

A Survey of Cross Country Generation Mix – Opportunities and Challenges: Bangladesh, Australia, and the U.S.A. Perspectives

Moon Barua

*Dept. of Electrical and Electronic Engineering
Chittagong University of Engineering and Technology
Chittagong 4349, Bangladesh
moonbarua27@gmail.com*

Shantanu Mutsuddy

*Dept. of Electrical and Electronic Engineering
University of Science and Technology Chittagong
Chittagong 4202, Bangladesh
mutsuddyshan2@gmail.com*

Nur Mohammad

*Dept. of Electrical and Electronic Engineering
Chittagong University of Engineering and Technology
Chittagong 4349, Bangladesh
nur.mohammad@cuet.ac.bd*

Mohammad Abdur Razak

*Dept. of Electrical and Electronic Engineering
Chittagong University of Engineering and Technology
Chittagong 4349, Bangladesh
razzak123006@gmail.com*

Abstract—Optimal electricity generation mix profile is one of the influential elements need to be considered for the economic growth of a country. This paper represents a survey of generation mix data in Bangladesh, Australia, and the USA. Overall power generation scenarios among these countries with different representative economic scale are critically reviewed. These countries follow a different kind of generation mix trend to meet their present and future demand. The study found some challenging factors and various obstacles in electricity generation to meet demand. The decreasing use of fossil fuel resources, environmental constrict, and the high cost of electricity production – a few dominant factors. Though developed countries like Australia and the USA are emphasizing renewable energy over fossil fuel-based resources and they are producing a big amount of electricity from renewable resources. However, renewable raises uncertainty in the system operation in proportion to the level of penetration. In fact, fossil fuel resources are depleting day by the day hence renewable energy will lead future electricity sector. Nevertheless, developing countries like Bangladesh is not producing electricity from renewable resources that much compared to developed countries. One common aspect found that the dependency on the gas-based power plant and renewable energy is increasingly rising. This study shows how a developing country and developed countries handling their electricity generation and price sector using various fuel sources that can help other countries to design their generation policy framework.

Keywords-- *Generation mix, Electricity generation, Load demand, Fuel types, Gas-based power plant, Renewable Energy, Nuclear power plant*

I. INTRODUCTION

Bangladesh has a low level of electrification with 9.35 million out of 170 million end-user customers. Yet, over 12% don't privilege of electricity use. It has an energy crisis for a long time. Demand and consumption of electricity are rising rapidly every year. Its current GDP growth rate is 7.65 (2017-18), the demand for electricity upswing due to the increase in economic activities in the country. A huge gap between power generation and demand causes the power outage to the consumer which may uplift production cost and create various operation and control problems [1]. Moreover, inadequate power supply results in power outage

would decrease overall economic growth, income and increase the production loss. The loss is almost 1% of Bangladesh's GDP which is a major concern for the electricity market operator [2]. To hold consistent GDP growth rate and to reduce this energy crisis, the policymakers in government and the stakeholder should take various initiatives. Building rentals and quick rental power plants are few among many such initiatives. Increasing the number of coal-based power plant to reduce dependency on the gas-based power generation plant is also an option.

A cross-border power transaction is another viable option. The government already imports a 660MW of electricity from India. Further, planning underway to import power from Nepal, Bhutan, and Myanmar to back up future energy security and crisis [2]. Another ongoing 2.4 GW nuclear power plant named Rooppur Nuclear Power Plant Project which is an inter-government agreement between Bangladesh and Russia is estimated to come in operation by the 2023. Furthermore, the government took a master plan, that is "The Power System Master Plan (PSMP) 2016", funded by the Japan International Cooperation Agency (JICA), aims at assisting Bangladesh [3] to establish a sustainable development in power and energy sector up to 2041 that covering power and energy security, and tariff scheme [4]. Now, amount of power outage in a tolerable range, which is a result of successful planning and implementation of the government's Master Plan.

Australia's electricity sector has historically depended upon coal-fired power stations, but recently renewable energy contribution in the mainstream power generation growing rapidly. Due to big area and people lived in the different region, they established an interstate power system operated by a single market operator [5]. Since 2005, the rooftop solar and wind power have increased substantially. Total energy generation due to sharing of renewable energy into the grid upholds [6]. Despite the benefits of renewable, Australian power grid faces few problems especially at peak Sun hours when solar generated power exceeds certain thresholds. Over voltage problem in distribution networks is strong enough to find alternative option like energy storage to store the solar power rather than feeding to the grid.

Australia's electricity generation policy had to stop the new project for construction of the coal-based power plant, as the major banks do not want to provide loans for any coal-based power plants from 2011 [7]. Additionally, some of the coal-based plants were already in retired due to aging. Anyway, it was expected in 2014 that an excess of supply of generation will persist up to 2025. In 2017, Australian Energy Market Operator published a report that the energy supply in the next two years is hoping to reach demand level, but it has a risk that the supply may not enough during peak demand times in hotter summer and cooler winter seasons. The electricity bill for households may be increased up to 72% from 2003 to 2013. This trend of price increase is assumed to be limited as the Australian government changes rules for transmission and distribution system. The competition in the electricity wholesale market increased substantially.

The United States electricity market consists of various stakeholders they provide services for various levels from power generation to delivery to the end-user customers. Approximately, four trillion kilowatt-hours of electricity is consumed each year. More than \$350 billion is transacted in the retail electricity market, which is a massive amount compared to any other countries in the world. Economic activity, advanced technological innovation and use, the weather, and daily personal and commercial activity is the driving factor for this massive demand for electricity.

Still, fossil fuels are the major source to generate electricity in the United States [8], although some variation is found in a few regions, for example, the Pacific Northwest mainly depends upon the hydro-power plant. More than 50% of total electricity production was depended upon coal. In 2010, due to the environmental issue, they had to decrease the coal-based power plant. The lower price of natural gas has also an impact to reduce the dependency on coal. Now coal and natural gas are near to the equal level in electricity production. Generation mix of the United States by fuel type was: coal (39%), natural gas (27%), nuclear energy (19%), hydro (6%) and various renewable (7%) in 2014. Over the decade 2004 to 2014, the greatest increase in the generation of electricity from natural gas (total generation in 2014 was 412 billion kWh greater than the generation in 2004), wind energy (an increase of 168 billion kWh) and solar energy (increased 18 billion kWh). During this period, the annual electricity generation from coal reduced up to 393 billion kWh, and from petroleum reduced up to 90 billion kWh. U.S.A. has a cross-broader power transmission grid with Canada and Mexico by using cross-border grid U.S.A. imports and exports electricity with these neighboring countries.

II. POWER GENERATION-MIX IN BANGLADESH

In South-East Asia, Bangladesh is one of the least per capita electricity consuming country [9]. In the PSMP -2010 power demand anticipation was prepared based on a 7% GDP growth rate [10]. According to this study, the peak demand would be almost 17,304 Mega Watt (MW) in the year 2020 and 25,199 MW in the year 2025. The PSMP-2010 demand forecast is given in Fig. 1.

Total power generation in 2010 (BPDB) by fuel type was gas-82.81%, furnace oil-5.75%, diesel-3.20% and coal-4.29%. Though in that year, derated capacity was 5271

MW, the maximum power generation was 4606 MW and the system distributional system loss was almost 13.06% in FY 2010 [2]. Table I shows that 88.52% of total electricity production comes directly from the gas-driven power plants and only 3.75% of total electricity production comes from coal. In this country county, a few coal-based power plants operate, though coals are one of the major fuel sources in the rest of the world to generate electricity [2]. Almost a 42% of the world's electricity comes from the coal-based power plant.

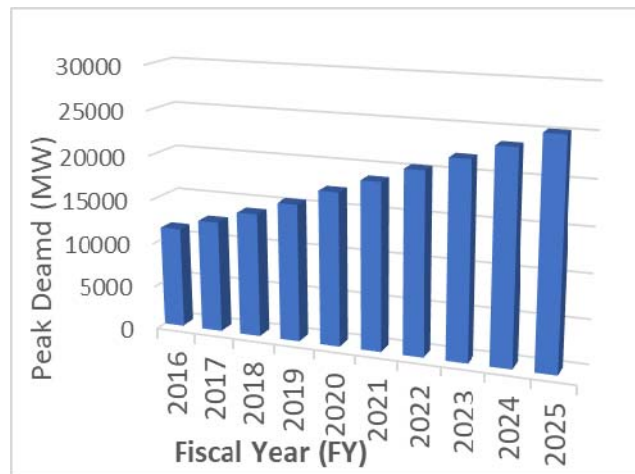


Fig. 1. PSMP Peak Demand -starting with 2010, projected till 2030 [4].

TABLE I INSTALL CAPACITY AND ACTUAL POWER GENERATION OF BPDB'S POWER PLANTS.

Fuel type	Install capacity		Actual generation	
	MW	%	GWh	%
Gas	4822	82.81	24316.49	88.52
Furnace oil	335	5.75	87651	319
Diesel	186	3.20	51736	1.89
Coal	250	4.29	728.56	3.75
Hydro	230	3.95	728.56	2.65
Total	5823	100.00	27,469.67	100.00

According to Fig. 2, power production from coal is in a rising trend in the last few years due to the low production cost of the coal-based plant than that of the oil-based power production. In addition, gas reserve in Bangladesh is depleting day by day. The reservation of gas will be exhausted at a high volume and create a huge gas crisis within 2020-2030 if some new gas field is not identified. That is why the government started to import LNG to meet the gas crisis.

Now electricity production in Bangladesh is almost 5504 Gigawatt-hour. According to Fig. 3 the average power generation in Bangladesh is 4003.71 Gigawatt-hour from 2013 until 2018 [11]. On the other hand, System Loss is 11.78% (June 2018) and Distribution Loss is 9.60% (June 2018) [12]. This loss trend is going down but the system loss in power system should not cross 4% to 8%. By

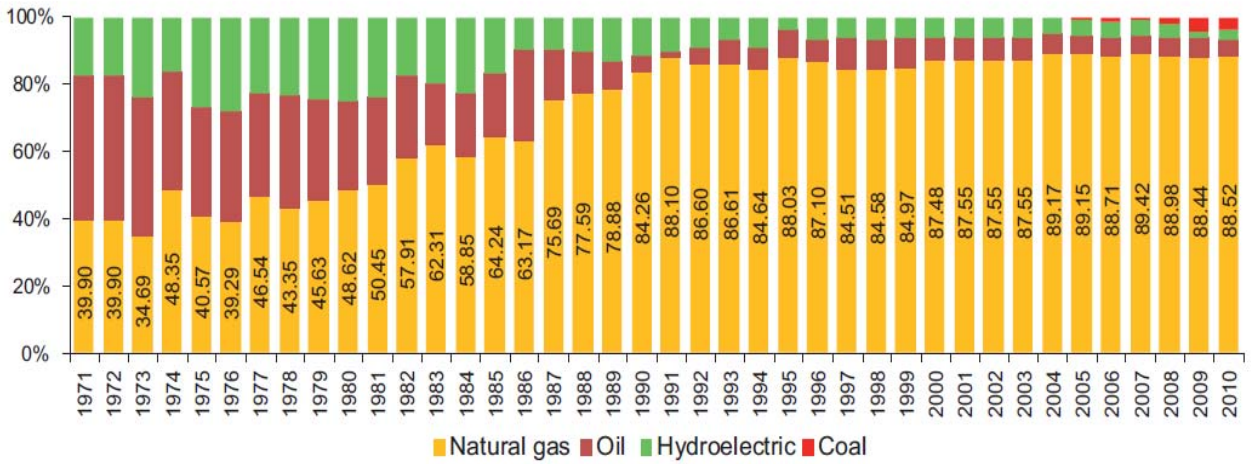


Fig. 2. Power generation mix from various energy sources [2].



Fig. 3. Bangladesh Electricity Production.

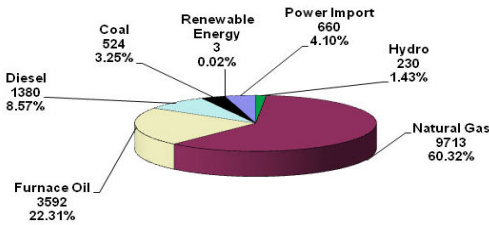


Fig. 4. Installed Capacity as on July 2018 (By Fuel Type) [13].

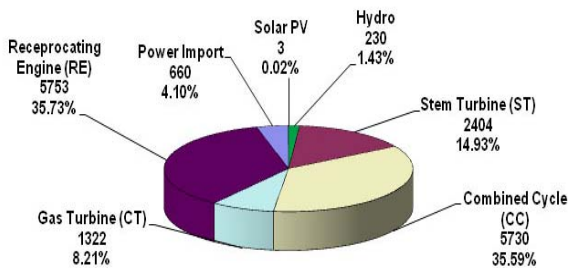


Fig. 5. Installed Capacity as on July 2018 (By Plant Type) [13].

upgrading the system and a proper maintenance could reduce system loss.

Currently, a 60.32% of total electricity production could produce from Natural Gas (June 2018) alone where the contribution other sources of electricity are Furnace Oil-22.31%, Diesel-8.57%, Power Import-4.10%, Coal- 3.25%, Hydro-1.43%, Renewable Energy-0.02% (Fig. 4) [13]. In Fig. 5 depicts that the installed capacity of electricity (June 2018) by plant type are Combined Cycle-35.59%, Steam Turbine-14.93%, Hydro-1.43%, Solar PV-0.02%, Power Import-4.10%, Reciprocating Engine-36.73%, Gas Turbine-8.21% [13].

III. POWER GENERATION-MIX IN AUSTRALIA

Australia's power generation still mainly depends on fossil fuels. In 2017, 84.3% of electric power generated from fossil fuel. According to Fig. 6, Australia's total electricity generation mix data (in 2017) by fuel type are 62.7%-Coal, 19.6%-Natural Gas, 6.3%-Hydro Power, 4.9%-Wind, 3.1%-Rooftop Solar, 1.4% Bioenergy [7]. The electricity production of Australia in 2016-2017 increased by 0.2 percent only, where the growth rate in 2015-2016 was 2 percent. Fig. 7 depicts the highest electricity production record in Australia was 258 terawatt-hours in 2016-2017 [7]. In 2016-2017 coal remained the main fuel source for power production and 63.8% of total electricity came from coal where 45.8% was Black Coal and 16.9% was Brawn Coal (Table II). In Table II, we see that fossil fuel contribution in electricity generation 217,562 GWh and 38146 GWh comes from renewable energy [7]. This time Natural Gas based electricity generation decreased by 0.2 percent (decreased 20 % of Australia's electricity). On the other hand, Renewable energy electricity generation increased almost 16 % in 2016-2017.

Present capacity (2017-2018 FY) of electricity generation of the National Electricity Market (NEM) is 44078 MW where demand is 32469MW [14] approximately. On the other hand, the price of electricity is rising rapidly day by day. The highest average charge of electricity in a province was 56.76 \$/MWh in 2006, but the present highest average charge of electricity in a province is 92.33\$/MWh (Table III) that is a pressure for the consumer [15]. The Australian government invests \$41.5 million in the 2018-19 Federal

TABLE II THE AUSTRALIAN ELECTRICITY PRODUCTION, BY FUEL TYPE [7].

2016-2017		Average annual growth		
	GWh	Share (per cent)	2016-17 (per cent)	10 years (per cent)
Fossil fuels	217,562	84.3	-0.8	-0.3
Black coal	118,272	45.8	3.5	-1.0
Brown coal	43,558	16.9	-10.7	-2.5
Gas	50,460	19.6	-0.2	4.2
Oil	5,273	2.0	-6.8	3.0
Renewables	40,455	15.7	6.1	8.2
Hydro	16,285	6.3	6.3	3.4
Wind	12,597	4.9	3.3	16.9
Bioenergy	3,501	1.4	-7.6	-3.0
- bagasse	1,435	0.6	-20.7	na
- wood, wood waste	355	0.1	42.7	na
- municipal, industrial waste	76	0.0	76.9	na
- sulphite lyes, biofuels	442	0.2	6.2	na
- landfill biogas	970	0.4	-8.6	na
- sludge biogas	223	0.1	5.6	na
Solar PV	8,072	3.1	18.0	59.2
- small scale	7,399	2.9	16.0	57.7
- large scale	672	0.3	47.1	na
Geothermal	1	0.0	133.3	na
Total	258,017	100	0.2	0.7

TABLE III THE AVERAGE PRICE HISTORY OF AUSTRALIA [15].

YEAR	NSW	QLD	SA	SNOWY	TAS	VIC
1999	23.35	53.17	47.69	23.57	N/A	24.51
2000	28.27	44.11	59.27	27.96	N/A	26.35
2001	37.69	41.33	56.39	37.06	N/A	44.57
2002	34.76	35.34	31.61	31.59	N/A	30.97
2003	32.91	37.79	30.11	29.83	N/A	27.56
2004	32.37	28.18	34.86	30.8	N/A	25.38
2005	39.33	28.96	36.07	34.04	77.27	27.62
2006	37.25	28.12	37.76	31.08	56.76	32.47
2007	58.72	52.14	51.61	55.19	49.56	54.8
2008	41.66	52.34	73.5	45.49	54.68	46.79
2009	38.85	34	50.98	N/A	58.48	41.82
2010	44.19	33.3	55.31	N/A	29.37	36.28
2011	36.74	30.97	32.58	N/A	29.44	27.09
2012	29.67	29.07	30.28	N/A	32.58	27.28
2013	55.1	67.02	69.75	N/A	48.3	57.44
2014	52.26	58.42	61.71	N/A	41.98	51.49
2015	35.17	52.52	39.29	N/A	37.16	30.35
2016	51.6	59.99	61.67	N/A	102.7	46.14
2017	81.22	93.12	108.66	N/A	75.4	66.58
2018	82.27	72.87	98.1	N/A	86.98	92.33

Budget to deliver a more affordable and reliable electricity to their people.

IV. POWER GENERATION-MIX IN THE USA

The USA power system found a very complex network of power generation plants, transmission and distribution lines [16], etc. The wholesale electricity market divided into the various regional zone. Regional Transmission Operator (RTO) regulate the prices of electricity and show the demand for their individual region such as Electric Reliability Council of Texas (ERCOT), New York ISO (NYISO) [17] etc. are the example RTO. The electricity supply in the USA. mainly regulated by centralized power plants. These power plants use various energy resources such as coal, natural gas, nuclear energy, and renewable energy resources [18]. Fig. 8 depicts that in 2002 the generation of electricity of the U.S.A. was 3,858,452 thousand megawatt-hours, in 2010 generation increased to 4,125,060 thousand megawatt hours and in 2016 generation was 4,034,268 thousand megawatt hours [19]. It is clear that the USA generation rate rising rapidly to face the present demand growth they will have to generate more electricity. Due to the environmental problem, the government is trying to decrease carbon emission and promote renewable energy [20].

Use of coal as a fuel in the electricity generation sector is decreasing over time due to the government's initiatives for environmental concern and international pressure. Besides, the natural gas-driven unit price is lower than the coal-fired unit that also another reason to decrease the coal-based power plant in 2018 (Fig. 9). In 2017 total power generation was 4014804.462 Million kWh where generation mix of various fuel type was Coal-1207901.306 Million kWh, Natural Gas-1272,864.166 Million kWh, Nuclear Electric Power-804949.635 Million kWh, Conventional Hydro-

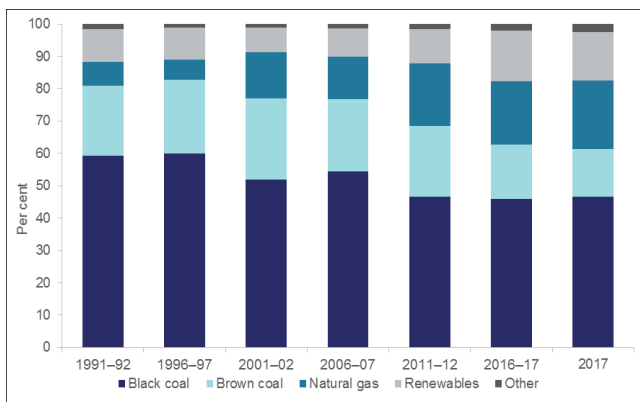


Fig. 6. Australian electricity generation fuel mix [7].

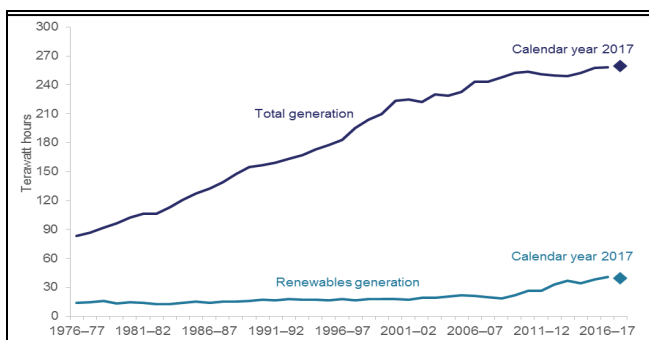


Fig. 7. Australia's Electricity Generation [7].

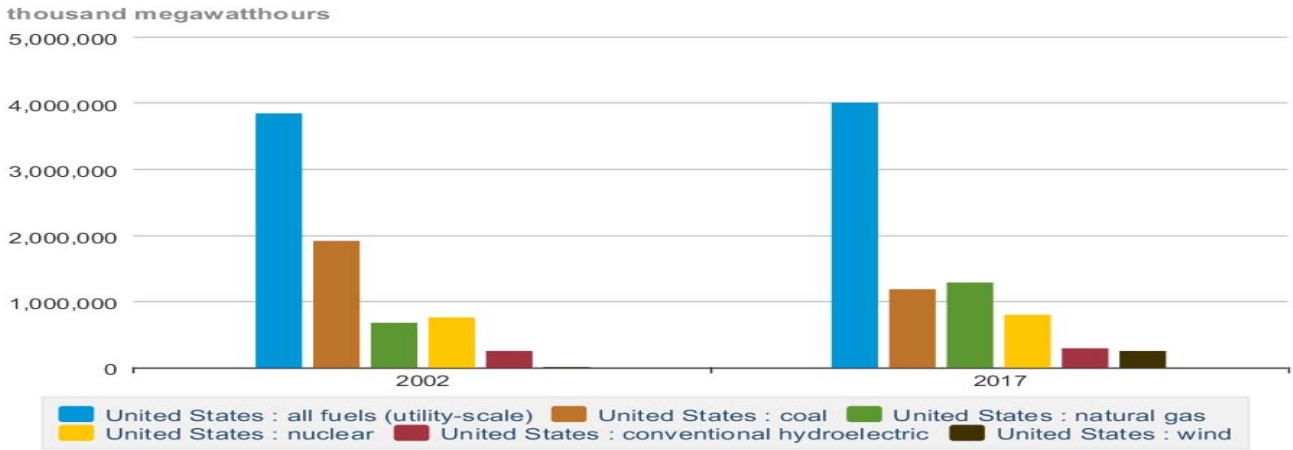


Fig. 8. US net electricity generation for all sector from 2002-2017 [19].

TABLE IV RECENT U.S. ELECTRICITY DATA [21].

May 2018		% Change from May 2017
Total net generation (thousand MWh)	339,056	5.4%
Residential retail price (cents/kwh)	13.15	1.1%
Retail sales (thousand MWh)	297,299	2.7%
Cooling degree-days	141	31.8%
Coal consumption (thousand tons)	47,563	-6.5%
Natural gas consumption (Mcf)	867,336	19.9%

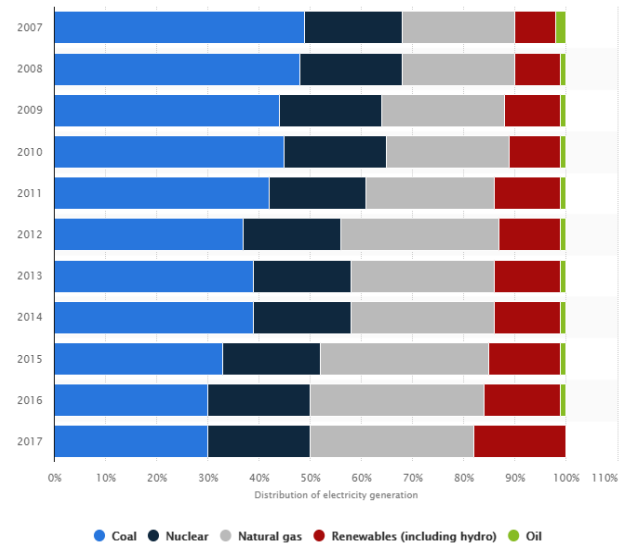


Fig. 9. U.S. distribution of electricity generation from 2007 to 2017, by fuel type [20].

Electric-30,044.503 Million kWh, Renewables- 387,245 Million kWh etc. Fig. 9 shows that the use of coal in electricity generation was 49% in 2007 which decreased to 30% in 2017 [21].

On the other hand, the use of natural gas and renewables to generate electricity is increased at this time from 22% and 8% to 30% and 18% respectively. In May 2018 total electricity generation was 339056 thousand MWh that is 5.4% higher than last year generation (Table IV). But in this time (2017-2018), residential retail price (cent/kWh) and retail sales price (thousand/MWh) increased up to 1.1% and 2.7% respectively [22]. The average price of electricity to the consumer in April 2018 was 12.63 cents/kWh for the residential user, 10.49 cents/kWh for the commercial user, 6.73 cents/kWh, 9.51 cents/kWh for transportation and this price is also 1.5% higher than the last year (April 2017). The USA Energy Information Administration (EIA) published an Annual Energy Outlook-2018 with a projection to 2050 [23] as shown in Fig. 10. In this projection, it is clear that the generation mix of USA will change according to the recent trend where gas and renewable energy [24] will be the major resources to generate electricity. From 2020 to 2050, solar photovoltaic [25] capacity will increase up to 127 GW and wind capacity will increase up to 20 GW.

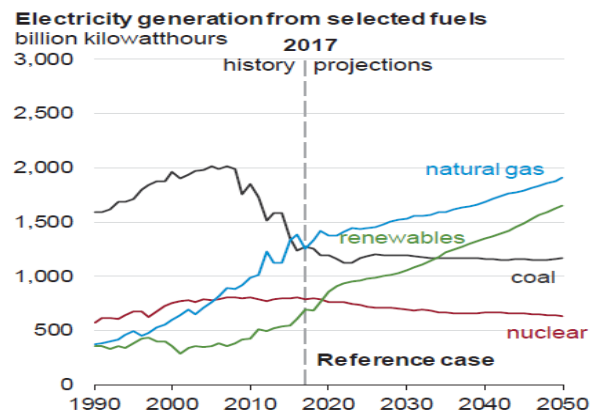


Fig. 10. The projected mix of electricity generation of U.S.A. [22].

During the projection period, electricity prices are projected to remain relatively flat ranging between 1.06 to 11.8 cents/kWh [23]. The good news is that U.S. electricity

generation cost is projected to decrease by 10% from 2010 to 2050 due to the dependency of natural gas and renewable energy [23].

V. CONCLUSION

This paper presents power generation profile, energy mixing and electricity price among three countries having a different economic scale. The Bangladesh government focused on the domestic and local coal-based power plant. Future energy security of Bangladesh could be achieved in two ways. Firstly, according to PSMP (2010) proposed power development plan of Bangladesh government need to build a new coal-based power plant and renewable energy. Secondly, Bangladesh will have to start cross-border power trade with Nepal, Bhutan, and Myanmar. Moreover, efficient generation mix not only depends on adequate electricity generation but also depends on other factors such as cost, benefit analysis, challenges, risk, and system loss need to consider for an efficient and profitable electricity generation. Besides, Bangladesh still used vertically integrated utility, such utilities served as the only electricity provider in the area and obliged to give electricity to everyone in the area. Therefore, the vertically integrated utility often charged their customers at an average tariff rate based on the total sum of the cost in a time. As a result, there is no competition in the electricity market so money flow is unidirectional from the customer to the electric utility. So, the government should have to encourage the entrepreneur to invest more in the electricity sector.

In Australia, it is expected that the contribution of coal and gas will be a large amount of total electricity production, but the government committed in the Paris COP21 and community to reduce carbon emission so they are facing pressure to the advancement of renewable energy. Changing the generation mix trend of Australia is not a simple matter of selecting a technology, but it is the combination of new and existing technologies and it must intimate with the latest policy. Recently, the Renewable Energy Target (RET) scheme of Australian government planning is in action which increases the use of a variety of renewable such as solar, geothermal, ocean, wind, hydro and bioenergy. South Australia, Western Australia, and the Northern region increased their electricity generation from natural gas and wind energy firm by a large percentage. The improvement of energy security of the government will be depended on the diversity of fuel type including renewable, the connection between the state border so that energy is possible to trade, and need to improve the smart-grids to build a strong and reliable electricity market. Besides, the policymakers should focus on the reduction method of electricity consumption which reduces the national electricity bill and improves energy security within environmental constriction.

The USA electricity generation is hard to foresee, but the recent trend and innovation may reshape the future electricity sector. Its energy sector faced some unpredictable problems in the last decade such as shale gas boom, the large price drop of the solar photovoltaic modules, negative demand growth, the reduction of coal-based power plants, and border challenges. They overcome this obstacle as they have a rich digital communication and physical power

network in the power system which enhanced the competition in the electricity market.

In conclusion, the dependency of the natural gas-based power plants increasing steadily. Lower gas price can decrease the wholesale market price for the nuclear power plant and coal-based power operator, as a result, to handle this situation government decreasing capacity of the nuclear power plant up to 24 GW within 2050 and retirement of the coal-based power plant by 19 GW in 2030. The USA government is targeting to increase their renewable generation up to 139% that is almost 1605 billion kilowatt hours in 2050. It is projected that in 2050 its electricity generation cost will decrease to 5.62 cents/kWh but transmission and distribution cost increased to 1.6 cents/kWh and 3.37 cents/kWh respectively.

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