

A Spatiotemporal Analysis and Forecasting of Electricity Generation-Mix in Bangladesh

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Abstract—An analysis is presented to show time series data of electricity generation mix and forecasting by 2030 in Bangladesh. The comparative studies have been analyzed using spatiotemporal data of Germany, Australia and Bangladesh. The spatiotemporal data has been taken out from World Bank data bank for analysis. A Linear regression technique is applied for forecasting electricity generation mix from 2015 to 2030. The result shows the rise of renewable energy sources, coal and oil, and the diminution of natural gas gradually.

Keywords— spatiotemporal, forecasting, electricity, energy mix, solar energy

I. INTRODUCTION

Power Generation mix refers to the combination of the various primary energy sources (fossil fuels, nuclear energy, renewable energy sources) used to meet electricity according to geographical region. For each region or country, the composition of the energy mix depends on the availability of usable resources domestically or the possibility of importing it. The Policy defines by historical, economic, social, demographic, environmental and geopolitical factors [1]. These differences can be appreciated by taking a look at the electricity generation and consumption information for a country.

World Energy Statistics presents comprehensive world electricity generation mix statistics on all energy sources: coal, gas, oil, electricity, renewable sources and waste. Coal is the highest source (39.3%) of electricity generation mix in the world.

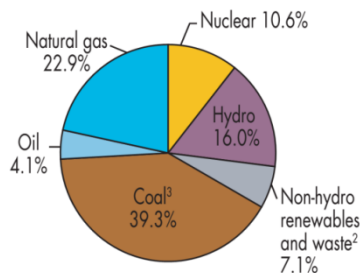


Fig. 1. Global Electricity Generation Mix

TABLE I. ELECTRICITY GENERATION MIX IN BANGLADESH

Gas	8810 MW (64.99%)
Furnace Oil	2785 MW (20.55%)
Diesel	880 MW (6.49%)
Power Import	600 MW (4.43%)
Hydro	230 MW (1.7%)
Coal	250 MW (1.84%)
Total	13,555 (100%)

It is followed by natural gas which is contributed 22.9% in World electricity generation. Hydro (16%), nuclear (10.6%), Renewable energy excluded hydro (7.1%) and oil (4.1%) are respectively in the list of electricity generation mix in the world. Fig.1. shows the percentage of different sources of electricity generation [2].

In Bangladesh, the dominant electricity generation-mix or sources are largely reliant on gas and imported oil. Table 1 describes percentage share of electricity generation mix by sources [3]. The Contribution of gas and oil are significant which accounted for 60.99% and 20.55% respectively of the country's total power generation in 2017, while gas occupying 89.22%, and oil 3% [4]. Electricity generation mix changes over time in Bangladesh. By 2030, coal and nuclear power plant will be operation in which have the ability to generate a huge amount of electricity at a time [5]. So, power generation mix would be changed to renewable energy due to global warming. Even solar energy is potential in Bangladesh as a sub-tropical region [6] and govt. has already planned 2000 MW by 2021 [7].

An agriculture earnings based Bangladesh is one of world's most populated countries. Demand of energy creates with rapid urbanization and industrialization in Bangladesh. So, Bangladesh government should ensure electrical energy for the people that will be affordable and environmentally friendly. Energy sector in Bangladesh is reviewed, and it is hard to accomplish Millennium development goals (MDG) and Sustainable Development Goal (SDG) without improving energy sector [8]. Bangladesh government has already taken step to break the tax for investors in renewable energy [9]. Though Renewable currently play a small role in Bangladesh's fuel mix, despite domestic roof-top solar power units have brought electricity to over a million homes which are not on the grid. There are lots of opportunities in urban building to establish on grid solar power. Ensuring

electricity for all, Bangladesh government is establishing coal and uranium based power plants, as these are able to produce huge electricity energy at a time. Electricity market and cost of energy are hard to determine for power plant project. So, the competitive electricity market is optimized by game theory for revealing existence Nash equilibrium for network incommmodity [10]. Last ten years, there is no any wind energy project in Bangladesh. This uncertainty of wind generation and market is managed proposing wind induced demand response (WIDR) using bi-level optimization frameworks [11]. The levelized cost of electricity (LCOE) including import and export is discussed in [12] for the each country. Next ten years, energy sector is expecting new generation-mix in electricity market carrying out the MDG and SDG towards development of Bangladesh.

In this paper, a spatiotemporal data of electricity generation mix of Bangladesh is analyzed and forecasted electricity generation sources for future indication using MS

Excel and MatLab. And a comparative study has been done for showing how generation mix is varied with geography location and changed with time being in three different geography locations (Germany, Australia and Bangladesh). Linear regression is used for forecasting to indicate future electricity generation mix in Bangladesh. Linear regression can find linear relationship between two continuous variables. One is predictor and other is response or dependent variable. It looks for statistical relationship between two variables is said to be deterministic if one variable can be accurately expressed by the other [13]. In research, electric power generation mix is analyzed for long-term indication deploying model in Malaysia [14]. World Bank organization maintain data bank for such kind research and analysis [15]. The objective of this paper is to explore electricity generation sources which are an effective generation-mix towards the long-term energy security of Bangladesh considering geographic, demographic, environment, socio-economical factors for the national sustainable development.

TABLE 2: COUNTRY PROFILE OF AUSTRALIA, GERMANY AND BANGLADESH [14]

Country Profile (2016)			
	Australia (AUS)	Germany (DEU)	Bangladesh (BGD)
Population, total (millions)	24.21	82.35	162.95
Population growth (annual %)	1.5	0.8	1.1
Surface area (sq. km) (thousands)	7,741.2	357.4	147.6
Population density (per sq. km of land area)	3.2	357.4	1,251.8
Urban population growth (annual %)	1.6	1.1	3.3
CO ₂ emissions (metric tons per capita)	15.37	8.89	0.46
Electric power consumption (kWh per capita)	10,059	7,035	310
Access to electricity (% of population)	100	100	75.92
Access to electricity, rural (% of rural population)	100	100	68.85
Access to electricity, urban (% of urban population)	100	100	94.01

II. METHODOLOGY

A. Country profile and Study

In this study, two countries are selected according to geographical location and development. As Developed countries their profile and status of electricity generation mix help to find result of developing country Bangladesh. Table 2 highlights information about the three countries which are indicated the present status of Australia, Germany and Bangladesh. Most of Points of table carry the information of electricity status phenomena over the countries that ease to do comparative study among them.

Bangladesh has topped the list of total population having 162.95m (m=Millions), 2nd to Germany (82.35m) and Australia (24.21m) is the last. As for population growth, it is the highest in Australia having 1.5%, Bangladesh is the second having 1.1% and Germany is the 3rd having 0.8%. Regarding population growth, land area determines the density of population of the country. Bangladesh is 1251.8 persons per sq. km of land area whereas Germany (357.4 person) and Australia (3.2 person) is the least number. Population of the country describes access to electricity and electricity 100% in both rural and urban but Bangladesh could not reach CO₂ emission of country. Australia and Germany access that point because of density of population in the country, rural and urban consumers consume 68.85% and 94.01% respectively.

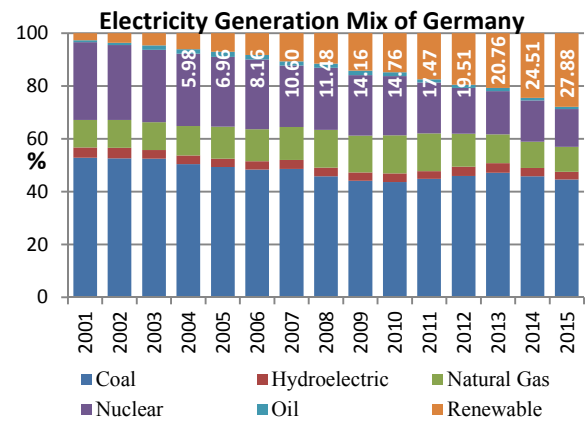


Fig.2. Percentage of Electricity Generation Mix in Germany

Electricity generation mixes of Germany in the period of 2001-2015 are shown in figure 2 where Coal is the largest percentage share of generation sources in the period of 15 years. There are two significant progresses reducing uranium sources and increasing renewable energy sources from electricity generation mix share over last 15 years (2001-2015).

The figure 3 shows percentage of the electricity generation of Australia about previous 15 years from 2001 to 2015. Australia is also highest percent source (80%-60%) using coal to produce electricity over the period. There is trend including natural gas in mix and renewable sources are

placing gradually over coal in last 10 years (2005-2015). There is no nuclear plant over this period significant of electricity generation sources in Australia.

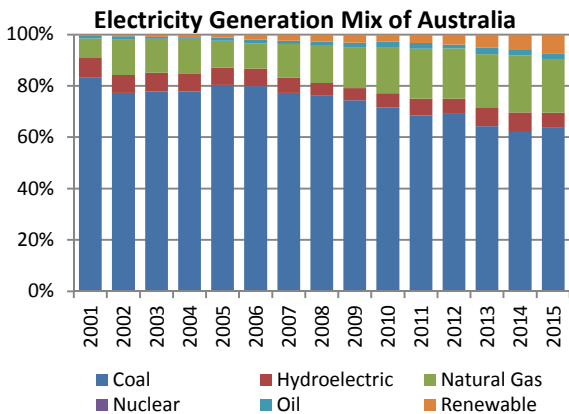


Fig.3. Percentage of Electricity Generation sources in Australia

The figure 3 shows percentage of the electricity generation of Australia about previous 15 years from 2001 to 2015. Australia is also highest percent source (80%-60%) using coal to produce electricity over the period. There is trend including natural gas in mix and renewable sources are placing gradually over coal in last 10 years (2005-2015). There is no nuclear plant over this period significant of electricity generation sources in Australia.

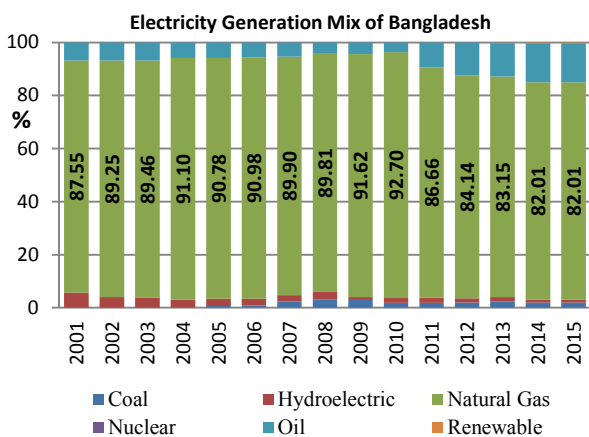


Fig.4. Percentage of Electricity Generation Mix in Bangladesh

Bangladesh fully depends on natural gas which is above 80% of electricity generation mix over the period of 2001 to 2015. Figure 4 shows the oil contribution in generation mix is gradually increasing 2010 to 2015. Coal started to share as electricity generation mix from 2005 and it would be increased more by 2030 [16]. Because of it has characteristic to generate huge amount electricity at a time. Nowadays, nuclear energy source is the most reliable to produce electricity in developed countries for producing burst amount of electricity at a time. But it would be in operation at Rooppur by 2023[17]. Renewable energy sources are the most preferable sources to produce energy. They are abundant and safe. But the figure 4 shows that from the year 2001 to 2015, Bangladesh get this very tiny amount share in electricity generation as sources. So there is lots of opportunity to build renewable energy plant, especially solar energy and bio energy are feasible for Bangladesh.

B. Theory of linear Regression

In statistical, linear regression is a linear approach to modeling the relationship with future value by using existing values and a set of statistical processes for estimating the relationships among variables or data. The known values are existing x-values (independent array or range of data.) and y-values (dependent array or range of data) and the new value is predicted by using linear regression. The equation (1) is for forecasting [18] [19]: \bar{x} and \bar{y} are mean value of x and y.

$$a = \bar{y} - b\bar{x} \dots \dots \dots (1)$$

$$\text{Here } b = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sum(x-\bar{x})^2}$$

C. Data Analysis and Simulation

Data is collected for World Bank data indicator for analysis and Microsoft excel and MATLAB are used for data analysis and evaluate the result. Forecast function is used to get future predictable electricity generation mix share in Bangladesh. There are remarks to simulate the data, these are: if input data is nonnumeric data, output generate error value. If they are empty or contain a different number of data points, function returns the error value.

III. RESULT AND DISCUSSION

A. Comparative Result

In the figures, Comparative studies have been observed between developed (Germany and Australia) and developing country Bangladesh to get forecasting electricity generation mix in Bangladesh. Forecasting is observed considering some factors like environment, global warming, and stability, socio-economic and geographical location.

Electricity generation mix from gas sources in Germany & Australia is pretty low which is between 10-20% for both countries. But Bangladesh share almost 90% of their electricity from gas, which did not come below 80 in past 15 years in figure 5. In figure 6, Electricity production source from coal, Australia is at the top, even though the production source is decreased 80% to 60% and Germany is keeping a constant as a mix around 50% in 2001-2015 and both countries are downwards trends. Whereas Bangladesh produces around 2% electricity from coal and it is upward trend as coal power plant has ability to produce big amount of power. Bangladesh has planned to generate large amount of electricity from coal by 2030. Next Figure 7 shows electricity production from nuclear source where only country exists, Germany which is decreasing their production from 30% to 12% in 2001-2015 time period. Bangladesh has started commission Nuclear power plant by 2024. Following figure 8 is displaying the electricity generation mix from renewable sources, where Germany made great advance from the initial 5% to 30% by 2001-2015. Even though Australia made slight improvement from 8% to 15% in 15 years, Bangladesh is yet to make visible improvement in this sector in spite of there are lots of opportunities on renewable energy in Bangladesh. Eventually, over the time period electricity generation mix changes and near future renewable energy, coal, uranium sources would be added accountable amount in electricity generation mix in Bangladesh.

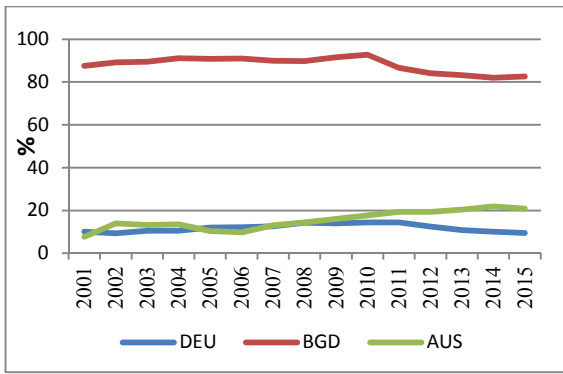


Fig 5. Electricity production from natural gas sources (% of total)

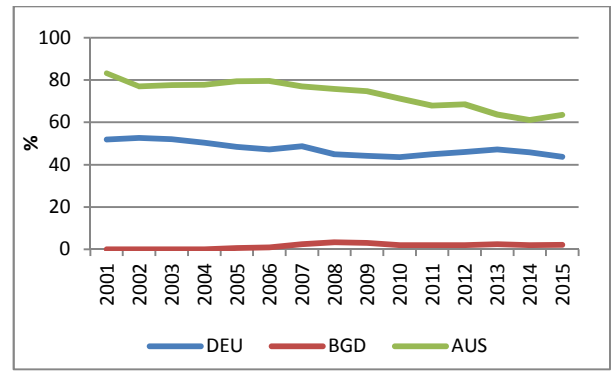


Fig 6. Electricity production from coal sources (% of total)

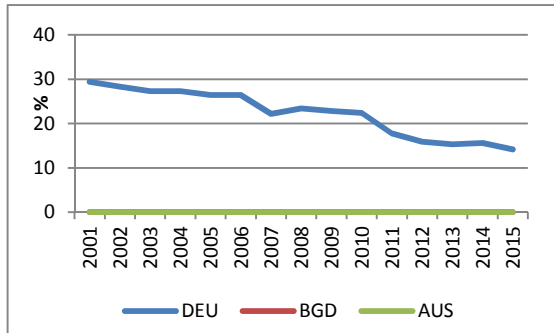


Fig 7. Electricity production from nuclear sources (% of total)

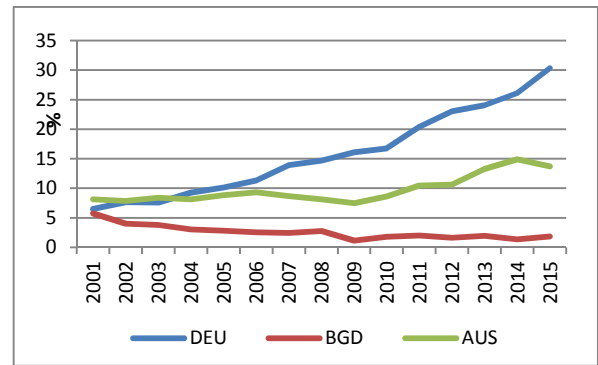


Fig 8. Electricity production from renewable sources (% of total)

B. Simulation Result

The simulation result shows forecasting of electricity generation mix 20016 to 2030 in figure 9. There is significant reduction of natural gas which reaches at 70% from 80% share in electricity generation over the period 2015-2030. Renewable energy share improve to 1.5% in 2030 and same as improvement of coal. So it is the position sign for country to reduce natural gas and improve renewable energy sources, and oil share is also gradually increasing but it should not be. As nuclear source was not in share, simulation function could not predict the future value. But as plan of Bangladesh, nuclear share would be added.

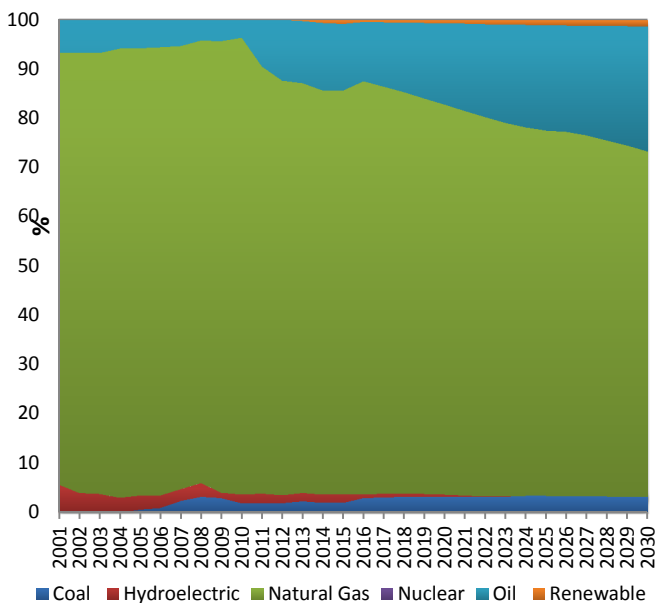


Fig 9. Electricity Generation Mix Forecasting in Bangladesh (2016-2030)

IV. CONCLUSION

In Bangladesh, the population is rapidly increasing and fossil fuel is depleting day by day. The consumption of electricity 310KWh per capita and 76% population get electricity in Bangladesh. Electricity demand is increasing demand day by day. Coal and Uranium will be added as a high percentage in electricity generation mix in Bangladesh. Both sources have the ability to produce a huge amount of electricity to fulfill the demand. Forecasting and comparative result have shown same output and prediction. Renewable sources will be mentionable share in electricity generation sources in Bangladesh according to forecasting result. End of the paper, it is clear that Electricity generation mix build prosper nation considering education environment, global warming, stability, socio-economic and geographical location.

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