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Future Consumption Scenarios of the Power Sector in Bangladesh

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Abstract
Future electricity demand is an essential prerequisite for planning the expansion of a power system. The purpose of this paper is to provide a forecast of electricity consumption in Bangladesh. The forecast is done here for total as well as sector-wise consumption up to 2040 considering the base year 2009. The time series analysis to find the trend line by the method of Least Squares (LS) is applied in this study. We accumulated data from the annual reports of the Bangladesh Power Development Board for the years 2009 to 2023 and used that for forecasting purposes. For convenience and policy purposes, the forecast is presented for every five-year interval. The findings have significant implications with respect to energy conservation and economic development. As the study differentiated sector-wise projected growth of electricity consumption in Bangladesh, it has implications for the planners related to the electricity distribution system. The findings can create awareness among the planners of power system expansion in Bangladesh to meet the continuous future development demand.

Keywords: Electricity Consumption, Time Series, Least Squares Method, Linear Trend Line, Forecast, Bangladesh.

1. Introduction

Electricity, one of the most common forms of energy, has become a fundamental need of human civilization these days. The effect of electricity consumption is evident when we look at our current socio-economic structure. From agriculture to heavy industries, everything is dependent on electricity. For countries like Bangladesh, the influence of per capita energy consumption on GDP is also evidenced (Islam & Mithen, 2024). The forecast of electricity consumption has become a crucial need in estimating energy usage which become an important issue due to the consideration of many aspects such as the depletion of fuel, environmental impact, and carbon dioxide emission for an economy. Moreover, electricity forecasting also plays a vital role in decision-making and future planning for the expansion of the power sector.

In Bangladesh, the electricity consumption has increased to 79270 Gigawatt hours (GWh) in 2023 from 23937 GWh in 2009. Progress in the field of electricity generation was also made (GoB, no date). However, there are still shortages of supply of electricity in the economy (Islam et al., 2021). For the future planning of the required production of electricity, we need a forecast scenario of future demand. The objective of this study is to forecast the total as well as the sectoral electricity consumption of Bangladesh. Regarding the sectoral categorization, the four main sectors agricultural, commercial,

industrial, and residential are taken into consideration. The subsequent sections of this study are organized as follows: In Section 2, previous literature and the approaches used in the earlier forecast of electricity consumption are reviewed, and Section 3 presents a brief overview of the data and methodology. Section 4 describes the results of this research as well as discussion. Section 5 concludes this paper with a conclusion.

2. Review of the Literature

In the literature, several dimensions of research are found related to electricity consumption forecast. However, for the convenience of discussion, we categorized them into two distinct sub-groups, studies related to countries other than Bangladesh and studies related to Bangladesh. Then in the last paragraph of this section justification or the gaps in the literature are discussed.

2.1 Studies on Countries other than Bangladesh

Several studies attempted to forecast the electricity required for a particular country and for different periods. For example, Ezennaya et al. (2014) forecasted Nigeria's for the period of 2013-2030, Gebremeskel et al. (2021) for Ethiopia for the period of 2018-2050, Mirjat et al. (2018) and Raza et al. (2022) for Pakistan for the period of 2015-2050 and 2019-2030 respectively. Even Lee et al. (2018) have tried to forecast electricity consumption for a University in Malaysia so that future development can be determined. Most of these studies employed the Long-rang Energy Alternative Planning System (LEAP) for their forecast (Raza et al., 2022; Gebremeskel et al., 2021; Mirjat et al., 2018). The LEAP is a software tool popularly used for analyzing energy policy and climate change mitigation impacts. However, for forecasting energy consumption different scenarios are used here. Raza et al. (2022) incorporated two scenarios for Pakistan and Gebremeskel et al. (2021) evaluated six scenarios representing alternative development pathways for Ethiopia.

Another group of literature is there where the intention is to develop a long-term model for electricity consumption. Some of these researchers used different techniques or models and compared them to have more reliable or accurate models. Ozoh et al. (2014) used the time-series technique (TST), Artificial Neural Network (ANN), and Modified Newton's Method (MNM) for forecasting electricity consumption. This also argued that MNM has more forecasting accuracy than other models used there. Similarly, Campillo et al. (2012) tried to design a model for short and long-term forecasting of electricity consumption in Sweden by combining several methodological approaches like econometric and behavioral consumption patterns. In this respect, Jain et al. (2018) and Mahia et al. (2019) claimed that the autoregressive integrated moving average (ARIMA) model has the potential to compete with existing techniques for electricity consumption forecasting.

Again, de Assis Cabral et al. (2017) considered a special ARIMA (ARIMASp) model over the ARIMA model and claimed to improve forecasts of electricity demand in Brazil. In other studies, Bianco et al. (2009) and Azadeh et al. (2011) used linear regression models to estimate the electricity consumption in Italy and Iran respectively to develop a long-term consumption forecast model. Similarly, Ezennaya et al. (2014) conducted research to forecast Nigeria's electricity demand through electricity consumption employing trend line analysis using the least squares (LS) technique.

2.2 Studies on Bangladesh

Several studies have also been found that are related to forecasting electricity consumption for Bangladesh. Considering different time series forecasting models, Ali et al. (2021) claimed that the ARIMA model is the best for forecasting per capita electricity consumption for Bangladesh. For this purpose, this research analyzed actual historical data on the artificial intelligence (AI) based program MINITAB 17. This research forecasted per capita electricity consumption as 1887.24 kWh for the year 2040. A bit earlier a similar type of research using a similar methodology, Islam (2010) forecasted 102017 GWh electricity consumption for the year 2020. However, now we found that the actual consumption was 63364 GWh for the year 2020 implying that the forecast was much more overestimated than the actual one.

Mondal et al. (2010) conducted another study using the LEAP model for forecasting sector-wise electricity demand up to the year 2035. However, for this forecast, this research used three scenarios, namely low GDP growth, average GDP growth, and high GDP growth path. The total electricity consumption in the average GDP growth scenario is projected here to be 131.58 TWh (equivalent to 131580 GWh) by 2035. Apart from this, in another study, Islam et al. (2013) used two distinct methods to predict the electricity demand for an isolated island in Bangladesh where historical data on electrical load demand is not available. The forecasting was calculated through inverse matrix calculation and linear regression analysis. The results indicated that the demand data derived from the two approaches was consistent.

Overall, from the above discussion, it is found that for Bangladesh electricity consumption forecast is very limited. Whatever is there, some of them already proved useless because of inaccurate predictions. Moreover, more research is required to have a firm pathway of projected electricity consumption for future planning. If our research findings are similar to some other previous forecasts for the same years then it will reconfirm the projected pathways of demand for electricity need for the future.

3. Data and Methodology

This research employs data on electricity consumption in Bangladesh from 2009 to 2023. All the data were extracted from various annual reports of the Bangladesh Power Development Board for the year 2010 to 2023 (BPDA, 2010-2023). Annual values of electricity consumption categorized in terms of usage (agricultural, commercial, industrial, residential, and others) were extracted in accordance with the objectives of this research. Among these, the *others* were constructed by adding all categories except agriculture, commercial, industrial, and residential sectors. In *other* sectors, construction, electric vehicle charging, street lighting, education, religion, hospitals, and so on are included.

We know that electricity consumption is rising fast because of the increase in population, continuous pressure for better living standards, emphasis on industrialization, and many more factors in sustaining positive economic growth. Therefore, sufficient, necessary, and reliable data on several related variables are essential for a sound forecast. The common difficulties for developing countries like Bangladesh are the availability of necessary and reliable data. If the information level is insufficient, forecasting will be poor or useless even model used is very complex. That is why the simple analysis of time series is used here. The compiled historical data on electricity consumption are reported in Table 1.

Table 1: Sector-Wise Electricity Consumption (in GWh) in Bangladesh

Year	Agricultural Sector	Commercial Sector	Industrial Sector	Residential Sector	Others
2009	1147 (4.8%)	2114 (8.8%)	8815 (36.8%)	11447 (47.8%)	414 (1.7%)
2010	1228 (4.9%)	2337 (9.5%)	9002 (36.6%)	11625 (47.2%)	430 (1.7%)
2011	1268 (4.8%)	2573 (9.7%)	7713 (29.0%)	12755 (48.0%)	2269 (8.5%)
2012	1461 (5.4%)	2718 (10.0%)	8185 (30.1%)	14328 (52.8%)	452 (1.7%)
2013	1505 (4.8%)	3077 (9.8%)	10697 (34.2%)	15558 (49.7%)	448 (1.4%)
2014	1732 (4.8%)	3312 (9.1%)	12269 (33.9%)	18454 (50.9%)	466 (1.3%)
2015	1636 (4.1%)	3685 (9.3%)	13306 (33.6%)	20470 (51.7%)	527 (1.3%)
2016	1635 (3.6%)	4231 (9.3%)	15528 (34.3%)	23053 (50.9%)	852 (1.9%)
2017	1553 (3.1%)	4660 (9.2%)	17819 (35.4%)	25223 (50.2%)	1010 (2.0%)
2018	1433 (2.6%)	5064 (9.2%)	18415 (33.4%)	29012 (52.7%)	1179 (2.1%)
2019	1611 (2.6%)	5701 (9.2%)	20733 (33.4%)	32662 (52.6%)	1330 (2.1%)
2020	1533 (2.4%)	6457 (10.2%)	17476 (27.6%)	36130 (57.0%)	1768 (2.8%)
2021	1737 (2.4%)	7562 (10.6%)	20298 (28.4%)	40324 (56.4%)	1550 (2.2%)
2022	1672 (2.2%)	8327 (10.9%)	21588 (28.1%)	42972 (56.0%)	2108 (2.8%)
2023	2093 (2.6%)	8791 (11.0%)	21903 (27.6%)	44146 (55.7%)	2337 (3.0%)

Note: GWh = Gigawatt hours; the percentage is shown in parentheses. Source: Compiled from BPDB annual reports data (BPDB, no date).

The electricity cannot be stored in an economically viable way, so there must be a constant equilibrium between supply and demand. Thus, the ability to make a good forecast is arguably one of the major challenges here. There are several methods available to estimate the trends as well as for forecasting. The method of curve fitting by the principle of least squares is used to estimate the trends. This method is a very popular and well-received method for fitting mathematical functions to a given set of data. Moreover, it is common that sometimes complex models provide less accurate results, but much simpler is appreciated especially when the forecasting module is just a part of a more complex planning tool, as in the case here.

The widely used and popular method of curve fitting by Least Squares (LS) is used to fit mathematical functions for electricity consumption here. This technique is also used in other fields for forecasting purposes (Hossain et al., 2022). There are various types of curves, like strait line, second-degree parabola, nth degree polynomial, and exponential form, which can be used for representing trends. From the graphical inspection of our data set, we applied a straight line to represent a linear trend for our analysis. The mathematical form is as below:

$$Y_t = a + bT \quad (1)$$

Where, Y_t = the estimated trend value for a given time t, a = the trend line value when T = 0, b = the slope of the trend line. i.e., the change in Y_t per unit time, T = the time limit.

Following the standard procedure for least squares, we get two normal equations:

$$\Sigma Y_t = na + b\Sigma T \quad (2)$$

$$\Sigma TY_t = na + a\Sigma T + b\Sigma T^2 \quad (3)$$

Now by solving equations (2) and (3) we get the formula to estimate parameters a and b as:

$$a = \frac{\Sigma Y}{n} - \frac{b\Sigma T}{n} \quad (4)$$

$$b = \frac{n\Sigma TY - \Sigma T\Sigma Y}{n\Sigma T^2 - (\Sigma T)^2} \quad (5)$$

Then the forecast is done using the estimated equation (1). However, for convenience and policy purposes, the forecast is presented for every five-year interval.

The accuracy of the forecast is measured here by using the Mean Absolute Deviation (MAD) as:

$$MAD = \frac{\Sigma(Actual - Forecast)}{N} \quad (6)$$

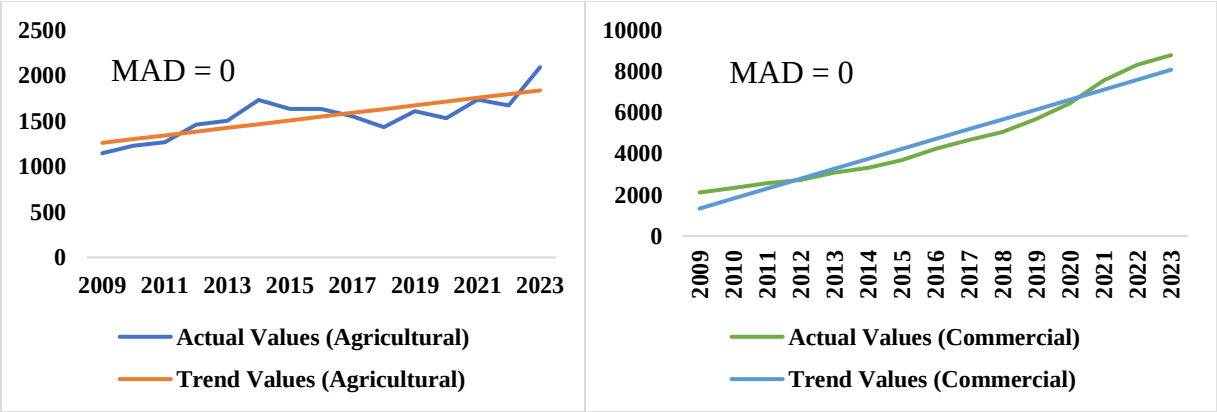
The smaller the value of MAD, the more accurate the forecast is (Spiegel and Stephens, 1999, p. 280).

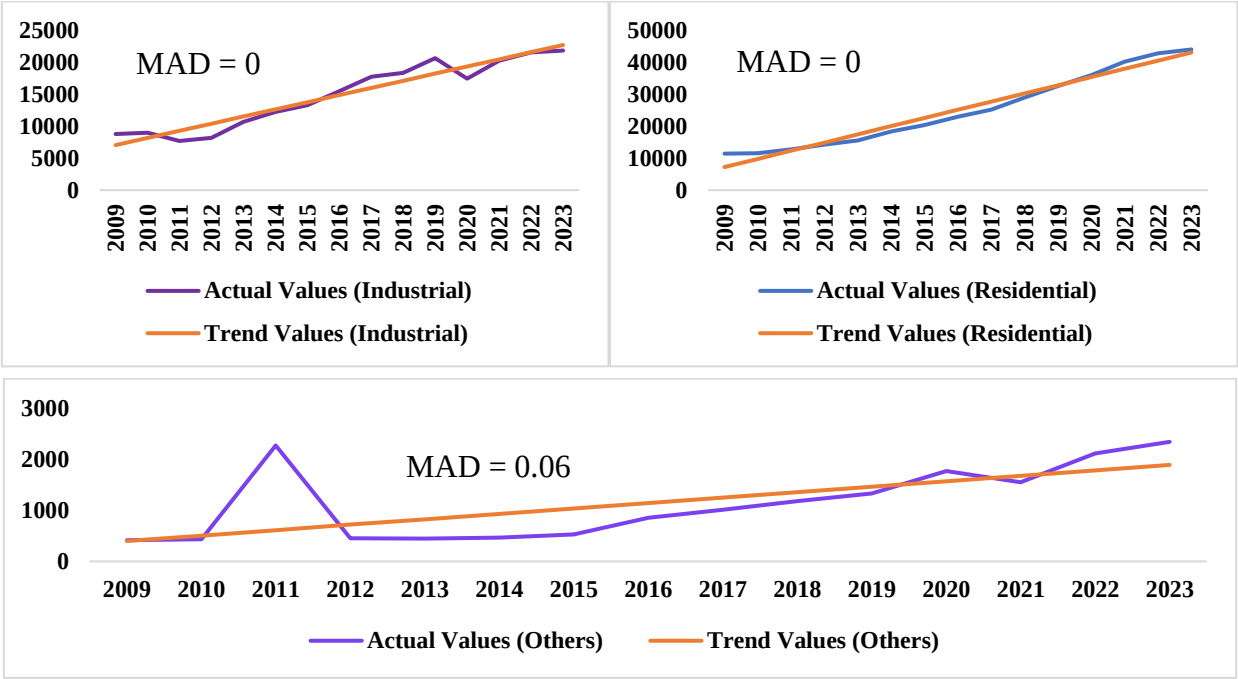
4. Results and Discussion

4.1 Calculation of Trend Line

Table 2 shows the calculations to have the required values for equations (4) and (5) which are needed for our trend line. Using those calculated values the estimated trend lines for each sector are shown in the last column there. These trend lines are used to forecast the electricity consumption for those sectors. However, the trend values for different sectors are calculated using these equations and compared them with the actual values. These comparisons are shown in Figure 1. The MAD values are also quite satisfactory here. It is found that the yearly rate of change in electricity consumption (shown as the slope of the trend line) is different for different sectors (Shown in Table 1). Among all these, the residential sector has the highest share of consumption as well as the highest increase in yearly consumption. This may be because of continuous population growth and more electrical goods used by the growing electrified households in Bangladesh (DataBd, no date). The industrial sector is next which is because of increasing industrial contribution in the GDP (Manik, 2023). Commercial and other sectors are the next two areas to increase annual electricity consumption respectively where the reasons are the same as previous two. The lowest increase would be in the agricultural sector. The energy sources are diesel fuel and electricity for this sector in Bangladesh. The overall consumption is increasing due to continuous switching to electricity from diesel power in this sector (Mondal et al., 2010).

Figure 1: Actual Consumption and Trend Values from Estimated Trend Equations





Note: The figure is the authors' self-construct. MAD refers to the mean absolute deviation calculated from equation (6). Here in the figure, the year is shown on the X-axis, and electricity consumption (in GWh) on the Y-axis.

Table 2: Calculation of Linear Trend Equations for Different Sectors

Year	T	T^2	TY					Trend Equations
			Agri.	Comm.	Ind.	Res.	Oth.	$Y_t = a + bT$
2009	- 7	49	- 8029	- 14798	- 61705	- 80129	- 2898	For Agricultural Sector $Y_t = 1549.6 + 41.27T$
2010	- 6	36	- 7368	- 14022	- 54012	- 69750	- 2580	
2011	- 5	25	- 6340	- 12865	- 38565	- 63775	-11345	For Commercial Sector $Y_t = 4707.27 + 481.89T$
2012	- 4	16	- 5844	- 10872	- 32740	- 57312	- 1808	
2013	- 3	9	- 4515	- 9231	- 32091	- 46674	- 1344	For Industrial Sector $Y_t = 14916.46 + 1121.91T$
2014	- 2	4	- 3464	- 6624	- 24538	- 36908	- 932	
2015	- 1	1	- 1636	- 3685	- 13306	- 20470	- 527	For Residential Sector $Y_t = 25210.60 + 2568.60T$
2016	0	0	0	0	0	0	0	
2017	1	1	1553	4660	17819	25223	1010	For Other Sectors $Y_t = 1142.67 + 106.261T$
2018	2	4	2866	10128	36830	58024	2358	
2019	3	9	4833	17103	62199	97986	3990	For the Overall Country Total $Y_t = 9505.3 + 863.986T$
2020	4	16	6132	25828	69904	144520	7072	
2021	5	25	8685	37810	101490	201620	7750	
2022	6	36	10032	49962	129528	257832	12648	
2023	7	49	14651	61537	153321	309022	16359	
Total	0	280	11556	134931	314134	719209	29753	

Note: Y is the electricity consumption, which is taken from Table 1 for each sector. Agri., Comm., Ind., Res., and Oth. refer to agricultural, commercial, industrial, residential, and other sectors, respectively. Other sectors include construction, electric vehicle charging, street lighting, education, religion, hospitals, and all others. Source: Authors' calculation.

4.2 Electricity Consumption Forecast

The forecasted consumption of electricity for different sectors up to the year 2040 is shown in Table 3. From the year 2025, the forecast is shown in five-year intervals up to the year 2040, a total of 15 years of forecast. For this purpose, the trend equations estimated in the previous section are used (shown in the last column of Table 2). It is seen here that like in the past, electricity consumption in different sectors is expected to rise annually in the future as well. The projected industrial consumption increases from around 25014 GWh in 2025 to around 41842 GWh in 2040 with an average growth of 22.4% in every five years. The growth of commercial, residential, and other sectoral electricity consumption is projected to be 26.6%, 26.6%, and 25.3%, respectively, every five years since 2025. However, it is worth mentioning here that the growth rate of forecasted electricity is decreasing over the years.

Table 3: The Forecasted Electricity Consumption in Different Sectors (in GWh)

Year	Agricultural	Commercial	Industrial	Residential	Others	Total
2025	1921.0 (25.3%)	9044.3 (40.1%)	25013.7 (43.1%)	48328.0 (33.8%)	2099.0 (18.7%)	86406.0 (36.4)
2030	2127.4 (10.7%)	11453.7 (26.6%)	30623.2 (22.4%)	61171.0 (26.6%)	2630.3 (25.3%)	108005.6 (25.0)
2035	2333.7 (9.7%)	13863.2 (21.0%)	36232.8 (18.3%)	74014.0 (21.0%)	3161.6 (20.2%)	129605.3 (20.0)
2040	2540.1 (8.8%)	16272.6 (17.4%)	41842.3 (15.5%)	86857.0 (17.4%)	3692.9 (16.80%)	151204.9 (16.7)
Average in 5 years	206.35 (10.7%)	2409.45 (26.6%)	5609.6 (22.4%)	12843.0 (26.6%)	531.3 (25.3%)	21599.7 (25.0)

Note: GWh = Gigawatt hours. Percentage growth per five years is shown in parentheses. For the year 2025, the growth is shown with respect to the year 2020. The average here is the simple average showing an average increase in five years since 2025. Source: Authors' calculation.

From the forecasted data, it is also seen that the share of residential consumption would be highest among all the sectors here. This could be the reason almost the entire country is connected to the electricity network as well as increasing urbanization and housing in Bangladesh (Parvez & Rana, 2021). Then the other major shares in the total consumption would be industrial, commercial and other sectors respectively. The share of the agricultural sector in the forecasted consumption is the lowest, although increased from 1921 GWh in the year 2025 to around 2540 GWh in the year 2040. The consumption would increase in the agriculture sector due to the use of electric motors instead of diesel engines for the irrigation pumps. Moreover, the installation of additional pumps is going on across the country to achieve self-sufficiency and is also expected to continue due to an increase in water demand for irrigation to tackle the adverse effects of climate change as well (Kirby & Mainuddin, 2022).

On average, our findings revealed that every five years, the consumption for commercial, residential, and other sectors would increase by more than 25 percent. Similarly, in the industrial sector, the consumption would increase by more than 22 percent in every five years. The lowest increase in consumption would be in the agricultural sector, around 11 percent every five years. The total electricity consumption was

57554 GWh in 2020 and is projected to increase 2.63 times to around 151205 GWh by 2040. Overall, the consumption for the whole country would increase around 25 percent in every 5 years.

It is projected here that the total electricity consumption would be around 151205 GWh in the year 2040 with an average increase of around 21600 GWh in every five years since 2020. This is consistent with the forecast done by Mondal et al. (2010). Mondal et al. forecasted 131580 GWh in 2035 with the average GDP growth scenario, and in this research, we forecasted around 129605 GWh for the same year.

For the policy implication, these findings are very significant. This forecast can be used as future electricity demand for policymakers. Electricity generation must meet the demands as forecasted here. Moreover, very simply, for future production, policymakers should target to increase electricity production by 25 percent every five years to meet the demand.

5. Conclusion

Electricity demand forecasting is very important for the planning and development of the power sector. Accurate forecasts can save costs as well as help to make correct decisions for future development. This study presents a forecasting effort for electricity consumption in Bangladesh. A very simple curve fitting by the least squares technique is used here to fit mathematical functions on electricity consumption data from 2009 to 2023. Later this mathematical function is used to forecast future electricity consumption for the next 17 years, up to the year 2040. However, for convenience and policy purposes, the forecast is presented here for every five-year interval. Moreover, the forecast is also done on different important sectors like agriculture, commercial, industrial, service, and the rest. The findings imply that electricity demand in different sectors will continue to rise. It is recommended that the government should prioritize the generation, distribution, and management of electricity in its policies to meet the future demand for electricity. To meet the future needs of the economy, concerned authorities could plan in accordance with this forecast here. Overall, for continuous and unhampered social and economic development, the government should work towards the supply of electricity which is about 25% more of the present consumption targeting every five years in the future.

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