solar Home System (SHS) provides reliable power for lighting and operating low powered appliances such as radio, television, small electric fans. The electricity provided by a SHS can also be used to run Direct Current (DC) driven equipment such as DC shouldering irons, drilling machines etc. and to charge the battery of mobile phones. Larger systems can run computers, refrigerators, pumps etc. IDCOL and BREB are distributing Solar Home System (SHS) to the people living in the off-grid areas. IDCOL through different partner organization has already distributed about 4.13 million SHSs have been installed under the program in the remote areas which enabled people to obtain electricity far sooner than would have been possible through grid electricity. Thus, the program has ensured supply of solar electricity to 18 million people i.e. 12% of the country's total population who previously used kerosene lamps for lighting purpose [10].

b. Solar Irrigation System

Solar powered irrigation is the breakthrough technology for energy stricken agro-based economy. Solar powered irrigation is the innovative and environment friendly solution for the

irrigation system, which currently depends on hugely inefficient electric and diesel pumps.

Figure 5. *Solar Pump System at Rangpur District in Bangladesh.*

Gradually replacing the electric and diesel pumps for irrigation with solar water pumps could save significant capacity of electricity and huge investment cost. Up to June'20, a 1515 solar irrigation pump has been installed by IDCOL. Electricity Generation from 1515 solar irrigation pump is 40 MWp. The remaining pumps will come into operation shortly. IDCOL has a target to finance 10,000 solar irrigation pumps by 2025 [10].

ii. Bio-fuel

Bio fuels can be produced from a variety of plants like rapeseed, mustard, corn, sunflower, canola algae, soybean, pulses, sugarcane, wheat, maize, and palm. The most popular option for producing bio-fuels is from non-edible oilseed bearing trees. The two most suitable species are: Jamal gota (Jatropha curcas) and Verenda (Ricinus Communis). Both of these trees can grow virtually anywhere in any soil and geo-climatic condition.

Bio-fuel use is not new in Bangladesh. In the early 20th century, bio-fuel was used for lighting lamps or lanterns. In an agriculturally based country like Bangladesh, bio-fuel can be a better alternative because a 30 percent blend of bio-fuel can be used along with our diesel or petrol. This can also be an excellent fuel to kindle lamps in rural Bangladesh. IDCOL has financed construction of more than 57,092 domestic biogas plants which provide clean energy solution to around 256,914 rural people of the country [10].

The use of bio-fuel is increasing in most European countries. Germany has thousands of filling stations supplying bio-fuel and it is cheaper than petrol or diesel. The German government declared that 5 percent of every liter of fuel must be bio-fuel by 2020.

iii. Wind Energy

Bangladesh is exploring the potential of wind power. In the coastal and Feni areas of Bangladesh, windmills with a total capacity of 2.9 MW are in operation [12]. Bangladesh has had to wait for a breakthrough in wind power technology to be competitive against other conventional commercial energy sources. Various projects have been undertaken to generate 357 MW of electricity from wind power by 2026. At present the projects are in the planning phase, these projects will be implemented by 2026 [12].

Figure 6. *Windmill in Kutubdia, Cox's bazar.*

Rising fossil fuel and CO_2 prices, technological advances and economies of scale with wider deployment are expected to make renewable-based systems increasingly cost-competitive in coming decades [13].

3.7. Primary Energy Sources

3.7.1. Natural Gas

Natural gas is the main energy source of Bangladesh and the power generation sector is heavily dependent on that. Since first discovery in 1955 as of today 26 gas fields, 24 in the onshore and 2 in the offshore have been discovered in the country [15]. Of them 20 gas fields are in production, one offshore gas field have depilated after 14 years of production while other offshore field has not been viable for production due to small reserve. The estimated GIIP (Proven plus Probable) recoverable reserve was 40.09 Tcf. Of them recoverable (Proven plus Probable) 30.06 Tcf [2]. As of June 2021, a total of 18.69 Tcf gas has already been produced leaving only 11.37 TCF recoverable reserve in proven plus probable category [3].

Table 11. *At a glance of Natural gas sector in Bangladesh.*

Description	Data
Total number of gas fields	26
Number of gas fields in production	20
Number of producing wells	112
Present gas production capacity	2750 MMCFD
Avg. gas production rate	1744-2752 MMCFD
Avg. gas production/day	2478 MMCFD
GIIP (Proven + Probable) Reserve	40.09 TCF
Total recoverable (Proven + Probable) Reserve	30.06 TCF
Cumulative production (June, 2021)	18. 69 TCF
Remaining reserve (Proven + Probable)	11.37 TCF
Annual Production by NOC	299.12 BCF (34%)
Annual Production by IOC	593.05 BCF (66%)
Present Supply (2478 mmcfd+600 mmcfd)	3078 MMCFD (along with LNG)
Present Demand	3508 MMCFD
Present Deficit	430 MMCFD (along with LNG)
Number of customer	43 lakh (appx.)

Source: HCU Data Bank.

Some key information about the historical natural gas production 2009-2021 sector is presented in below:

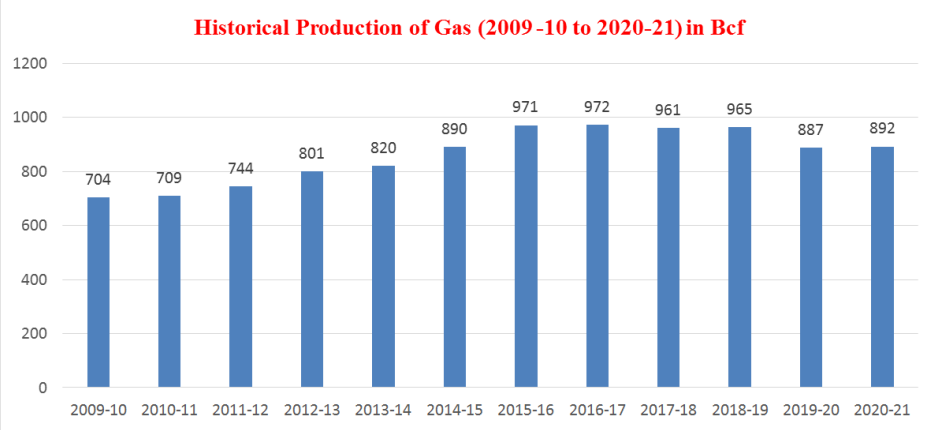


Figure 7. *Historical Gas Production in Bangladesh [16].*

3.7.2. Liquefied Natural Gas (LNG)

To meet the growing energy demand of the country, the government initiated the import of LNG from abroad. At present, a total of 1000 MMCFD LNG is added to the national grid [17].

Floating LNG Terminal:

1) Agreement with Excelerate Energy, Singapore has been signed for setting up FSRU. Already, floating LNG terminal has been installed in Maheshkhali in Cox's Bazar district. Currently, daily 500 MMcfd re-gasified LNG is added to the national grid by Excelerate Energy.
2) SUMMIT LNG Terminal Co. (Pvt.) Ltd. has signed the Agreement (BOOT) to set up FSRU at Maheshkhali in Cox's Bazar district with a capacity of supplying daily 500 mmcf re-gasified LNG. 500 MMcfd re-gasified LNG is added to the national grid since April 2019.

Table 12. *Year-wise LNG Import in Bangladesh (Bcf).*

Year	MLNG	SLNG	Total
2018-2019	106.03	9.85	115.89
2019-2020	102.86	100.02	202.88
2020-2021	100.60	115.50	216.10

Source: HCU Data Bank.

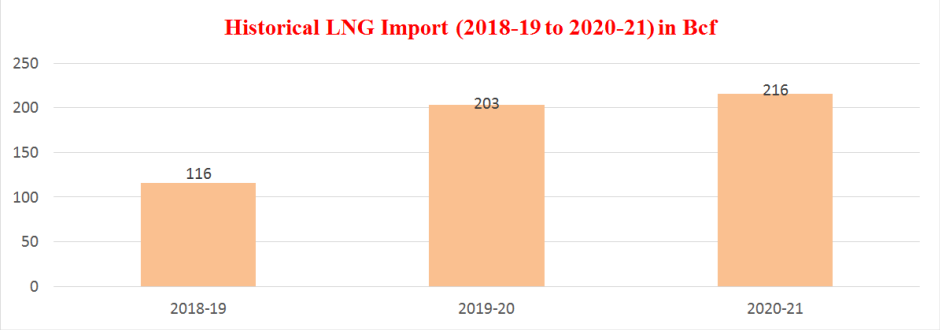


Figure 8. *Historical LNG Import in Bangladesh [16].*

The Government's Perspective Plan 2041 for setting up Gas Turbine power plants. The plan is to generate about 9,570 MW from total Gas Turbine power plant by 2031 and 19,857 MW from total Gas Turbine power plant by 2041 [8].

3.7.3. Coal

Energy is the main indicator of economic growth for a country and constitutes one of the vital infrastructural inputs in socio-economic development. At present, natural gas is the main indigenous primary energy source of Bangladesh. Several studies reveal that domestic production of natural gas. will be depleting soon in the near future. Considering the uncertainty of sustainable supply of primary energy, it is imperative to diversify the primary energy sources in the country. In that case, domestic coal can be a major alternative energy source for the energy security of the country.

At present 2.09% of electricity has been produced from domestic coal [4]. Five coal fields so far discovered, namely Barapukuria, Khalaspir, Phulbari, Jamalganj and Dighipara If initiatives are taken for exploration all over the country, there are enough possibilities to discover more coal mines. Out of the discovered mines, coal from 4 deposits (118-509 meters) is extractable at present. Production from Jamalganj may not be viable with present day's technology due to the depth of the deposits. The amount of coal reserves in Bangladesh coal fields are shown in the Table 13.

The Coal Reserves have increased from 1054 Million Metric Ton to 5738 Million Metric Ton during the tenure of the present government for feasibility study of Jamalganj Coal field.

Table 13. *Coal Fields of Bangladesh (Million Ton) [21].*

Place/Field (Discovery Year)	Reserve	Calorific Value (BTU/lb)
Barapukuria, Dinajpur (1985)	390	11,040
Khalaspir, Rangpur (1995)	523	12,700
Phulbari, Dinajpur (1997)	572	11,900
Jamalganj, Jaipurhat (1965)	5738	11,000
Dighipara, Dinajpur (1995)	600	13,090
	Total = 7823	

Table 14. *Last Six Years Coal production and Imports scenario (Metric Ton).*

Year	Public (Production)	Import (Private)	Total
2015-16	1,021,638.00	3,812,060.00	4,833,698.00
2016-17	1,160,657.81	2,801,407.00	3,962,065.00
2017-18	923,276.00	3,394,534.24	4,317,810.00
2018-19	803,315.00	5,754,025.00	65,57,339.00
2019-20	808,358.00	6,828,032.00	7,636,390.00
2020-2021	753,973.00	6,751,041.00	7,505,014.00

Furnace Oil: Source: HCU data Bank.

Coal might be the alternative fuel to natural gas. These coals can conveniently meet the energy needs of Bangladesh for 50 years. It is notable that the coal of Bangladesh is considered to be high quality in terms of its high level of heat generation capacity as well as low Sulphur content. Some key information about the last Six Years Coal production and Import is presented in the Table 14.

Bangladesh High Sulphur furnace oil (HSFO), 180/380 CST furnace oil is imported. The major users of imported furnace oil consume 43% of total furnace oil imports from HSFO fired power plants (5,687 MW). The Eastern Refinery limited (ERL) also produce furnace oil private power producers are allowed to import fuel oil for their own power plant consumption since 2011 & the consumption is increasing gradually.

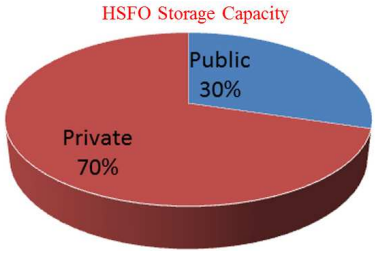


Figure 9. *Contribution of HSFO storage capacity of Private and Public companies in Bangladesh.*

Table 15. *Public and Private Companies High Sulphur furnace oil (HSFO) Storage Capacity in Bangladesh (MT) [20].*

Public	Private	Total
150,665	356,012	506,677

Table 16. *Furnace oil scenario of last 4 years (in Ton).*

FY	Public	Private	Total
2017-2018	343129.00	1056470.85	1,399,599.85
2018-2019	274915.00	1658028.88	1,932,943.88
2019-2020	22852.00	2385007.00	2,407,859.00
2020-2021	70736.50	2623932.03	2,694,668.53

Source: HCU Data Bank.

3.7.4. High Speed Diesel (HSD)

92% of the Liquid fuel used in Bangladesh is imported. Locally produced gas condensate shares only 8% of total liquid fuel consumption. About 0.52 million metric tons per year locally produced gas condensate, which is fractionated mainly into petrol, diesel and kerosene, is the only domestic source of liquid fuel. Major consumer of liquid fuel is transport followed by power, agriculture, industry and commercial sectors.

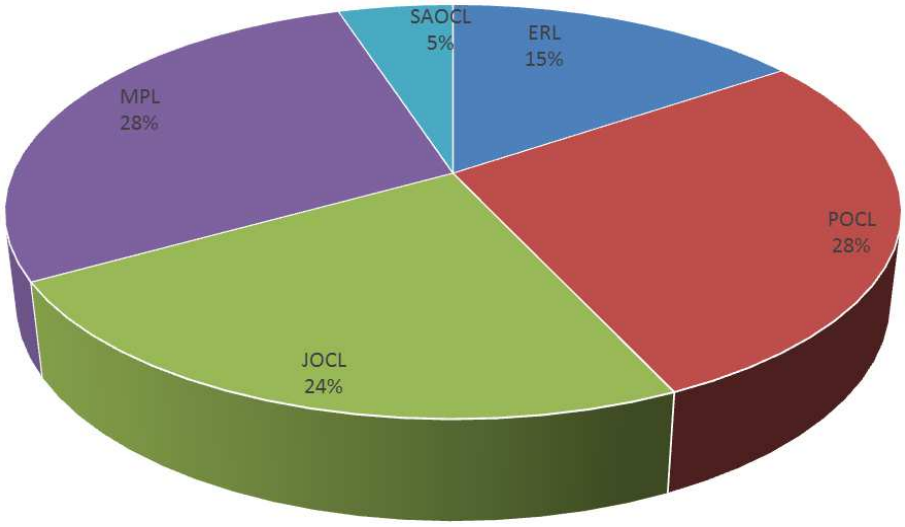


Figure 10. *Public Companies HSD Storage Capacity in Bangladesh [22].*

Diesel is the dominant liquid fuel used in the country. Diesel used during last five years are shown in the Table 17.

Table 17. *Sale of High speed Diesel during last 5 Years (Metric Ton) [18].*

Products	2016-17	2017-18	2018-19	2019-20	2020-21
Diesel	4000044	4835712	4593486	4023409	3978588

Table 18. *Public Companies High Speed Diesel (HSD) Storage Capacity in Bangladesh (MT) [20].*

ERL	POCL	JOCL	MPL	SAOCL	Total
84500	167832	152137	169526	30500	604495

3.8. Primary Energy Annual Growth Rate

Table 19. *Primary energy annual growth rate projection 2014- 2041 [1].*

Primary Energy Sources	2014		2041		Annual growth Rate ('14-'41)
	ktoe	(share)	ktoe	(share)	
Natural Gas	20,726	56%	44,149	33%	2.8%
Oil	6,263	17%	32,153	24%	6.2%
Coal	1,361	3%	33,747	26%	13.8%
Nuclear	-	-	11,942	9%	-
Renewable	36	0%	129	0%	4.9%
Biofuel and Waste	8,449	23%	4,086	3%	(-) 2.7%
Power (Export)	377	1%	6,027	5%	10.8%
Total	37,212	100%	1,32,233	100%	4.8%

The projection of primary energy for Bangladesh is shown in Table 19. As can be seen from the table that coal will be used extensively for power generation in future.

4. Energy Pricing and Policy

4.1. Energy Pricing

Electricity (Power) plays a vital role in the economy of a developing country in many aspects. Day to day the demand of the electricity is growing up. To meet the growing demand of the electricity, Bangladesh power development Board has given high priority in the electricity generation. Beside own generation, Bangladesh power development Board also purchase electricity from the Private Companies generally termed as IPP (Independent Power Producer), Rental power plant and Public power plant to meet the growing demand.

There are two types of electricity subsidies in Bangladesh. The first type of subsidy is provided for the fuel in electricity generation. This reduces the cost of power generation. Electricity tariffs are also Subsidized which is lower than the production costs. Low electricity cost has played a critical role in growth and development of the Bangladesh economy. Although the per-unit supply cost of electricity has risen over time, the rate of increase is rather small. However, Bangladesh power development Board has recently taken steps to install new power plants and to purchase electricity from independent power producers to meet the growing demand of electricity. This results in an increase in the cost of electricity production.

Table 20 shows the cost of power generation in recent years. Considering the rising supply cost of electricity, the Government has also introduced slabs in energy pricing to reduce the losses of bulk electricity tariff rates so as to reduce subsidies for high end customers. Subsidies can be further reduced by reducing system losses. Optimization in generation, transmission and distribution System, transparency of the system and proper training of the existing manpower is essential for reducing loss to the minimum.

Table 20. *Power Generation cost in TK/Kwh [4-6].*

Financial Year	Cost TK/Kwh
2014 - 2015	6.27
2015- 2016	5.55
2016-2017	5.66
2017-2018	6.33
2018-2018	6.01
2019-2020	5.91
2020-2021	6.61

4.2. Energy Policy

Bangladesh has been conserving a GDP growth of more than 7.5% for quite some time despite various adversities. Its economy grew 5.47% last fiscal year (2020-21) according to preliminary official estimated [23]. This economic development has caused an escalation in the demand of electricity consumption; which is sure to rise more & more in imminent future. Electricity production of the country is needed to be upgraded with a view to coping with the enhanced demand and continuing economic prosperity.

Bangladesh has one of the lowest per capita energy consumption for the same per capita GDP of developed countries. Table 21 shows the comparison of per capita power consumption with the GDP with some developing countries. It can be seen that Bangladesh is producing more with less energy compared to these higher income countries. So Bangladesh has the potential do better and achieve higher economic growth if the energy supply can be ensured. Energy policies for the country plays an important role in this development. The Strategic Policies in the energy sector are:

i. Fuel Diversification.
ii. Private Sector Participation.
iii. Harnessing Renewable Energy Resources.
iv. Energy Efficiency & Conservation (EE&C).
v. Tariff Rationalization.
vi. Regional Co-operation on Cross Border Power Trade [22].

Table 21. *Per Capita Energy Consumption [4, 24].*

Name of country	Per Capita GDP (USD)	Per Capita Power Consumption (Kwh)	Year
Bangladesh	2138.79	422	2021
Bangladesh	1968.69	378	2020
Bangladesh	1118.87	320	2014
Pakistan	1251.18	448	2014
India	1573.89	805	2014
China	7678.60	3927	2014
Nepal	844.85	146	2014
Srilanka	3819.25	531	2014
Vitenam	2030.28	1424	2014

At present around 97% of the people have access to electricity and per capita generation (including captive power & RE) is only 422 kWh in Bangladesh [4]. So, the Government has set up a goal of providing electricity to all by 2021 and to ensure reliable and quality supply of electricity at a reasonable and affordable price, Bangladesh Government is also trying to follow 'Bangladesh Private Sector Power Generation Policy.

Since the fossil fuel is depleting rapidly, the GoB has adopted important strategies to develop renewable energy as part of fuel diversification program. In line with the Renewable Energy policy, the Government is committed to facilitate both public and private sector investment in renewable energy projects to substitute indigenous non-renewable energy supplies and scale up contributions of existing renewable energy based electricity productions.

The Government has given priority on developing renewable energy resources to improve energy security and to establish a sustainable energy regime alongside of conventional energy sources. Government has made the most strategic power generation plan in terms of fuel diversity. The change has been made considering availability of gas supply in future and analyzing primary fuel supply scenarios for future power generation. So, Renewable Energy based projects can help Bangladesh to meet its policy goals for secure, reliable and affordable energy access to people.

Energy efficiency and conservation are very important for sustainable development in the country. The government has drafted an energy efficiency and conservation master plan up to 2030. It is expected that if 20% energy efficiency improvement is achieved by 2030, the electricity demand will be reduced by 8 GW compared to base value. This will result in reducing fuel imports for power generation which means a saving of 2.3 trillion BDT between 2015 and 2030. The yearly saving will be around 135 billion Taka which is equivalent of 6% of National budget and 1% GDP (2013) [19]. Cross Border Power Trade with neighboring countries can play an important role for ensuring energy security and to meet future electricity demand in Bangladesh. At present, Bangladesh imports 1160 MW of electricity from India. Of this, 160 MW is coming from the India's Tripura while the remaining from the Bheramara HVDC [7].

India is developing a cross-border trade policy that will allow Bangladesh Power Development Board to have access to electricity from any Indian company in real time. The Government is also planning to import the unutilized hydropower resources in Bhutan and Nepal.

5. Result and Discussion

5.1. Major Initiatives in Energy Sectors of Bangladesh

Floating Storage and Re-gasification Unit (FSRU); Construction of Gas Transmission Pipelines for LNG Transmission; Land Based LNG Terminal-1 Nos; Dimictic Gas Exploration Program of BAPEX; Multi-client Seismic Survey in the Bay of Bengal; Production Sharing Contract for Offshore Blocks; Construction of Chittagong-Dhaka Oil Pipeline; India-Bangladesh Friendship Oil Pipeline; Installation of Single Point Mooring (SPM) with Double Pipeline; Eastern Refinery Limited Unti-2 Energy Hub in Maheskhali, Coxes Bazar; LPG Expansion Program.

5.2. Supply of Affordable Primary Energy

Adoption of least-cost power expansion path requires the adoption of low-cost energy options Hydro, natural gas, coal and unclear arc all a part of the low-cost expansion path. Liquid fuels arc expensive and their use will be minimized over the longer-term, as low-cost fuels are available. Along with better pricing and demand management policies for efficient use of natural gas, efforts will continue to discover new fields. At the same time, a long-term strategy has been developed in the context of the PSMP to import liquefied natural. Gas (LNG). Two FSRUs (Floating Storage and Re-Gasification Units) having storage capacity of 1,38,000 cubic meter LNG have already been installed. Petrobangla has also plan to set up an onshore LNG Terminal with a capacity of 7.5 million tons a year. Bangladesh has already signed long term LNG Sales Purchase Agreements (SPAs). Beside this, Master Sales Purchase Agreements (MSPA) with shortlisted suppliers/traders have been signed. About 7,823 million metric tons of coal resources have been discovered so far five coal fields in Bangladesh. At Present, about 1 MTs of coal is being produced annually from coal mine at Barapukuria, Dinajpur. Some key information about the Natural gas and Coal demand and supply projection in the country is shown in the figure and Table 22.

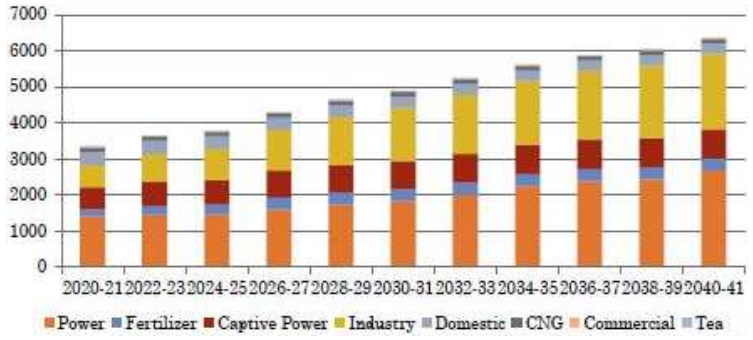
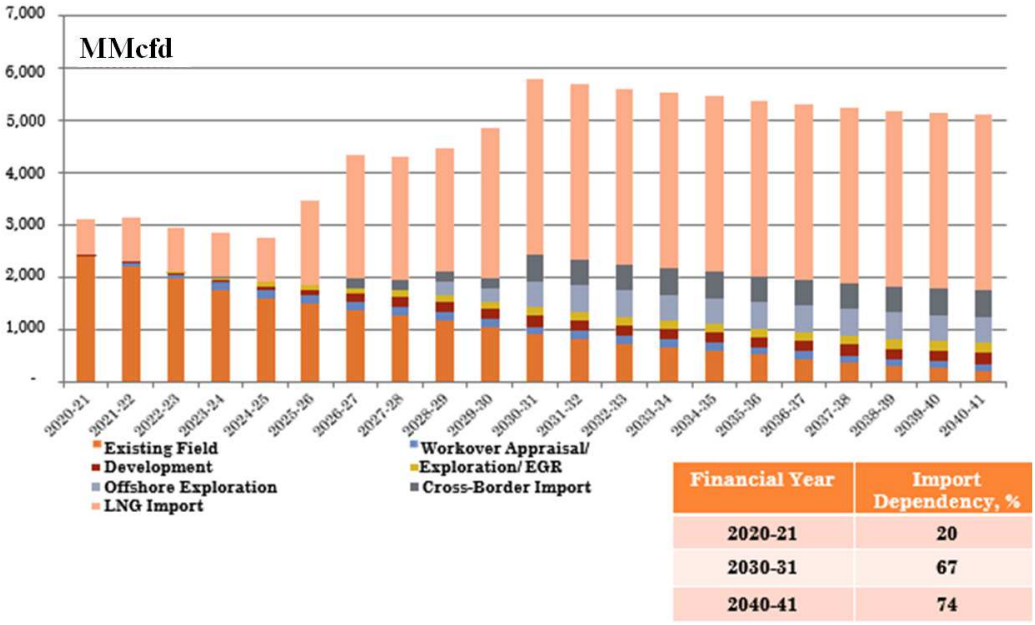


Figure 11. *Prediction of Gas Demand till 2041.*



Financial Year	Import Dependency, %
2020-21	20
2030-31	67
2040-41	74

Figure 12. *Import dependency and Prediction of Gas supply until 2041.*

Table 22. *Prediction of Coal Demand & Supply 2041 [1].*

	Name of Item		2030	2041
			Thousand MT	
Demand	Power Station	New Power Coal fired Station	25,172	42,157
		Barapukuria PS (125MW x 2)	433	433
		Barapukuria PS (275MW x 1)	477	477
	Industry	Forecast following IEA Import figures	5,129	8,810
		Present Local user at BCMCL	300	300
Total Demand			31,511	52,177
Supply	Domestic	BCMCL & Other new mine	6,200	11,200
	Import	Balance Between Total Demand and Domestic Production	25,311	40,977
Total Supply			31,511	52,177

5.3. Oil Scenario of Bangladesh

The government has kept the supply of fuel oil uninterrupted from January 2009 till today. There was no crisis in the supply of fuel oil though the country. The demand for fuel oil in the country during the year 2008-09 was 33.26 Lac metric tons. In the Fiscal Year 2019-2020 and 2018-19, about 55.03 Lac MT and 65.49 Lac MT of liquid fuel was used in the country. In the Fiscal Year 2019-2020 and 2018-19, 6.74% and 17.15% of the total liquid fuel was used in power sector [18]. The storage capacity of liquid fuel has been enhanced to 13.08 Lac MT. Energy security for liquid fuel has been increased to 40-45 days.

The government has initiated a nation-wide fuel oil pipeline network to facilitate supports for meeting increasing demand of petroleum oil through a safe, convenient, cost-saving, and system loss free distribution system in the country. Construction of Chattagram-Dhaka 246 km pipeline for fuel oil is being implemented. 16 Kilometer jet A-1 fuel oil pipeline project from Kanchan Bridge to the airport is under construction. The installation 131.5 Km oil pipeline (126.65 Km in Bangladesh part) is in progress for fuel oil supply

through the pipeline from Numaligarh, India (India-Bangla Friendship Pipeline). Installation of single point mooring (SPM) through Double Pipeline Project is being implemented for imported fuel oil. The country will save around Tk 800 Crore annually in fuel oil transmission after the project is implemented. Besides, for the purpose of upgrading the exiting oil refining capacity from 15 lac MT to 45 lac MT, activities are in progress to install ERL Unit 2. In January 2009, country-wide Liquefied Petroleum Gas (LPG) consumption was only 45,000 metric tons. Because of diverse initiative taken by government the supply of LPG has increased at about 10 lac metric tons. Some key information about the Oil demand and supply projection in the country is shown in the Table 23.

Table 23. *Prediction of Oil Demand & Supply 2041 [1].*

Item	Quantity (Million Ton)
Expansion of Eastern Refinery (ERL)	4.5
New complex by (KPC)	8.0
Imported refined oil	20.0
Total	32.50

Table 24. *Primary Energy Mix for Power Generation 2030 [25].*

Fuel-wise composition (MW)	2030
Coal	17,969
Gas/LNG	23,744
Liquid	5,591
Import	3,496
Nuclear	2,232
RE (Hydro, Solar, Wind etc.)	230
Total	53,262

5.4. Primary Energy Mix for Power Generation at Projected 2030

Fuel wise forecasted generation capacity may be 53,262 MW which will require for meeting up demand of 40,669 MW in 2030. Out of this generation capacity, Gas/LNG based capacity will be higher compared to other fuels like coal, power import etc. in 2030. To meet the future demand, 10% power will be required from liquid fuel-based power plants and 7% from imported power of total net generation capacity in 2030. Year-wise fuel mix in power generation plan is shown in Table 24.

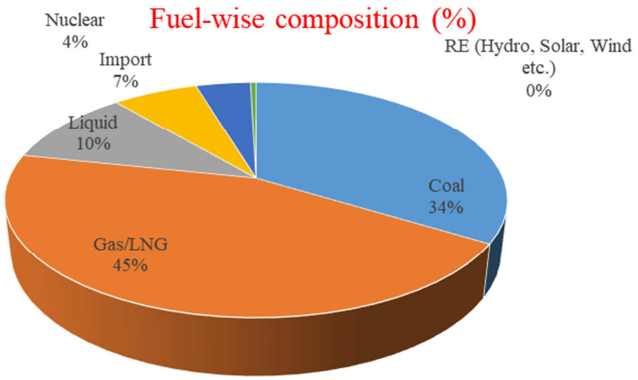


Figure 13. *Primary energy Mix for power generation projected -2030 in Bangladesh [25].*

5.5. Primary Energy Mix for Power Generation at Projected 2041

Fuel wise forecasted generation capacity may be 79,507 MW which will require for meeting up demand of 72,379 MW in 2041. Out of this generation capacity, Gas/LNG based capacity will be higher compared to other fuels like coal, power import etc. in 2041. To meet the future demand, 2% power will be required from liquid fuel-based power plants and 15% from imported power of total net generation capacity in 2041. Year-wise fuel mix in power generation plan is shown in Table 25.

Table 25. *Primary Energy Mix for Power Generation 2041 [25].*

Fuel-wise composition (MW)	2041
Coal	25,596
Gas/LNG	34,165
Liquid	1,840
Import	11,996
Nuclear	5,580
RE (Hydro, Solar, Wind etc.)	330
Total	79,507

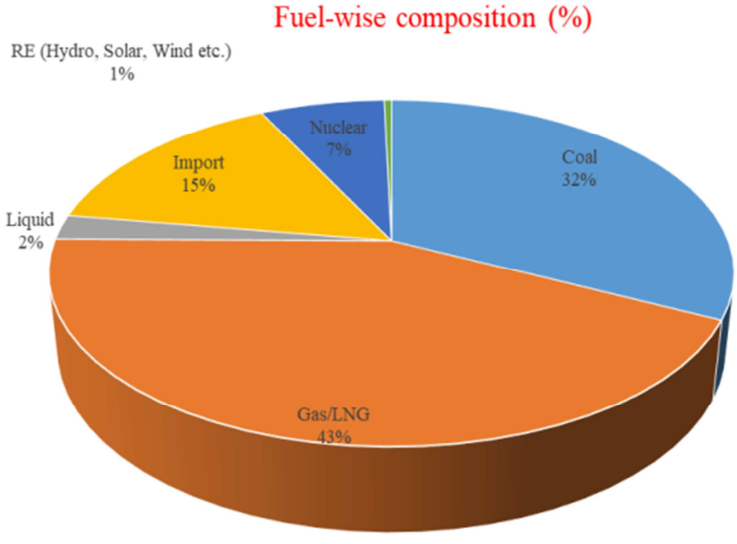


Figure 14. *Primary energy Mix for power generation projected-2041 in Bangladesh [25].*

5.6. Per Capita Generation of Electricity (Projected)

Total net energy generation is projected to be 298659 GWhr which will generate 1641 KWh of electricity per capita in (2030) and total net energy generation is projected to be 445824 GWhr which will generate 2286 KWh of electricity per capita in (2041).

Table 26. *Per Capita Generation of Electricity [25].*

FY	Net Energy Generation (Gwh)	Power Generation (MW)	Per Capita Generation of Electricity (kWh)
2029-30	298659	53,262	1641
2040-41	445824	79,507	2286

5.7. Comparative Energy Scenario

World total energy supply (TES) increased by 65.6% from 1990 to 2018, reaching 594 EJ. This increase was driven by Asia, responsible for 82.1% of the world growth in the period. Chinese TES alone more than quadrupled, accounting for over a fifth of world TES in 2018. The European share of world TES almost halved from 35.2% in 1990 to 18.4% in 2018, with an absolute drop of 17.1 EJ. The United States, whose share of world TES dropped by 6.7 percentage points since 1990 to reach 15.7% in 2018, showed an absolute increase in TES of 13.1 EJ during this period. International bunkers were equal to 17.3 EJ in 2018 (accounting for 2.9% of world TES), virtually doubling from 1990.

Table 27. *Comparative Energy Scenario of Bangladesh and others countries [14].*

Country	GDP/Capita (USD)	TES/pop (kgoe/cap)	Self sufficiency	Energy Intensity (kgoe/000 USD)
Bangladesh	1498	260	81.6	170
China	9605	2300	80.1	240
Germany	43129	3640	36.9	80
Italy	31512	2490	23.1	80
Japan	35780	3370	11.8	90
Luxemburg	105667	6410	5.6	60
Korea	30971	5470	15.8	180
Singapore	60571	6690	2.4	110

6. Challenge for Vision 2041

1) Affordable, Reliable and Modern Energy for all
2) Energy Efficiency & Conservation
3) Clean Fuel and Technology
4) Suitable Energy mix
5) Increase share of Renewable Energy
6) On-shore and Off-shore exploration of gas
7) Development of domestic Coal field
8) Imported Energy (LPG & LNG)
9) Energy pricing and subsidies
10) Huge financing of Energy related projects.
11) State of the art capacity building: import of natural gas through pipeline Arranging Huge Investment
12) Narrowing demand supply gap
13) Efficient use of gas
14) Market price adjustment

7. Future Recommendation

1) Fuel Diversification (LNG, LPG, Coal, Renewable & Nuclear)
2) Improvement of Energy Efficiency and Conservation
3) Intensifying E&P both in off-shore and on-shore
4) Cross Border Energy
5) Biomass and Biofuel
6) Unconventional form of energy (CBM, UCG, Gas Hydrate etc.)
7) Policy and institutional interventions
8) Immediate adjustment of all energy prices
9) 4 IR Based Energy System
10) Energy Transition (Fossil-fuel to non-Fossil-fuel) for Net Zero Economy.
11) R &D and HRD to adopt advanced technology.
12) By 2030, gas production will be increased by 850-870 mmcfd if BAPEX, SGFCL, BGFCL and IOC's conduct workover and exploration and development of well drilling activities.

8. Conclusion

The economy of Bangladesh is expanding in an unprecedented motion. Government articulated to transform the country from LDC to lower middle income country by 2021, upper middle income Country by 2031 and develop country by 2041 Accordingly, energy sector has already set its targets in PP2041. Supply of affordable modern primary energy for all is a big challenge. Economy of the country is growing very fast; demand of primary energy supply is increasing tremendously indigenous production is not enough to feed ever fast growing demand. It is expected that targets of power and energy sectors as stipulated in PP2041 and SDG7 will be realized accordingly.

Acknowledgements

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