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An Investigation and Modelling Forecasting on Electricity Demand Pattern in Bihar

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ABSTRACT: Electricity demand in any region reflects its socio-economic dynamics, climatic conditions, and demographic characteristics. Bihar, a highly burgeoning state in India, exhibits peculiar electricity consumption patterns influenced by its rural-urban divide, dependence on agriculture, and acceleration of industrialization. This study looks into Bihar's load characteristics from a seasonal and diurnal perspective. The demand analysis would consider factors like temperature, humidity, and socio-economic activities that could be modeled as predictors for demand variations established through historical data and linear regression. It would be useful for capacity planners and policymakers to improve grid management and planning.

KEYWORDS: Electricity demand, Electricity demand forecasting, Energy policy, Load characteristics analysis, Renewable energy integration, Rural electrification, Seasonal Agricultural electricity usage

I. INTRODUCTION

Electric consumption trends in Bihar are undergoing moderately radical changes due to economic development and lifestyle changes. Electricity is consumed at the very instant it is generated. Hence, accurate demand forecasting is essential to system operation and stability. Demand in Bihar is characterized by a large agricultural load, increasing urban demand, and distinctive seasonal peaks due to climatic conditions.

These characteristics mean that, unlike any other commodity, with electricity, the moment it is produced, it has to be consumed. It means the moment the light or air-conditioning unit is switched on, assuming all other loads remain constant, a power plant must increase generation immediately to cater to that increased demand [1]. Electricity is one of the basics of modern society. Electricity demand is ever-increasing because of varied and extensive needs. In turn, this increasing demand weighs heavily on limited resources: capital investment, material, and manpower. Hence, precise forecasting of electricity consumption has become one of the utmost necessities for effective power sector planning. The energy crisis has further highlighted the necessity for accurate electricity demand forecasting [2].

Digitalization is set to more crucially contribute to the decarbonization of building energy systems while promoting sustainability and operational efficiency. Recent advancements in the AI-enabled digitalization of building energy systems have allowed for accelerated economic data collection and advanced analytics in those systems. Non-intrusive load monitoring (NILM) is a common method for estimating appliance-wise energy use from aggregate household consumption data. However, the existing NILM research is mainly involved in algorithm and sensor development, and the applicability of NILM in energy management and policy design remains understudied. This study dwells on the use of smart meter NILM data from 13 cities in India across five climate zones to evaluate the impact of COVID-19-related public policy measures, including lockdowns, on the electricity demand in the residential sector [3].

This paper studies the electricity demand in Bihar in the light of regional and temporal variations induced by agricultural load, climatic impacts, and socio-economic transformations. By analyzing these determinants, we envision arriving at a very strong model for predicting future electricity needs, thereby aiding energy planning in the region.

II. THEORY

In India, per capita household energy requirement the total direct and indirect-representing some 0.4 kW in 1993-1994 was much less than the global mean of 2 kW. Further, 60% of the population is reported to consume less than 0.5 kW per capita in a year. Along with these quantifiable differences, there are marked differences in the types of energy sources and patterns of energy consumption in households [4]. This study looks at the electricity transformation of Bihar following a three-step approach.

- (i) Carry out a village experiment to estimate a demand curve for solar microgrids, free from influences exerted through other sources of power.
- (ii) Develop and estimate a demand model where experimental price variations are considered to estimate the household's willingness to pay for electricity.
- (iii) Consider estimated demand across all energy sources to assess the Bihar transition concerning proposed options on access, price, and quality.

The state government has undertaken various initiatives in the energy sector in the recent past. Consumers throughout the state are now being supplied with reliable and quality power. Per capita consumption of electricity has gone up from 329 kwh in 2021-22 to 1277 kwh in 2024-25, giving an 18.33 percent growth over four years. The projected Peak Demand for Power in Bihar has increased from 6966 MW in 2021-22 to 8243 MW in 2024-25, calculating a growth of more than 18.33 percent over four years.

Findings show that demand for solar microgrids is highly elastic. With a price of INR 200, demand was practically zero; at INR 100, it shot up to 17 % of households before tapering off again throughout the experiment. Treated villages reported higher consumption of electricity, more light bulbs and mobile phones, and less money spent on phone charging. Demand for microgrids collapsed by thousands after the experimental subsidy was withdrawn [5].

There are widespread and chronic shortages, while also supplying poor-quality power. Demand has now outstripped supply, resulting in acute peak-time and general energy shortages. After 1991, the government recognized private investment in power generation, yet the State Electricity Boards (SEBs) remain the primary agencies for electricity generation and distribution. The fundamental problem of the sector is that the poor financial health of the SEBs has constrained investment in generation capacity, thus worsening the existing supply-demand gap [6,7]. Regarding characteristics, one uniqueness stands out about electricity demand is its non-storability along with variations such as seasonal and diurnal implications.

Forecasting electricity demand is an essential requirement by practitioners and planners of the electricity system but exactly differs only in forecasting horizons that they desire. Whatever category the planners act in, their concerns are long-run horizons; system operators consider more of this medium- and short-range forecasting. Hence depending on the forecasting horizon electricity demand can be classify into three categories.

- (i) Long-term demand forecasting
Long-term forecasting serves policy establishment, system planning, and resource allocation.
- (ii) Medium-term demand forecasting
Medium-term forecasting applies to yearly maintenance planning of power plants and monthly peak demand and energy management. Fig. 1 shows the peak electricity demand in Bihar from 2015 to 2024 [18].

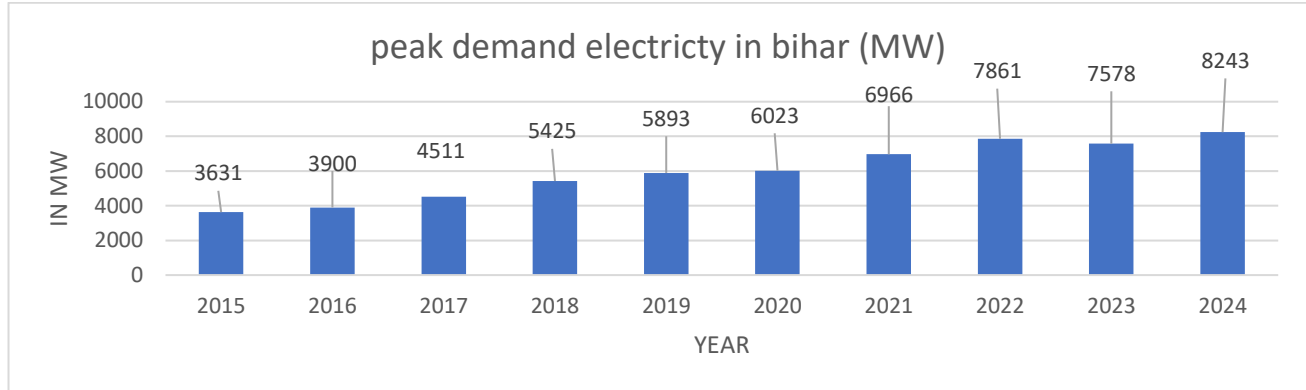
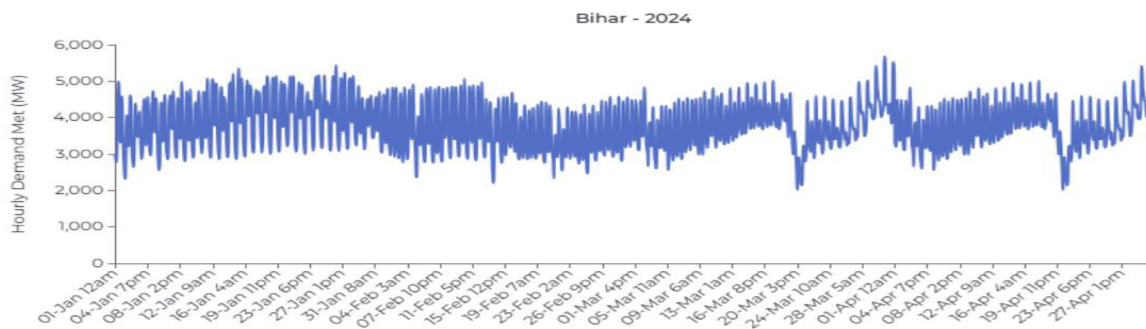


Fig. 1 Peak demand of Bihar

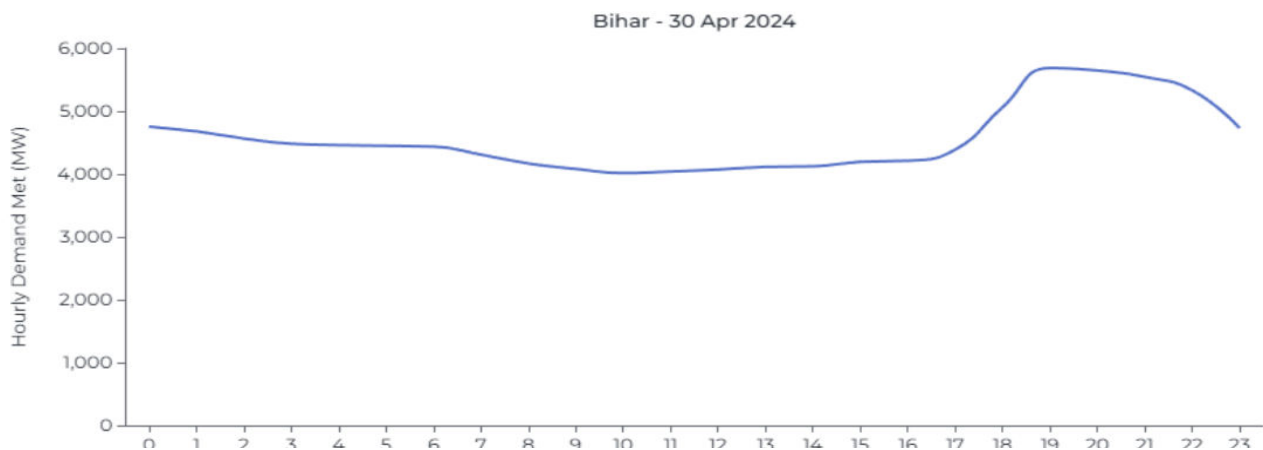
(iii) Short-term demand forecasting.

Short-term forecasting is concerned with scheduling the daily operation of power plants and electrical networks to ensure load management within a day. [8,9,10]. Fig. 2 shows the daily demand load curve from 1st January 2024 to 30th April 2024 of Bihar while Fig. 3 shows the hourly demand load curve of Bihar[18].



Data for 2024 is from 1st January 2024 to 30th April 2024

Fig. 2 Daily demand load curve of Bihar



Data for 2024 is from 1st January 2024 to 30th April

Fig.3 Daily Demand load curve of Bihar

The electricity demand is generally considered to be price inelastic in the short temper; however, in the long run, the electricity demand may have some elasticity. It can be stated for a country with a very rapid rate of per capita income growth that electricity demand will increase at an accelerated rate (income elastic demand). When income starts to rise in rural households lacking electricity in the first place, the demand for electricity will get an extra boost [11,12,13].

III. MODELLING AND FORECASTING DEMAND FOR THE ELECTRICITY

Some factors affect the forecasting demand for electricity.

3.1 Factors Affecting Demand

- (i) **Temperature and humidity:** These two are significant factors influencing electricity consumption in residential and agricultural segments.
- (ii) **Economic Activities:** Increased household income and urbanization are also associated with increased demand for electricity.
- (iii) **Agricultural seasons:** The requirement for irrigation during many seasons causes huge demand variations [14,15,16].

3.2 Regression Analysis

- (i) Using historical data, temperature, humidity, and socio-economy were incorporated into a linear regression demand model with seasonal decomposition to separate trends.

The electricity infrastructure and production are essential for a developing economy such as India, with a 1.2 billion population and covering an area of 3.29 million km². With a GDP of US\$ 2.3 trillion in 2015 and an average growth of 7% per year, the development of the electricity sector would also contribute to sustaining the country's economic output. Total electricity generation in India in 2015 was that of 1300 TWh from both utilities and non-utilities. Electricity consumption from all sectors in 2013 was at about 824 TWh, hence with an average growth rate of 9%, it was estimated at around 980 TWh in 2015. The electric network suffers about 25% transmission losses. The average availability of power for Bihar is shown in table no1.

Table no 1- Average availability of powe in Bihar

Year	The average availability of power	
2005	6-8 hours (Urban Area)	2-3 hours (Rural area)
2015	22-23 hours (Urban Area)	18-20 hours (Rural Area)
2021	23-24 hour (Urban Area)	21-22 hours (Rural Area)

It shows that the electricity infrastructure and production of electricity has increased for Bihar and hence, supports the economic development.

IV. ELECTRICITY DEMAND PATTERN IN BIHAR

Understanding of the electricity demand pattern helps to improve energy infrastructure and ensure equitable distribution of power within the state.

4.1 Agricultural Demand

- (i) A huge proportion of the power consumed in Bihar is for agricultural purposes, primarily irrigation [15,16].
- (ii) Demand peaks during the Kharif and Rabi seasons, reflecting reliance on electric pumps.

4.2 Urbanization and Domestic Consumption

- (i) In urban centers, electricity consumption is rising due to greater household adoption of appliances and air conditioning [17].
- (ii) Prepared by lighting and cooling loads, evening peaks become a strong feature.

4.3 Industrial Load

- (i) Industrial consumption is gradually rising, yet it still only accounts for a small fraction of total consumption-comparison as agriculture and domestic.
- (ii) Small-scale industries are beginning to establish their presence in energy consumption.

V. ONGOING PROJECT IN BIHAR

Some ongoing projects are active in Bihar to improve the electricity demand pattern in Bihar.

- (i) The Government is envisioned for "HAMARA AADHAR URJASWIT BIHAR". In the process of achieving self-sufficiency in this sector, various schemes are being implemented with investments of more than 8,000 crores aimed at strengthening the Generation, Transmission, and Distribution system.
- (ii) Due to its successful implementation of flagship programs like Har Ghar Bijli under 'Saat Nischay Yojana', Bihar tops in the country with an increase of 474% in its electrification. There has been an increase in the range of 43% during the decade (2012-21) at the national level; while the increase is recorded at 474% in the case of Bihar, according to the Night Time Light Atlas (NTL Atlas) prepared by ISRO.
- (iii) The state government under the ambitious scheme of "Mukhya Mantri Upbhokta Sahayata Yojana" is providing a subsidy amount of Rs. 13,114 Cr. to power consumers of the state in FY-2023-24. As a result, the increase in energy charge by BERC of 24.10% hike will not trouble power consumers anymore.

VI. IMPLICATION FOR ENERGY PLANNING**6.1 Capacity Building**

- (i) Capacity augmentation to meet peak seasonal demand.
- (ii) Integration of renewable energy generation with sustainable rural electrification [17].

6.2 Policy Recommendations

- (i) Provide incentives for energy-conserving practices in agriculture and industry [16].
- (ii) Strengthen grid infrastructure to connect to rural and underserved areas.

6.3 Future Work

- (i) Real-time data for dynamic demand forecasting from smart grids.
- (ii) Study the influence of electrification policies and subsidies on consumption patterns.
- (iii) This study serves as a foundation for further research on regional energy planning in comparable socio-economic contexts.

VII. CONCLUSIONS

Bihar's electricity demand pattern embodies the manifold interplay of climatic, economic, and demographic factors. It Embraces advanced forecasting models while correlating energy policy with supply. The state can create a more resilient and equitable power distribution system by implementing advanced forecasting models and aligning energy policies with consumption trends.

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