Abstract: The aim of this paper is to study the trend and pattern of electricity consumption in Assam in order to investigate the share of various sectors in the total electricity consumption and to study the growth rate with the help of various growth curves viz. Linear, Quadratic, Logarithmic, Cubic, Exponential and Inverse considering the time period 1980-2016. The distinction of demand and supply of electricity along with the differences of T&D Losses in comparison to the national averages are also discussed to get a clear picture of electricity consumption in Assam. Although all the sectors showed an upward trend of electricity consumption but the Domestic sector accounted the highest share while the contribution of Agriculture sector was very negligible in comparison to the sectors like Commercial and Industry. Again, in order to find the growth model of best fit for electricity consumption, the models are compared in terms of adjusted \( R^2 \), the Absolute Mean Error (AME), the Root Mean Square Error (RMSE) and the Mean Absolute Percentage Error (MAPE) and found the best fitted model through Cubic equation. Considering the importance of forecasting electricity consumption both for policy makers and related organization in order to meet the ever increasing demand, forecasting of electricity consumption in Assam has also been done with the help of the best fitted model for the next ten years.

Key words: Trend, Pattern, Electricity, Forecasting, Transmission and distribution (T&D).

Cite this article

1. Introduction

For the inclusive economic growth and development of a country, the role of electricity is very crucial. For sustainable economic development of a region, power is the basic infrastructure and that is why per capita electricity consumption is considered as an important index of standard of living of the region. Recognizing the importance of electricity for sustainable economic development, various initiatives have been taken by each and every country of the world to increase power generation and to provide reliable and quality power for all. India has now become the world’s third largest producer and second largest consumer of electricity. The government of India has made remarkable achievements in the generation of thermal, hydel and in particularly in solar, wind and other green energy besides improving in transmission and distribution losses, separation of feeder and metering of power to consumers to meet the increasing demand in various sectors viz. residential, commercial, industrial, transport, service, agriculture etc. of economy.

Assam, located in the North-Eastern region of India though has immense potential of power ranging from hydel to natural gas including oil and coal resources yet the progress of power sector in Assam is not satisfactory in comparison to its possibilities. But like the worldwide scenario, the demand for electricity in Assam shows an increasing trend. As per reports of 2011 census, the household electrification rate in Assam is very poor which was only 37% against the national average of 67.2%. There are various factors responsible for this poor level of electricity access in Assam like recurring floods, large sections of the households being located in hilly districts etc. The problem of Transmission and Distribution Losses of electricity in Assam is also high in comparison to the
In spite of all these problems, the Government of Assam has taken various innovative steps to improve the power supply scenario in order to attain Sustainable Development Goal [7] which ensure access to affordable, reliable, sustainable and modern energy for all by 2030. A better understanding of electricity consumption pattern and the factors affecting it is essential for designing effective and credible energy efficiency programs, optimize planning of capacity addition and the better adaptation to the rapidly changing business models and technologies in the power sector. Through this paper attempt is made

• To study the trend and pattern of sector wise consumption of electricity in Assam.

• To study the discrepancies between demand and supply of electricity in Assam along with the difference of Transmission and Distribution Losses of electricity with respect to national average.

• To study the growth rate of electricity consumption in Assam with the help of various growth curves viz. Linear, Quadratic, Logarithmic, Cubic, Exponential and Inverse considering the time period 1980-2016.

• To find the growth model of best fit for electricity consumption in Assam by comparing the predictive performances viz. adjusted $R^2$, the Absolute Mean Error (AME), the Root Mean Square Error (RMSE) and the Mean Absolute Percentage Error (MAPE) of the considered models.

• Forecasting of electricity consumption in Assam with the help of the best fitted model for the next 10 years.

Research works on the electricity sector is limited in Assam and mainly restricted to the short term forecasting only. Mahanta and Talukdar (2021) made a long term forecasting of electricity consumption in Assam by using Multiple Linear Regression and Autoregressive Integrated Moving Average (ARIMA) models and found the efficiency of ARIMA better than Multiple Linear Regression for Assam. Therefore, through this paper, the same author would like to focus on the above mentioned objectives so that the findings would help the Government as well as for other policy makers for implementation of proper policy by studying the trend, pattern and future projection of electricity consumption in Assam by using different forecasting techniques.

2. Literature Review

There are large number of literature available for studying the trend, pattern and forecasting of electricity consumption for different countries with different methodology.

Kumbhar and Kadam (2018) in his study on changing scenario of electricity generation and consumption pattern in Maharashtra found the more rapid growth in the consumption of Agricultural sector than Industrial and Domestic sector. Similar attempt was made by Rajkumari and Gayithri (2017) to study the trend and pattern of electricity consumption in Karnataka and here also the share of agricultural category was higher than Industries and Commercial category. Sahu (2008) while studying the trend and pattern of energy consumption for whole India with the help of trend analysis and regression techniques, obtained positive relationship between Total Primary Energy Consumption to Gross Domestic Product (GDP), Population and Per Capita Energy consumption.

Mohamed and Bodger (2005) and Bianco et al. (2009) used multiple linear regression models for forecasting electricity consumption by identifying the effects of economic and demographic variables. Again Li and Li (2017) used the ARIMA model, Grey Model (GM) and the combination of ARIMA and GM to compare the forecasting of energy consumption in Shandong, China and obtained the best result by the combination of GM-ARIMA model. Artificial Neural Network was extensively used by Adhiswara et al. (2019), Widodo (2016), Paul (1998) etc. for forecasting electricity consumption of various countries. Patel and Patel (2020) and Singh and Singh (2020) made use of stochastic process and linear regression model to forecast the daily heat temperature pattern of Ahmedabad and potato yield from farmers’ fields in Manipur respectively. Again Özcu et al. (2012) made comparison of Neural Networks and Support Vector Regression for forecasting electricity consumption in Turkey while Saravanan et al. (2012) used Regression Analysis, Artificial Neural Networks (ANNs), combining Regression Analysis with Principal Components (PC) and combining ANNs with PC to forecast future projection of electricity demand in India.

Various types of growth curves are used for
studying the growth rate and forecasting of electricity consumption in various countries by the researchers. Mohamed (2004) made comparison of three growth models viz. Logistic, Harvey Logistic and Harvey along with Multiple Linear Regression, Variable Asymptote Logistic (VAL) and Autoregressive Integrated Moving Average (ARIMA) for forecasting electricity consumption in New Zealand and found the best fitted model by Harvey both for Domestic and Total electricity consumption while Harvey Logistic was the best for Non-domestic electricity consumption. Again to study the growth rate of electricity consumption in Greece, Skiadas et al. (1997) used a stochastic Bass innovation Diffusion model while Gutierrez et al. (2006) tried to forecast the electricity consumption in Morocco with the help of the time-Homogeneous Gompertz Diffusion Process (HGDP) and the time-Non-homogeneous Gompertz Diffusion Process (NHGDP) and found the better result with the second model considering the macroeconomic exogenous factors - the gross domestic product per inhabitant, the final domestic consumption and the gross fixed capital formation. To forecast the electricity consumption in New Zealand, Bodger and Tay (1987) made comparison of Logistic and Energy Substitution Models.

By extensive review of literature, it is found that to study the growth rate of electricity consumption throughout the world; various complex growth curve techniques were used. But we would like to study the growth rate of electricity consumption in Assam with the help of some time-dependent growth curves model. To our knowledge, study on the trend and pattern of electricity consumption in Assam has not been done so far. Therefore, an attempt is made to fill this gap in literature with the help of this paper.

3. Data and Methodology

Data on total electricity consumption as well as
consumption of various sectors like Domestic, Commercial, industrial, Agricultural etc. for the period 1980-2016 are collected from Economic Survey, Assam and Statistical Hand Book Assam published by Directorate of Economics and Statistics, Assam (Source: Commercial Wing of Assam State Electricity Board). Again Data on Power Requirement and Availability and Electricity Transmission and Distribution Losses are obtained from the publications of Reserve Bank of India (Source: Central Electricity Authority, Ministry of Power, Government of India).

3.1 Definition of growth curves

The growth models are used to study the behaviour of some variables, as they vary with respect to time. A growth curve is a graphical representation of how a particular quantity increases over time. To determine the type of growth pattern of the quantity whether it is linear, quadratic, cubic, exponential etc. these curves are used in variety of application from population biology and ecology to finance and economics [Bodger and Tay (1987)]. Paul (1998) mentioned the various advantages of time dependent growth model over the multivariate forecasting techniques like quick and inexpensive application for producing better forecasting model and these models may not require extraneous information. Here to investigate the nature of growth of total electricity consumption in Assam, six types of time-dependent models fitted with the help of SPSS are as follows:

1. Linear : \[ Y_t = b_0 + b_1 t + e_t \]
2. Quadratic : \[ Y_t = b_0 + b_1 t + b_2 t^2 + e_t \]
3. Logarithmic: \[ Y_t = b_0 + b_1 \ln t + e_t \]

4. Cubic: \[ Y_t = b_0 + b_1 t + b_2 t^2 + b_3 t^3 + e_t \]

5. Exponential: \[ Y_t = b_0 \exp(b_1 t) e_t \]

6. Inverse: \[ Y_t = b_0 + b_1 / t + e_t \]

where, \( Y_t \) represents the total electricity consumption in Assam in Million Unit (M.U) and \( e_t \) is the error term assumed to be distributed as normal with mean zero and constant variance. In order to select the best model for forecasting electricity consumption in Assam, the considered models are compared in terms of the following criteria:

1. Adjusted \( R^2 \):
\[
Adjusted \ R^2 = 1 - \left[ \left( 1 - R^2 \right) \times \frac{N - 1}{N - K - 1} \right]
\]

where, \( N \) is the number of observations used in model and \( k \) is the number of independent regressors, i.e. the number of variables in the model, excluding the constant.

2. Absolute Mean Error (AME)
\[
AME = \frac{1}{N} \sum |Y_{t\ observed} - Y_{t\ predicted}| / N
\]

3. Root Mean Square Error (RMSE)
\[
RMSE = \sqrt{\frac{1}{N} \sum (Y_{t\ observed} - Y_{t\ predicted})^2} / N
\]

4. Mean Absolute Percentage Error (MAPE)
\[
MAPE = \frac{1}{N} \sum \left| \frac{Y_{t\ observed} - Y_{t\ predicted}}{Y_{t\ observed}} \right| \times 100
\]

The greater value of Adjusted \( R^2 \) and the minimum values of the last three criteria are desirable for the adequacy of a model.

3.2 Hypothesis

Taking into consideration the objectives of this study, the hypothesis to be examined is framed as:

There are no significant differences in the efficiency of different growth models under consideration in regards of forecasting of electricity consumption in Assam.

4. Statistical Analysis of the Electricity Consumption Scenario in Assam

4.1 Trend and pattern of electricity consumption in Assam

The total amount of consumption of electricity in Assam has increased from 638 M.U to 6526 M.U from the year 1980-81 to 2016-17. The Assam State Electricity Board (ASEB), established in 1958 under Electricity (Supply) Act 1948, has been taking prime responsibility of integrated power development of the state. Through the Indian Electricity Act 2003 and as a part of Assam Power Sector Development program, Government of Assam unbundled the Assam State Electricity Board in the year 2004 into three Government Companies viz.

1. The Assam Power Generation Corporation Limited (APGCL)
2. The Assam Electricity Grid Corporation Limited (AEGCL)
3. The Assam Power Distribution Company Limited (APDCL)

The APGCL and AEGCL are constituted to take the responsibility of generation and transmission respectively while the APDCL controls the responsibility of distribution of power. The various types of consumers of electricity in Assam are classified as Low Tension (LT) and High Tension (HT) category. Under LT category, the following types of consumers are included

- Domestic
- Commercial
- General Purpose
- Public Lighting
- Agriculture
- Small Industries Rural
- Small Industries Urban
- Temporary Supply (Domestic/Non-Domestic)

Similarly, under HT category, we have as follows:

- Domestic
- Commercial
- Public Water Works
- Bulk (Govt. Education)
- Bulk Supply (others)
- HT-Small Industries
- HT-I Industries
- HT-II Industries
- Tea, Coffee and Rubber
- Oil and Coal
- HT Irrigation

By observing the amount of consumption of electricity of various types of consumers of the two above mentioned categories, the following sectors are made for convenience of our study.

1. Domestic
2. Commercial
3. Agriculture
4. Industry
5. Tea, Coffee and Rubber
6. Others (smaller types like general purpose, public lighting, temporary supply, public water works etc. are included in this sector.)

The electricity consumption of the various sectors mentioned above is shown with the help of the Fig. 1.

When we consider about the pattern of consumption of various sectors, it is clear from Fig. 1 that the domestic sector accounts the higher share than the other sector and the share of agricultural sector is very negligible. There is a continuous rise in domestic sector from 1997 and the rate is very high in comparison to the other sectors. In case of Industrial sector, it is seen that up to the year 1998, Industrial sector consumed the highest portion of electricity but there was a sharp fall in the year 1999 and after that period it showed a slow upward trend. The commercial and Tea, Coffee and Rubber sectors, two important parts of Assam’s economy also showed an overall increasing rate. Similar trend is also noticed in case of sector others followed by infrastructural development. But the most surprising fact is that the economy of Assam is mainly based on agriculture. But due to excessive dependence on orthodox method of cultivation, Assam is far behind the use of modern agricultural technology in comparison to the other developed states of the country and the least amount of consumption of electricity by this sector depicts the pathetic situation clearly.

4.2 Power supply (Availability) and demand (Requirement) position in Assam

The availability (M.U) and requirement (M.U) status of electricity have been shown with the help of the Fig. 2.

The above Fig. 2 shows the distinction between the demand and supply of electricity in Assam. Although there has been an increasing trend in both the demand and supply of electricity, yet there is always a gap between these two factors. The power distribution company is compelled to purchase electricity from other sources and agencies in order to fill this gap between

<table>
<thead>
<tr>
<th>Model</th>
<th>Adj $R^2$</th>
<th>AME</th>
<th>RMSE</th>
<th>MAPE</th>
</tr>
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<tbody>
<tr>
<td>Linear</td>
<td>0.721</td>
<td>589.730</td>
<td>758.748</td>
<td>29.543</td>
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<tr>
<td>Quadratic</td>
<td>0.892</td>
<td>412.486</td>
<td>465.935</td>
<td>23.274</td>
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<tr>
<td>Logarithmic</td>
<td>0.455</td>
<td>806.523</td>
<td>1061.020</td>
<td>40.497</td>
</tr>
<tr>
<td>Cubic</td>
<td>0.989</td>
<td>117.198</td>
<td>148.210</td>
<td>7.342</td>
</tr>
<tr>
<td>Exponential</td>
<td>0.888</td>
<td>387.063</td>
<td>580.172</td>
<td>15.476</td>
</tr>
<tr>
<td>Inverse</td>
<td>0.151</td>
<td>1020.848</td>
<td>1324.772</td>
<td>50.908</td>
</tr>
</tbody>
</table>

Table 1: Values of diagnostic criteria for selecting growth model for total electricity consumption in Assam.
demand and supply.

4.3 Transmission and distribution (T&D) losses of electricity in Assam

When supplying power to various categories of consumers, it passes through various stages from transformation of higher voltage level to final distribution in the premises of the various consumers and the losses related to this process is called Transmission and Distribution losses. Though Indian Electricity sector experienced considerable achievement in recent years, yet India’s T&D losses are almost 20% of its generation which is more than twice of the world average. The status of T&D losses of electricity is more unpleasant in case of Assam than the overall Indian scenario.

Fig. 3 shows the difference of T&D Losses of electricity in percentages between Assam and India. Though the situation is improving yet the T&D Losses of Assam is always higher than the national average and it becomes an area of concern for such a power deficit states like Assam.

4.4 The growth of electricity consumption in Assam

The total electricity consumption in Assam from 1980 to 2016 is shown in Fig. 4 and it is clear from the figure that except for the year 1999, there is almost an increasing trend in consumption of electricity though there are some ups and downs during some intermediate years.

By observing the values of Adj $R^2$, AME, RMSE and MAPE for our considered growth models, it is clear that Adj $R^2$ is considerably higher in case of the cubic model whereas AME, RMSE and MAPE are significantly less here as compared to the other growth models. Considering this and also from Fig. 5, we may infer that the best fitted model for total electricity consumption in Assam is the cubic model followed by quadratic and exponential.

Therefore, the estimated growth type of model selected for electricity consumption in Assam is as follows:

$$Y_i = 136.949 + 300.439t - 20.559t^2 + 0.464t^3$$

4.5 Forecasting of electricity consumption in Assam

Since from the analysis of our study it is found that the cubic growth model is the best fitted for the total electricity consumption in Assam, therefore, forecasting of electricity consumption for the next ten years i.e. from 2017 to 2026 has been done with the cubic model.

5. Policy Implication

Since the economy of Assam is mainly based on Agriculture, the lowest contribution of the agricultural sector to the total electricity consumption is actually a matter of concern for the economic growth in Assam. The recent Comptroller and Auditor General (CAG) of India report reveals that only 23.2% of the surveyed beneficiary farmers in Assam received irrigation water in the dry season. It is found from the literature also that in the developed states in India, agriculture sector accounted a higher share in the total electricity consumption. Government of Assam should take proper initiatives for the development of Agricultural sector in Assam by the application of advanced irrigation and farming system like Resource conservation technologies (RCTs) [Singh and Singh (2020)] and providing necessary subsidies to assist the farmers in Assam which would ultimately boost the economy of Assam also to greater extent. To measure the technical efficiency, Dagar et al. (2020) made extensive studies in their research works by using Stochastic frontier analysis, taking evidence from skilled and unskilled agricultural labour in India, from North India and from Haryana respectively. Dagar et al. (2020) and Dagar et al. (2021) also studied the variations in technical efficiency of farmers with distinct land size across agro-climatic zones and Covid-19 risk management and technical efficiency of farmers post migration of agricultural labour in India. Again in case of studying the changing pattern of consumptions of electricity over time and across different sectors, successive surveys

<table>
<thead>
<tr>
<th>Year</th>
<th>Forecasted Figures</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>7317.82</td>
</tr>
<tr>
<td>2018</td>
<td>8097.87</td>
</tr>
<tr>
<td>2019</td>
<td>8945.35</td>
</tr>
<tr>
<td>2020</td>
<td>9863.03</td>
</tr>
<tr>
<td>2021</td>
<td>10853.69</td>
</tr>
<tr>
<td>2022</td>
<td>11920.12</td>
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<tr>
<td>2023</td>
<td>13065.10</td>
</tr>
<tr>
<td>2024</td>
<td>14291.41</td>
</tr>
<tr>
<td>2025</td>
<td>15601.84</td>
</tr>
<tr>
<td>2026</td>
<td>16999.17</td>
</tr>
</tbody>
</table>
can be conducted for better results [Trivedi et al. (2020)]. Also to reduce the gap between demand and supply of electricity, attention must be given to the maximum exploitation of Renewable Energy sources for generating electricity due to its eco-friendly nature. One of the significant reasons behind the substantial energy and peak demand deficits in Assam is the high T&D losses and therefore the Central Government and the Asian Infrastructure Investment Bank (AIIB) signed a loan agreement for Assam Intra-State Transmission System Enhancement project for the improvement of electricity transmission system.

6. Conclusion

Here, attempt is made to study the trend and pattern of electricity consumption with the help of various growth curves and the differences of demand and supply as well as the transmission and distribution losses of electricity in Assam is also discussed. In case of consumption of electricity by various sectors, it is found that the share of domestic sector is the highest and the agricultural sector consumed the least. Rapid growth in household electrification rates, the increasing disposable income which lead to the usage of more electricity enabled appliances, changing lifestyle, rapid urbanization etc. are mainly responsible for the highest share of domestic sector than the other sector. Though the electricity consumed by the Tea, Coffee and Rubber industry showed an increasing trend but the erratic power supply creates a challenge to tea industry which is the single largest industry of the state. Similarly, increasing trend of electricity consumption is also noticed in case of the sector Industry, Commerce and others. But in comparison to these sectors, the electricity consumed by the Agricultural sector is very negligible. Economy of Assam is largely dependent of agricultural sector. But along with natural problem like recurring flood, the irrigation facility in Assam is extremely limited which leads to the excessive dependence on vagaries monsoons. This is the main reason of the least amount of electricity consumption by this important sector of Assam’s economy. Again, by comparing the predictive performances of the models in terms of adjusted $R^2$, AME, RMSE and MAPE, the cubic model is found the best fitted and therefore forecasting of total electricity consumption up to 2026 has been done with this model and the model shows an annual average increasing rate of total electricity consumption as 9.82%. The same authors found the ARIMA model better for forecasting electricity consumption in Assam than Multiple Linear Regression considering the same time period in their previous work. Therefore, in future attempts would be made to compare the pairwise predictive performances of these models. Though the Assam Government has taken various steps like development of large capacity thermal power projects, increase the contribution of Renewable Energy, reduce the transmission and distribution losses etc. to minimize the discrepancies between demand and supply of electricity, yet the problems like high dependence on electricity imports, low private sector investment in generation, recurring floods, large sections of the households being located in hilly districts etc. are creating challenges for supplying uninterrupted electricity to all types of consumers.

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