Aggregate Electricity Consumption Profiles of the North-Eastern Grid States of India

Thangjam Aditya[a]

[a]*Indian Institute of Management Shillong*

1. Introduction

The Indian electricity grid is divided into five regional grids (northern, southern, eastern, western and north eastern) based roughly on their geographical location. The north eastern grid (NEG) comprises Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland and Tripura(NERLDC, n.d.-c). While the north eastern grid is characterized by its low demand, it has been facing relatively higher peak demand shortages (Shukla & Thampy, 2011).

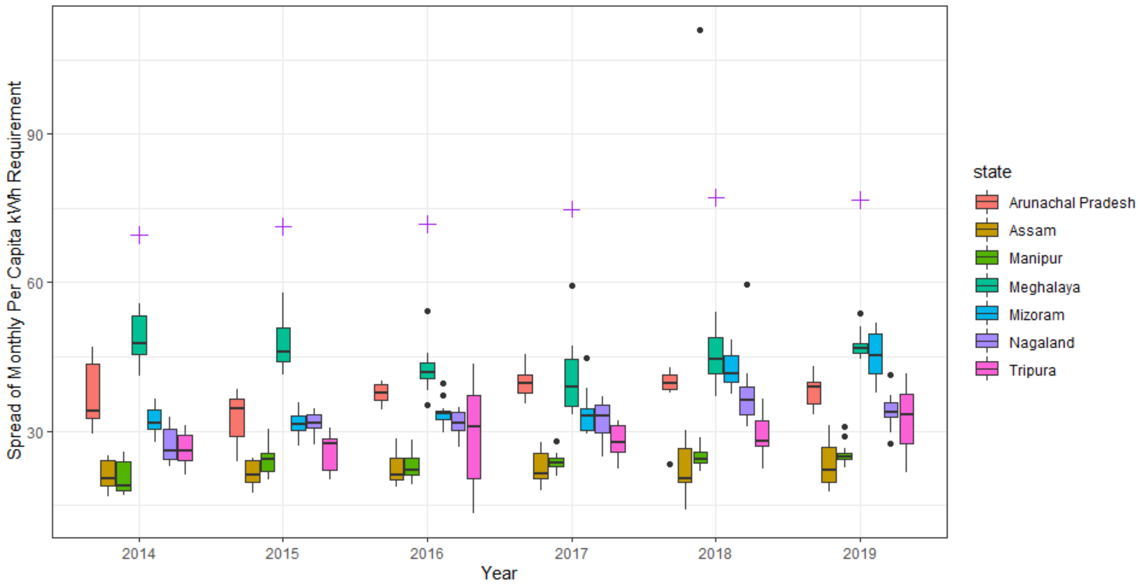

Figure 1 Spread of monthly MkWh consumption in the NEG states (purple plus sign refers to the national average value)

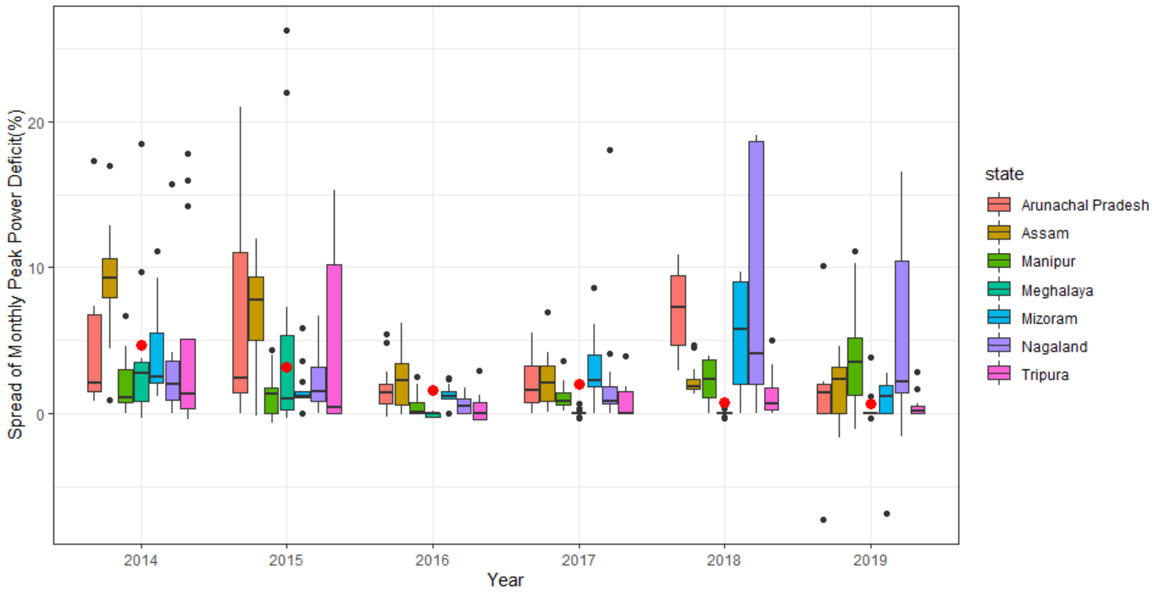

Figure 2 High spread of peak power deficits in the majority of NEG states (red dot refers to the national level deficit)

The low demand is evident from Figure 1 while the poor performance in reducing peak deficit is evident from Figure 2.

The problem with dismissing this issue by attributing the cause to the developmental lag of the NEG states is that no comprehensive understanding of the region-specific factors affecting electricity demand is attainable. This would have serious implications on the competency of the utilities to predict demand. The low demand and high shortages might be interlinked. For instance, low anticipated demand might lead to high unmet demand. A good supporting evidence for this is the high magnitude (in the order of ten when taken in percentage terms) of daily load forecasting errors of the NEG states(NERLDC, n.d.-a). These errors may be minimized by looking into the "demand black-box" which falls outside the scope of forecasting. The main objective of this paper is to contribute towards better understanding of electricity demand characteristics in the NEG states.

The paper largely uses an exploratory approach for understanding seasonality and inter-state patterns in electricity consumption. Based on previous established literature in other regional or larger country contexts, a regression analysis of per capita electricity demand using power availability (Khandker et al., 2014; Sedai et al., 2020), per capita GDP(Sen, 2012; Sen et al., 2018) and HDI(Kanagawa & Nakata, 2008; Sen et al., 2018) is attempted for the NEG states.

The paper is organized as follows- in Section 2, data preparation and limitations are discussed; in Section 3, the methods used for analysing the data are described; in Section 4, the observed patterns in electricity demand of the NEG states are discussed; in Section 5, the cues arising out of the study for a more detailed confirmatory study are summarized.

2. Data

The study uses a combination of four secondary datasets, namely, monthly power supply position (NERLDC, n.d.-b), state HDI (Global Data Lab, n.d.), state real GDP (Indiastat, n.d.), decadal change in Census 2001 and 2011 state population(Office of the Registrar General & Census Commissioner, 2011). The data is panel in nature comprising observations of seven NEG states for the period of six years from 2014-2019. The data used for the analysis has the following limitations-

- The panel is short;
- The 2019 values for state population, HDI, state real GDP are predicted.

In order to ensure that the panel is balanced, the missing values of state population, HDI and state real GDP for 2019 were obtained using exponential triple smoothing of 2001-2018 data. For population, the decadal growth rate from 2001-2011 is assumed to repeat in the following decade. Also, uniform annual growth rate is assumed across years to obtain annual growth rate from the decadal growth rate.

3. Methods

Data visualization was used to understand seasonality and clustering of monthly kWh consumption of states and peak power deficits. The visualization also helped in finding a. appropriate variables for clustering the NEG states and b. linearity of relationships among explanatory variables for regression analysis. In regression analysis, the fixed and time effects were investigated using OLS with state and time as dummy variables. The regression model is given below in Equation (1)-

$$kWh_{per-capita(it)} = \alpha + \sum_{3} \beta_{1kit} X_{it} + \sum_{6} \beta_{2i} S_i + \sum_{5} \beta_{3t} T_t + \varepsilon_{it} \quad (1)$$

Where, i is the index for state; t is the index for year; X refers to per capita GDP, HDI, power availability; S is the set of six state dummy variables with Arunachal Pradesh as the reference; T is the set of five dummy variables for year with 2014 as the reference.

The per capita conversion is required to account for distribution of GDP and demand within the population of states. It also allows for comparability of states along these dimensions. Since panel data on power availability is not available, peak power deficit is taken as a proxy for power availability. Peak power deficit is the peak power demand met as a percentage of the peak power demand requirement.

4. Analysis and Result

The analysis is divided into exploratory analysis and regression analysis. The exploratory analysis is aimed at examining a. seasonality vis-à-vis kWh requirement and power deficit b. clustering of states vis-à-vis regression variables c. linearity of relationship between predicted variables and regressors. The regression analysis looks at the validity of the causal impact of peak power deficit, per capita real GDP and HDI on electricity demand (both met and requirement). The regression is done yearly aggregated values as monthly SGDP and HDI values are not available.

4.1 Exploratory Analysis

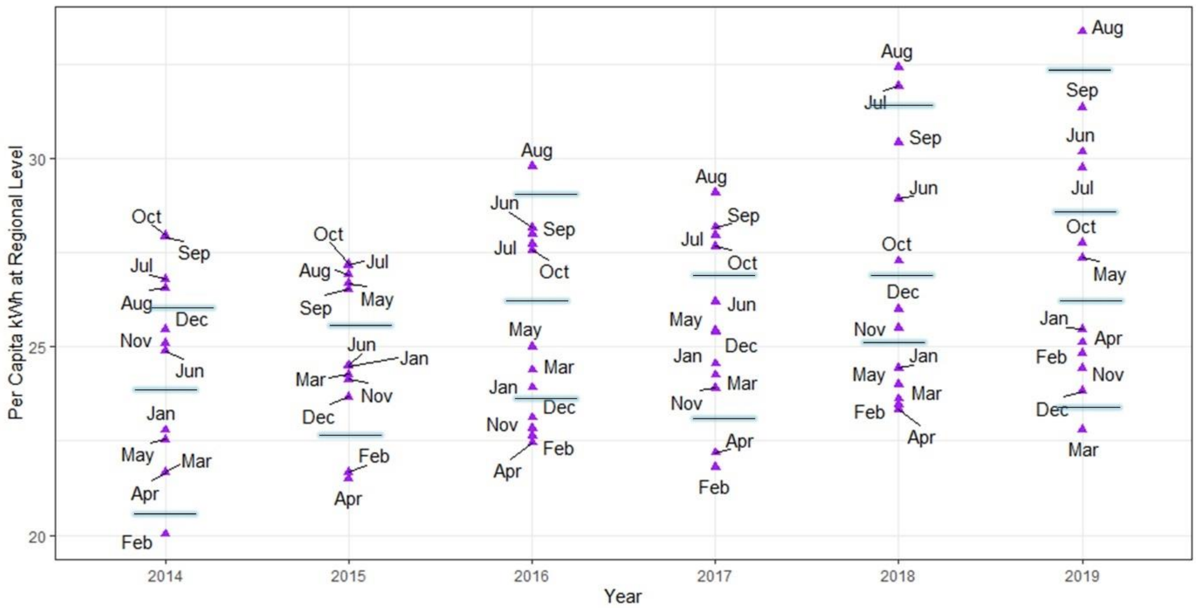

Figure 3 Regional per capita kWh consumption clustered using month.

From Figure 3, it can be seen the per capita kWh requirement can roughly be clustered into four categories in ascending order, given in Table 1.

Table 1 Clusters extracted from month wise plot

Cluster	Months	Characteristics
C1	February, March, April	Pre and mid of summer

C2	November, December, January	Festive, winter
C3	May, June, July	Summer peak and rainy
C4	August, September, October	Festive, pre-winter

C4 is also interesting in terms of per capita kW demand. For the states of Assam, Tripura, Nagaland and Arunachal Pradesh, C4 is around the peak of the curve. But for Mizoram, Manipur and Meghalaya, C4 is around the rising part of the trough.

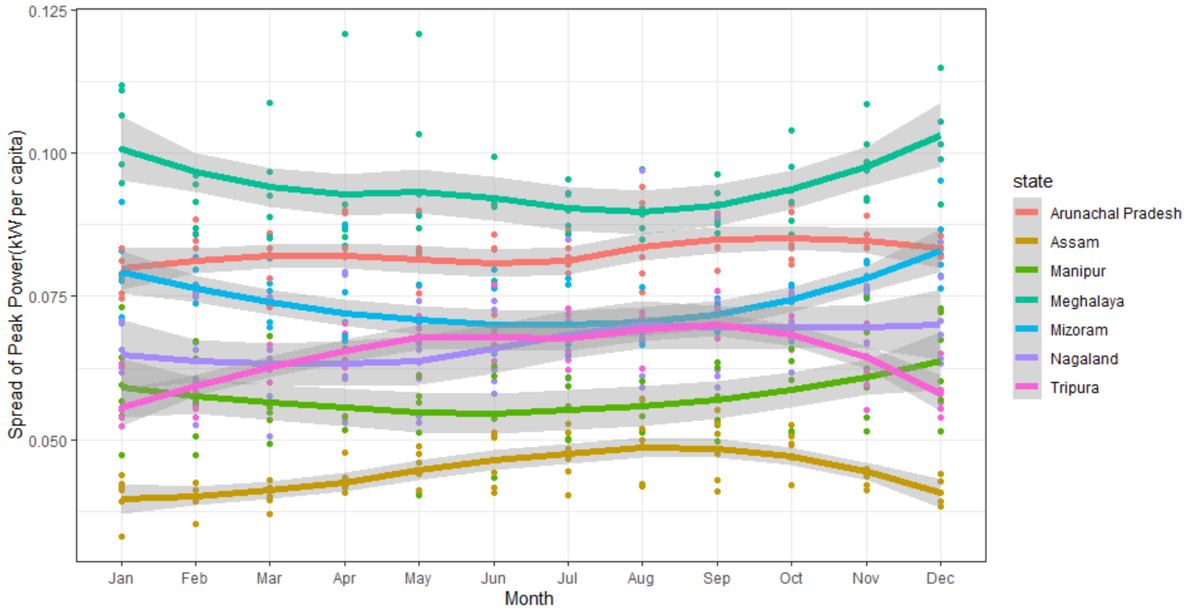

Figure 4 Seasonality in peak power requirement

The dichotomy may be further examined considering urban population share, the differences in occurrences of festivals due to different dominant religions and the presence of industries. As seen in Figure 6, Assam and Tripura have higher ease of doing business score. These states are also dominated by Hindus. Higher business and household activity during the C4 might explain the rise of per capita kW in C4. Mizoram, Manipur and Meghalaya have a significant number of Christians. This might explain the fall of per capita kW in C4 (rise in winter months where the festive season is).

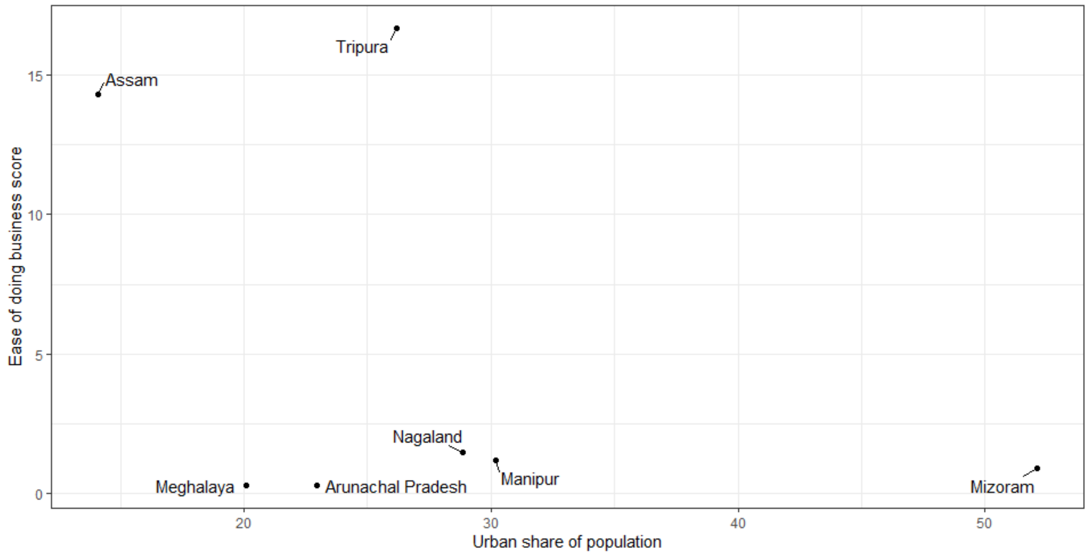

Figure 5 State clusters according to urbanization and business activity

Source: Compiled using RBI (2019) and Census 2011 India. (2011).

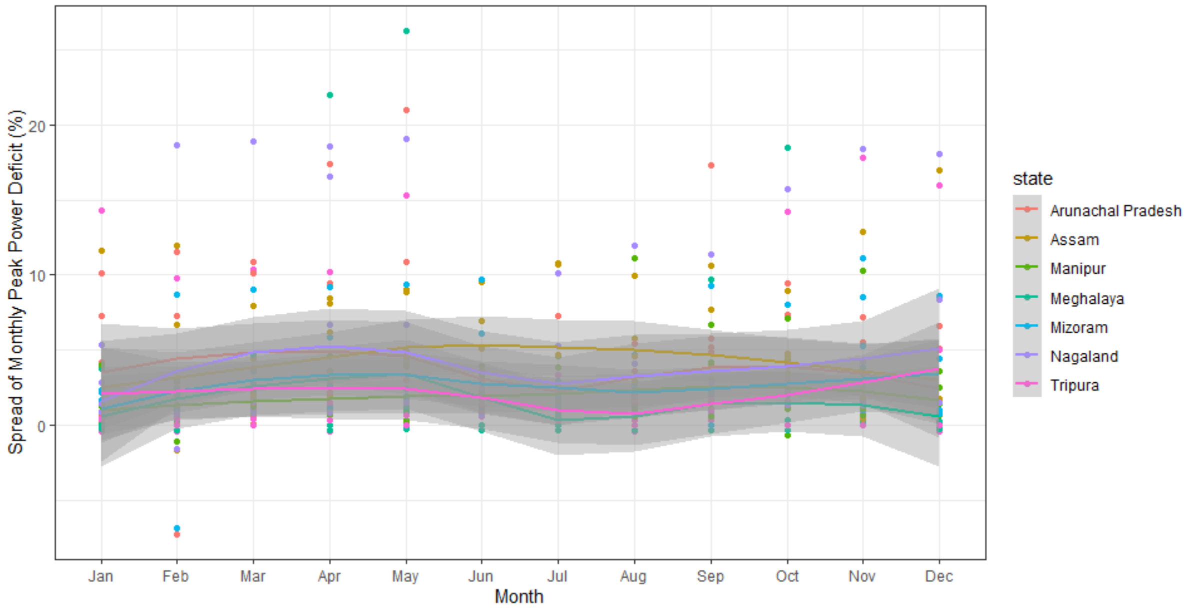

Figure 6 Rise monthly peak power deficit in C1 and C4.

Another interesting seasonal aspect is the rising trend of peak power deficits in C1 and C4. It would be interesting to see if the dependence on hydropower is linked to this trend. During these months, the flow rate is expected to reduce since they are either dry summer or winter months.

4.2 Regression Analysis

A stepwise OLS regression was employed on the full models of per capita kWh requirement and per capita kWh met. Initial pool of predictors is selected based on the correlation plots in Appendix A. The best final models using AIC as the selection criterion are given in Table 1. As seen in Table

2, it is observed that per capita kWh requirement and per capita SGDP have VIFs for M2. This is expected as both these have a correlation coefficient of 0.44.

Table 2 VIFs for main predictors

Predictor	VIF M1	VIF M2
Per Capita kWh Requirement		12.432
Per Capita SGDP	8.127	46.796
Peak Power Deficit	1.354	2.233

Table 3 Best Fit Models for per capita kWh requirement and per capita kWh met

Predictors of Best Model	Annual Per Capita kWh Requirement (M1)	Annual Per Capita kWh Met (M2)
Per Capita kWh Requirement		0.858***
		(0.053)
Per Capita Real SGDP	0.004***	-0.001**
	(0.001)	(0.001)
Peak Power Deficit	1.432	-1.520***
	(0.915)	(0.332)
Year2015		14.649***
		(5.151)
Year2016		18.540**
		(6.923)
Year2017		31.963***
		(7.657)
Year2018		39.800***
		(9.306)
Year2019		49.836***
		(10.967)
Assam	-44.708	-77.092***
	(35.374)	(20.582)
Manipur	-4.955	-74.865***
	(37.490)	(20.975)
Meghalaya	214.749***	-42.480**
	(32.146)	(19.353)

Mizoram	-43.843**	11.397
	(20.992)	(8.224)
Nagaland	0.646	-30.153***
	(23.058)	(10.354)
Tripura	-34.762	-43.190***
	(24.710)	(11.400)
Constant	65.725	177.030***
	(84.709)	(50.545)
Observations	42	42
R^2	0.907	0.994
Adjusted R^2	0.884	0.990
Residual Std. Error	33.295 (df = 33)	9.412 (df = 27)
F Statistic	40.230*** (df = 8; 33)	299.119*** (df = 14; 27)

HDI is interestingly left out in the best fit models while per capita SGDP is included. This might mean the expected household welfare outcomes of electricity access in the NEG states is not realized. Also, it is interesting to see that there is insignificant change in per capita kWh requirement from 2014-19 while there is an increasing trend for the met per capita kWh. The former suggests a stagnancy in electricity demand while the latter suggests improvement in power availability. Power deficit is a significant predictor of per capita kWh consumption. For a 1 % rise in power deficit, the annual met per capita kWh falls by about 1.5 kWh.

It is unexpected that the coefficient of per capita SGDP is -0.001 for M2. This needs further investigation.

References

Census 2011 India. (2011). Retrieved June 14, 2020, from Census2011.co.in website: https://www.census2011.co.in/religion.php

Global Data Lab. (n.d.). *Subnational HDI*. Retrieved 14 June 2020, from https://globaldatalab.org/shdi/shdi/IND/?levels=1%2B4&interpolation=0&extrapolation=0&nearest_real=0

Indiastat. (n.d.). *State-wise Gross State Domestic Product (GSDP) in India {(At Constant 2011-2012 Prices) (2011-2012 to 2019-2020)}*. Indiastat. https://www.indiastat.com/table/economy-data/8/national-income/175/975775/data.aspx

Kanagawa, M., & Nakata, T. (2008). Assessment of access to electricity and the socio-economic impacts in rural areas of developing countries. *Energy Policy*, *36*(6), 2016–2029. https://doi.org/10.1016/j.enpol.2008.01.041

NERLDC. (n.d.-a). *Load Forecast Error*. Retrieved 14 June 2020, from https://www.nerldc.org/load-forecast-error/

NERLDC. (n.d.-b). *Power Supply Position Report*. Retrieved 14 June 2020, from https://www.nerldc.org/power-supply-position-report/

NERLDC. (n.d.-c). *Salient Features*. Retrieved 14 June 2020, from https://www.nerldc.org/salient-features/

Office of the Registrar General & Census Commissioner. (2011). *Population and decadal change by residence: 2011 (Persons)*. https://www.censusindia.gov.in/2011census/PCA/PCA_Highlights/pca_highlights_file/India/Chapter-1.pdf

RBI (2019). Retrieved June 14, 2020, from Rbi.org.in website: https://m.rbi.org.in/Scripts/PublicationsView.aspx?id=18911

Sedai, A. K., Nepal, R., & Jamasb, T. (2020). *Flickering Lifelines: Electrification and Household Welfare in India*. CBS Department of Economics.

Sen, A. (2012). Diversity in Unity: An Empirical Analysis of Electricity Deregulation in Indian States. *The Energy Journal*, *33*(1). https://doi.org/10.5547/ISSN0195-6574-EJ-Vol33-No1-4

Sen, A., Nepal, R., & Jamasb, T. (2018). Have Model, Will Reform? Assessing the Outcome of Electricity Reforms in Non-OECD Asia. *The Energy Journal*, *39*(4). https://doi.org/10.5547/01956574.39.4.asen

Shukla, U. K., & Thampy, A. (2011). Analysis of competition and market power in the wholesale electricity market in India. *Energy Policy*, *39*(5), 2699–2710. https://doi.org/10.1016/j.enpol.2011.02.039

Appendix A

Figure A Distribution and correlation plots of variables considered for regression