JOURNAL OF ENERGY SYSTEMS

2025, *9*(1)

2602-2052

DOI: 10.30521/jes.1549293

Review Article

Forecasting electricity demand in Türkiye: A comprehensive review of methods, determinants, and policy implications

Hakan Elbaş *
Bursa Technical University, Graduate School, Department of Intelligent Systems Engineering, Bursa, Türkiye, hakan.elbas@gmail.com
Turgay Tugay Bilgin
Bursa Technical University, Faculty of Engineering and Natural Sciences, Department of Computer Engineering, Bursa, Türkiye, turgay.bilgin@btu.edu.tr

Submitted: 12.09.2024
Accepted: 23.01.2025
Published: 31.03.2025

* *Corresponding Author*

Abstract: This review examines the methods, determinants, and forecasting horizons used in electricity demand forecasting in Türkiye. The study investigates how Türkiye's electricity demand is influenced by economic, climatic, socio-demographic, and technological factors, and explores the evolving landscape of forecasting techniques, from traditional statistical models to advanced machine learning and hybrid approaches. The research addresses three key questions: The significant determinants of electricity demand in Türkiye, the most effective forecasting methods, and the application of these insights to improve energy planning and policy development. Through a systematic analysis of peer-reviewed literature, official reports, and case studies, the study reveals the complex interplay of factors affecting electricity demand and the increasing sophistication of forecasting methodologies. Economic growth, industrial production, climate change, urbanization, and technological advancements emerge as primary drivers of demand, while artificial neural networks and hybrid models demonstrate superior forecasting capabilities. The study highlights the importance of integrated modeling approaches, sector-specific strategies, and the incorporation of climate projections in long-term planning. It also emphasizes the need for aligning energy policies with broader economic and environmental objectives. This review provides valuable insights for researchers, policymakers, and industry stakeholders, offering a comprehensive framework for understanding and improving electricity demand forecasting.

Keywords: *AI, Demand forecasting, Energy consumption, Energy planning, Energy policy*

Cite this paper as: Elbaş, H., & Bilgin, TT., Forecasting electricity demand in Türkiye: A comprehensive review of methods, determinants, and policy implications. *Journal of Energy Systems 2025; 9*(1): 132-158, DOI: 10.30521/jes.1549293

2025 Published by peer-reviewed open access scientific journal, JES at DergiPark (https://dergipark.org.tr/jes)

1. INTRODUCTION

Over the past few decades, the rapid increase in electricity demand in Türkiye underscores the critical need for accurate demand forecasting. This requirement extends beyond technical considerations; it is a fundamental aspect of ensuring national energy security and economic stability. As Türkiye's economy continues to expand, energy consumption correspondingly rises, driven by factors such as industrialization, urbanization, and technological advancement. Furthermore, the integration of renewable energy sources and the ongoing impacts of climate change introduce additional layers of complexity to the forecasting process. Consequently, reliable predictive models are essential for policymakers and industry stakeholders.

Accurate electricity demand forecasting is imperative for several reasons. It ensures a stable and efficient supply of electricity, which is crucial for sustaining economic growth and enhancing living standards. Furthermore, precise demand forecasts are essential for effective energy planning, policy formulation, and infrastructure development, enabling the country to meet its future energy needs while minimizing environmental impacts. Conversely, inaccurate forecasts can lead to either over- or under-investment in energy infrastructure, resulting in economic inefficiencies and potential energy shortages or surpluses.

This study aims to provide a comprehensive review of the methodologies, determinants, and forecasting horizons utilized in electricity demand forecasting in Türkiye. By analyzing a broad spectrum of literature, the study seeks to identify the primary factors influencing electricity demand and evaluate the effectiveness of various forecasting models and techniques. Articles were sourced from multiple databases and selected based on their relevance, methodological rigor, and contribution to the field. The research focuses on addressing several key questions:

RQ1: What are the most significant determinants of electricity demand in Türkiye?
RQ2: Which forecasting methods are most effective in capturing these dynamics?
RQ3: How can these insights be applied to improve future energy planning and policy development?

By addressing these questions, this study aims to contribute to the academic literature on energy demand forecasting and offer practical insights for policymakers, energy planners, and researchers. Through a detailed examination of case studies and policy recommendations, the paper provides a comprehensive perspective on the challenges and opportunities associated with forecasting electricity demand in Türkiye.

2. METHODOLOGY

This comprehensive review article examines the methodologies employed in electricity demand forecasting within the context of Türkiye, drawing upon an extensive analysis of scholarly literature. The selection of topics was guided by their relevance to Türkiye's energy market, the country's unique energy landscape, and prevailing global energy trends. To ensure a rigorous and comprehensive analysis, references were chosen based on specific criteria. Studies addressing contemporary issues in Türkiye's energy sector, exploring innovative forecasting techniques, and providing insights valuable for both national and international energy policymaking were given precedence.

2.1. Search Procedure

To maintain the integrity and relevance of the review, references were sourced from reputable databases and official sources. The search process utilized a range of electronic databases, including Google

Scholar, Springer, Elsevier, Scopus, ScienceDirect, and Taylor & Francis. Additionally, sector-specific sources such as Statista, the Turkish Ministry of Environment, Urbanisation and Climate Change (CSB), the Turkish Electricity Transmission Corporation (TEİAŞ), and the Load Dispatcher Information System (YTBS) provided invaluable data and context-specific information.

The search strategy employed a carefully curated set of keywords to ensure comprehensive coverage of all critical aspects of electricity demand forecasting in Türkiye and globally. These keywords included, but were not limited to, “electricity demand forecasting”, “energy demand models”, “machine learning in energy forecasting”, “renewable energy integration in Türkiye”, “economic impacts on energy consumption”, “climatic conditions and electricity use”, and “policy development in energy forecasting”.

2.2. Inclusion and Exclusion Criteria

To further refine the selection of studies, specific inclusion and exclusion criteria were established. The inclusion criteria encompassed:

a) Studies published in peer-reviewed journals, theses, and conference proceedings,
b) Research conducted from 2000 to 2023, with an emphasis on recent studies to capture the latest developments,
c) Studies accessible through electronic databases,
d) Articles written in Turkish and/or English,
e) Research specifically focused on Türkiye, as well as studies providing comparative analysis with global contexts,
f) Studies exploring various methodologies (including statistical models, machine learning techniques, and hybrid models) for electricity demand forecasting,
g) Studies addressing policy implications and practical applications in energy management.

Conversely, the exclusion criteria comprised:

a) Studies conducted outside the specified timeframe, unless they provided significant foundational theories or models,
b) Research focused on regions other than Türkiye without relevant comparative insights.

This selection process ensures a comprehensive and current review of electricity demand forecasting methodologies applicable to Türkiye's unique energy landscape. By adhering to these criteria, this review aims to provide a robust foundation for understanding and advancing electricity demand forecasting practices in Türkiye, with potential implications for broader international contexts.

3. LITERATURE REVIEW

The prediction of electricity demand and the accuracy of these forecasts can be better comprehended through specific case studies, which provide real-world insights into the challenges and successes of various forecasting methods. This section examines multiple case studies from Türkiye to explore how different forecasting models have been practically implemented. By evaluating these case studies, this review seeks to assess the practical applications of electricity demand forecasting, identifying the factors that contribute to accurate predictions as well as those that pose significant challenges. These studies will not only illustrate the methodologies employed but also underscore the contextual factors—such as economic conditions, policy changes, and technological advancements—that affect the reliability of these forecasts. A thorough understanding of these practical applications is essential for refining forecasting techniques and enhancing their relevance to energy planning and policy-making in Türkiye.

3.1. Causal Link between Electricity Use and Economic Growth

The relationship between electricity consumption and economic growth in Türkiye has been a subject of considerable academic interest, particularly in the context of how these two variables influence each other. According to a study by [1], there is a unidirectional causality from electricity consumption to economic growth in Türkiye. This finding suggests that increases in electricity consumption are a driving force behind economic growth, implying that energy policies aimed at meeting the rising electricity demand are crucial for sustaining economic development. This study serves as a notable example of the critical role that energy consumption plays in fostering economic growth, underscoring the importance of a reliable electricity supply to support Türkiye's economic expansion.

3.2. Implications of COVID-19 on Residential Electricity Demand Management

The COVID-19 pandemic has significantly impacted residential energy consumption patterns, particularly in Türkiye. As households spent more time at home due to lockdowns and remote work, there were substantial changes in energy consumption habits. A study by [2] thoroughly investigates these changes, focusing on the flexibility in residential demand response during the pandemic. The study reveals that as time spent at home increased, the use of household appliances also rose, leading to higher energy consumption during specific hours, especially midday. This shift in consumption patterns presents both challenges and opportunities for managing residential energy demand in Türkiye. The findings highlight the need for improved demand-side management strategies to accommodate these changes and ensure grid stability, particularly during periods of high demand, such as lockdowns or extreme weather events.

3.3. Electricity Consumption Trends by Sector: Insights for Demand Forecasting in Türkiye

Sectoral electricity consumption in Türkiye is a key factor in accurately forecasting energy demand. The industrial, residential, commercial, and service sectors each exhibit distinct consumption patterns, making it essential to forecast these profiles to maintain energy supply security. The study by Ref. [3] analyzed sectoral electricity demand in Türkiye, highlighting the impact of increased electricity consumption in the industrial and service sectors on overall demand. Their findings underscore the significance of understanding sector-specific consumption trends to formulate reliable and sustainable energy supply strategies.

Fig. 1 provides a graphical representation of total energy consumption by sector in Türkiye, measured in Million Tons of Oil Equivalent (Mtoe) over several years. This visual overview illustrates the contributions of various sectors, including industry, transportation, and residential services, to the country's total energy demand. Such insights are crucial for developing targeted policies that effectively address the unique needs and challenges faced by each sector.

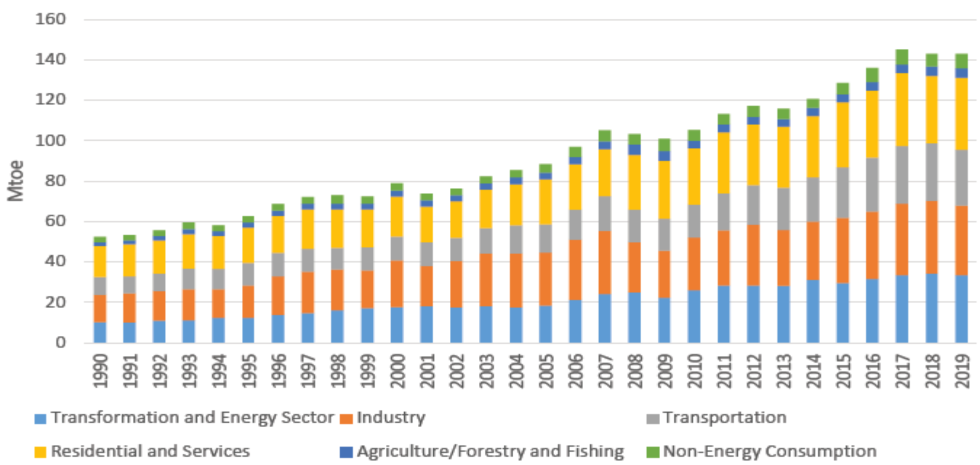

Figure 1. Total energy consumption by sectors in unit of Mtoe after Ref. [4].

3.4. Renewable Energy Sources and Electricity Demand

The use of renewable energy sources significantly impacts electricity demand in Türkiye. Evaluating the potential of renewable energy sources is crucial for energy supply security and sustainability. Ref. [3] examined the potential impacts of renewable energy sources on electricity demand in Türkiye, emphasizing the importance of incorporating these sources into energy demand forecasting to ensure a stable and sustainable energy supply. As Türkiye continues to develop its renewable energy infrastructure, understanding the contribution of different renewable sources becomes increasingly important for accurate forecasting and strategic planning.

In 2019, Türkiye's gross electricity production from renewable energy sources was composed of hydro (66.60%), wind (16.30%), geothermal (6.70%), bioenergy and wastes (6.90%), and solar (3.50%), as presented in Table 1. This distribution highlights the dominance of hydroelectric power, though there is also significant growth in wind and other renewable sources. These proportions illustrate the key role of renewable energy in Türkiye's overall electricity production and the necessity for continued investment in these areas to meet future energy demands.

Furthermore, Fig. 2 provides an overview of the share of renewable electricity in gross electricity consumption from 1990 to 2019, showcasing a clear upward trend. This visual representation underscores the increasing reliance on renewable energy in Türkiye’s energy mix, reflecting the positive impact of policy measures aimed at promoting the use of renewable sources. The consistent growth in the share of renewable energy in electricity consumption indicates Türkiye's progress towards achieving greater energy sustainability, which is vital for reducing dependency on fossil fuels and mitigating environmental impacts.

Table 1. Gross electricity production from renewable energy sources in GWh in year 2019 after Ref. [5].

Source	**Generation** (GWh)	**Share** (%)
Hydro	88,822.80	66.60
Wind	21,730.70	16.30
Geothermal	8,951.70	6.70
Bioenergy and Wastes	4,624.20	6.90
Solar	9,249.80	3.50
Total	133,379.20	100.00

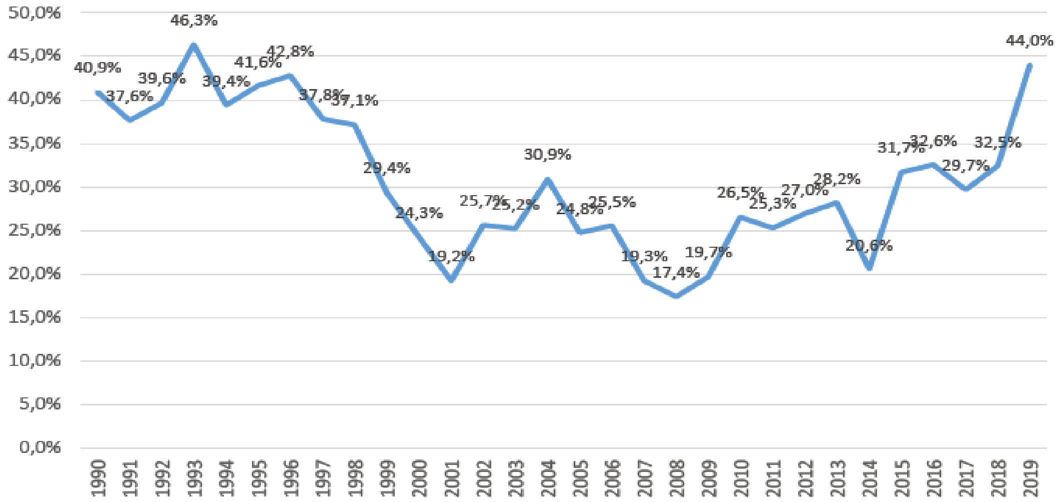

Figure 2. Share of renewable electricity in gross electricity consumption (%) after Ref. [6].

4. DETERMINANTS OF ELECTRICITY DEMAND IN TÜRKİYE

Electricity demand in Türkiye is shaped by a range of factors, including economic growth, climatic conditions, socio-demographic changes, and technological advancements. Economic variables, such as GDP growth, drive energy consumption, while climatic fluctuations affect heating and cooling requirements. Additionally, population growth and urbanization influence electricity consumption patterns, and technological innovations, such as the adoption of energy-efficient appliances, further modify demand. This section provides a comprehensive analysis of these factors and their impact on electricity consumption in Türkiye.

4.1. Electricity Demand in Relation to Economic Growth and Industrial Production

Economic growth and industrial production are key determinants of electricity demand in Türkiye. The interrelationship between economic activity and electricity consumption has been the subject of extensive research, with findings indicating a reciprocal influence between these variables. For example, Ref. [1] identified a significant correlation between electricity consumption and economic growth, suggesting that increased electricity use promotes economic expansion. This correlation implies that electricity is not only a fundamental input for economic growth but also crucial for maintaining economic stability. Any disruptions in electricity supply could have adverse effects on economic performance, as illustrated in Fig. 3 and 4, which present the correlation between the logarithm of electricity consumption and real GDP in Türkiye over the study period.

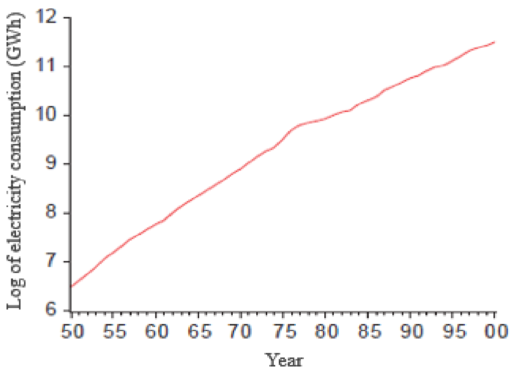

Figure 3. The plots of the log of electricity consumption in Türkiye after Ref. [1].

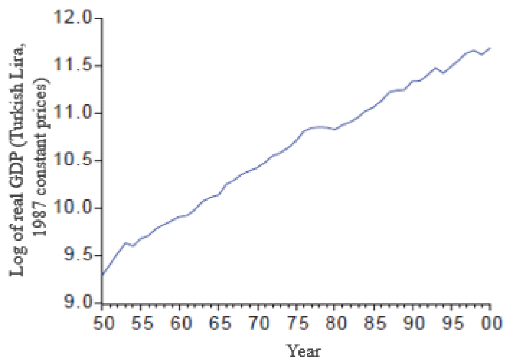

Figure 4. The plots of the log of real GDP in Türkiye after Ref. [1].

Industrial production plays a particularly crucial role in driving electricity demand due to the energy-intensive nature of manufacturing and production activities. As the industrial sector grows, so does the need for electricity to power machinery, equipment, and production processes. This demand is further influenced by economic cycles, where periods of economic expansion lead to increased industrial output and, consequently, higher electricity consumption. Ref. [7] highlighted the sensitivity of industrial and residential electricity demand to economic variables, emphasizing how fluctuations in economic activity directly impact energy consumption.

Fig. 5 illustrates the relationship between annual economic growth and electricity demand in Türkiye, showing a significant co-movement between these variables [8]. This pattern indicates that periods of economic growth are typically associated with increased electricity demand, while economic downturns coincide with reductions in consumption. This dynamic underscores the importance of incorporating economic indicators and industrial production data into electricity demand forecasting models to enhance their accuracy and reliability.

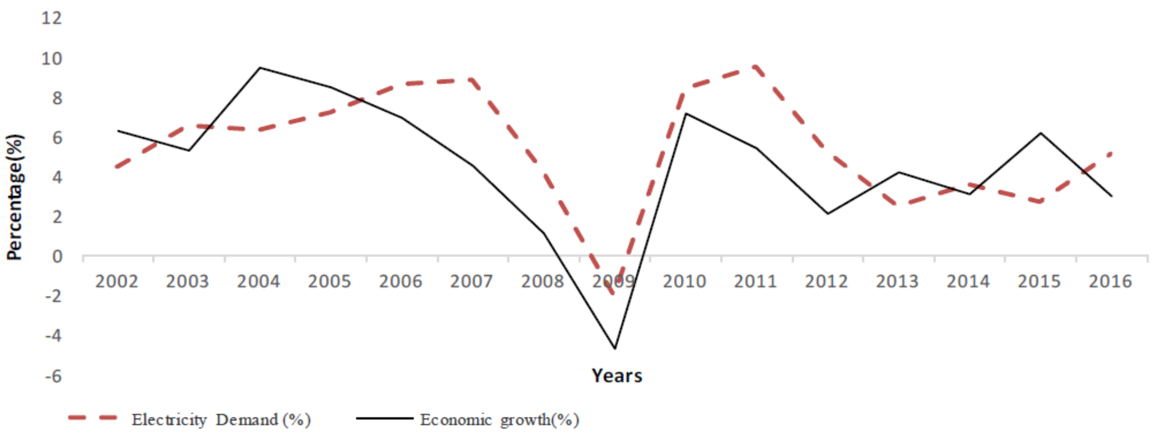

Figure 5. The relationship between annual economic growth and electricity demand after Ref. [8].

Moreover, specific industries, such as steel, cement, textiles, and automotive manufacturing, are among the most energy-intensive sectors in Türkiye. The electricity demand in these industries is closely tied to production levels, which are influenced by both domestic and international market conditions. Ref. [9] provides a detailed analysis of Türkiye's electricity demand, showing a strong correlation between economic growth and electricity consumption, particularly within the industrial sector. This relationship highlights the necessity for energy policy and planning to be closely aligned with industrial production trends to ensure a stable and reliable energy supply. Ref. [10] further explores this relationship by analyzing the effects of economic growth on electricity consumption across different sectors. The study underscores that as the economy grows, the demand for electricity in both the industrial and residential sectors increases. This growth is especially pronounced in energy-intensive industries, which are vital for economic development but also significantly contribute to overall electricity demand. Therefore, understanding these patterns is crucial for formulating effective energy policies and ensuring a reliable energy supply to support continuous economic growth.

In conclusion, understanding the interplay between economic factors and industrial production is essential for accurate electricity demand forecasting. By integrating economic growth data and industrial production trends, energy demand models can provide more precise predictions, supporting effective energy planning, infrastructure investments, and policy development.

4.2. Technological Developments

Technological developments create complex impacts on energy efficiency and electricity demand. New technologies can increase energy efficiency, thereby reducing electricity demand, while simultaneously causing an increase in electricity demand due to the adoption of new electrical devices and technologies. For instance, smart grids and energy-efficient appliances are designed to optimize electricity usage and reduce wastage, potentially lowering overall demand. However, other innovations, such as electric vehicles (EVs) and the integration of renewable energy sources, tend to increase electricity consumption due to their energy-intensive nature. Additionally, the rise of 5G networks and industrial automation, which rely heavily on electricity, further drive up demand. The adoption of artificial intelligence (AI) and machine learning in data centers has also contributed to higher electricity consumption due to the energy required for processing and storage. These impacts are summarized in Table 2, which outlines how various technological advancements influence electricity demand.

In the context of forecasting, advanced technologies like artificial neural networks (ANNs) have been particularly effective. Ref. [11] demonstrated that ANNs could be utilized for long-term electricity demand forecasting in Türkiye, producing more accurate results compared to traditional methods. Their study highlights how integrating AI technologies into demand forecasting can significantly improve the reliability of predictions, making it a valuable tool for energy planning and policy development.

Table 2. Impact of technological developments on electricity demand.

Technological Development	Impact on Electricity Demand	Description	References
Smart Grids	Decrease/Increase	Smart grids optimize electricity distribution, reducing waste and peak demand, while enabling higher use of smart devices.	[12]
Electric Vehicles (EVs)	Increase	The adoption of EVs significantly increases electricity demand as transportation shifts from fossil fuels to electric power.	[13]
Energy-Efficient Appliances	Decrease	Adoption of energy-efficient appliances reduces overall electricity consumption in households and businesses.	[14]
Renewable Energy Integration	Increase	Integration of renewable energy sources can vary electricity demand based on resource availability and storage solutions.	[15]
Industrial Automation (IoT)	Increase	IoT and automation in industries lead to higher electricity demand due to the need for continuous power supply.	[16]
Blockchain Technology	Increase	Blockchain operations, particularly mining, consume substantial amounts of electricity.	[17]
5G Networks and Data Centers	Increase	The deployment of 5G networks and the growth of data centers require significant power, increasing electricity demand.	[18]
Teleworking and Remote Work	Decrease/Increase	Teleworking reduces demand in commercial buildings but may increase residential electricity consumption.	[19]
Artificial Intelligence (AI)	Increase	AI and machine learning, especially in data centers, contribute to higher electricity consumption.	[20]
Battery Storage Technology	Decrease	Advanced battery storage reduces peak demand by storing excess energy and releasing it during high demand periods.	[21]

4.3. Climatic Conditions and Socio-demographic Factors

Climatic conditions have a significant impact on electricity demand. Seasonal temperature changes in Türkiye directly affect electricity demand, particularly during the summer months when increased temperatures raise the need for cooling, leading to a significant increase in electricity usage. Ref. [3] explored these effects in detail, noting that rising temperatures elevate electricity consumption due to the increased operation of cooling systems. Their study also emphasized that the growing energy demand, coupled with limited fossil fuel resources in Türkiye, would likely exacerbate energy insecurity and environmental challenges if not managed with sustainable energy policies.

Climate change can have significant and long-term effects on electricity demand, particularly due to changes in cooling and heating needs as temperatures rise. The increase in Cooling Degree Days (CDD) necessitates greater energy use for air conditioning, leading to higher overall electricity consumption, especially during hotter seasons. These shifts underscore the importance of integrating climate change projections into long-term electricity demand forecasts. As highlighted in the study by Ref. [22], incorporating climate variables into forecasting models is essential to accurately predict future electricity needs and to develop energy policies that are resilient to the impacts of climate change. This forward-looking approach ensures that energy systems can adapt to the anticipated increases in demand, thereby maintaining energy security while addressing environmental sustainability. Table 3 presents a detailed breakdown of the seasonal electricity demand in Türkiye for 2023, highlighting the various energy sources utilized throughout the different seasons. This data is crucial in understanding how different seasons affect energy consumption patterns and the reliance on various energy sources.

Winter: According to [23], electricity demand increases in winter due to the need for heating. This is reflected in Table 3, where coal (39.60%) and natural gas (23.67%) are heavily relied upon. The increased demand for heating leads to higher consumption of these fossil fuels during the colder months.

Spring: [24] note that with milder temperatures in spring, there's a shift towards renewable energy sources. This is evident in Türkiye's increased use of hydropower (26.61%) and wind energy (10.25%) during spring, as shown in Table 3. The reliance on these renewable sources helps balance the moderate electricity demand during this season.

Summer: [25] found that summer electricity demand spikes due to cooling needs, consistent with Table 3, where electricity demand peaks at 90.562.227 MWh. Natural gas (20.86%) and hydropower (21.65%)

play crucial roles in meeting this high demand, while solar energy also contributes significantly (7.32%) due to longer daylight hours.

Autumn: As temperatures begin to drop, the demand for electricity decreases slightly, with coal (40.37%) and natural gas (20.87%) remaining the dominant energy sources, according to [26]. The data in Table 3 shows that autumn mirrors winter in terms of energy source reliance, though with slightly less demand.

In conclusion, Türkiye's electricity demand and energy source usage vary significantly across the seasons, with different energy sources playing key roles depending on the temperature and weather conditions, as detailed in Table 3.

Table 3. Türkiye's Seasonal Electricity Demand in 2023 after Ref. [27].

Season	Electricity Demand (Mwh)	Coal %	Natural Gas %	Hydropower %	Wind %	Solar %	Geothermal %	Other Sources %
Winter	79,607,517.00	39.60%	23.67%	14.77%	11.03%	3.78%	3.79%	3.35%
Spring	76,605,500.00	31.58%	18.05%	26.61%	10.25%	6.18%	3.78%	3.55%
Summer	90,562,227.00	34.95%	20.86%	21.65%	9.50%	7.32%	2.75%	2.98%
Autumn	79,162,823.00	40.37%	20.87%	14.61%	11.44%	5.84%	3.51%	3.37%

Population growth and urbanization are also significant factors influencing electricity demand in Türkiye. The rapid urbanization process, characterized by accelerated migration from rural areas to cities, has led to a substantial increase in electricity consumption across residential, commercial, and service sectors. As urbanization intensifies, the demand for electricity rises, particularly in urban areas where energy is essential for sustaining economic activities and improving living standards. Ref. [28] highlighted the strong impacts of population growth and urbanization on residential electricity demand in Türkiye, emphasizing that these socio-demographic factors play a crucial role in shaping the country's energy needs.

Moreover, as illustrated in Fig. 5, the trend of urbanization in China also shows a similar correlation with energy consumption and economic growth, indicating that urbanization not only drives increased energy demand but also contributes to economic expansion [29]. The Fig. 6 provides a clear visual representation of how urbanization, energy consumption, and GDP have evolved together, highlighting the interconnectedness of these variables in the context of rapid urban growth.

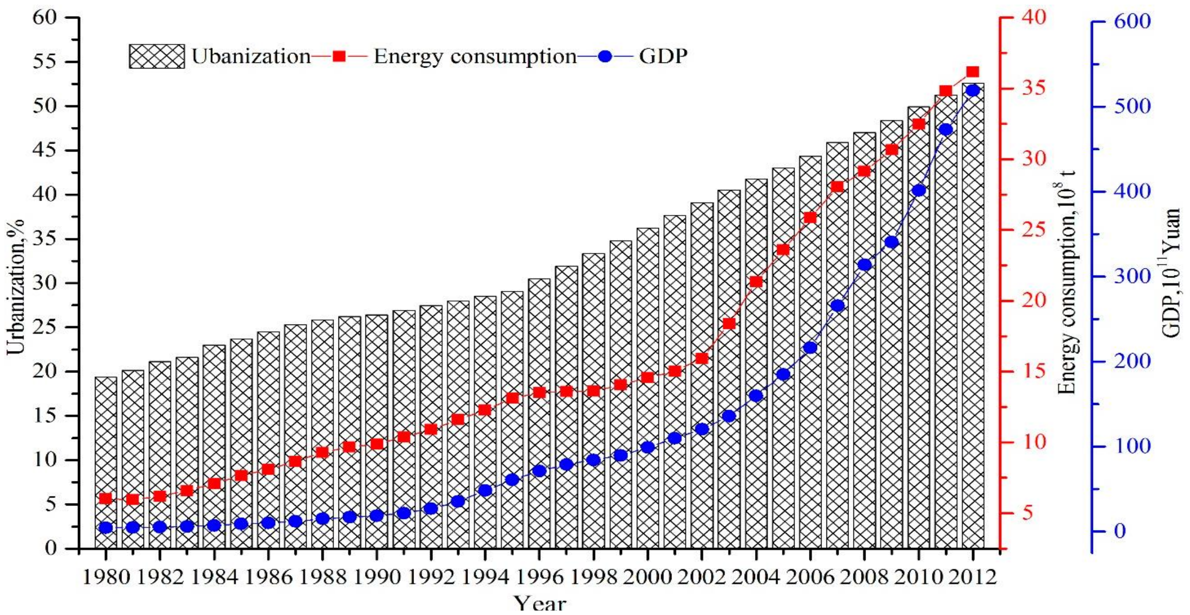

Figure 6. The Changing Trend of Urbanization, Economic Growth and Energy Consumption in China between 1980–2012 after Ref. [29].

5. METHODOLOGIES FOR ELECTRICITY DEMAND FORECASTING

Electricity demand forecasting utilizes various methods, including statistical models, machine learning, and hybrid approaches. Each method offers unique strengths, from analyzing economic impacts to identifying patterns in historical data. In Türkiye, these techniques have been effectively applied, with ARIMA models used for long-term forecasts and machine learning algorithms enhancing short-term predictions, reflecting the evolving energy needs of the country.

5.1. Statistical Models

Statistical models are crucial tools in forecasting future electricity demand based on historical data, allowing for a deep understanding of how past consumption patterns can predict future needs. Among these methods, ARIMA models are widely recognized for their effectiveness in capturing the trends and seasonality inherent in electricity demand data. For instance, [30] utilized ARIMA models to predict Türkiye's primary energy demand, successfully demonstrating the model's capacity to provide accurate forecasts across different fuel types. This study laid the groundwork for the extensive use of ARIMA in energy forecasting within Türkiye.

Beyond ARIMA, other innovative statistical models have also been employed to enhance the accuracy of electricity demand forecasts. Ref. [31] introduced a Grey model with a rolling mechanism, in conjunction with ARIMA, to improve short-term forecasting precision. Their approach reflects the ongoing evolution in the field, as researchers continuously seek to refine models to address the complexities of energy consumption patterns.

The application of these models is not limited to Türkiye; globally, various studies have employed statistical models to understand and forecast electricity demand in different contexts. Table 4 provides a comprehensive overview of some key studies that have utilized statistical models, highlighting the specific models used, their key findings, and the authors who contributed to this body of work. The table reflects the chronological development of statistical analysis in electricity forecasting, illustrating both the progress in model sophistication and the expanding scope of these studies.

Table 4. Forecasts made with statistical models.

Title	Model(s) Used	Key Findings	Reference
ARIMA forecasting of primary energy demand by fuel in Turkey	ARIMA	Provided accurate forecasts for Türkiye's primary energy demand for different fuel types.	[30]
Grey prediction with rolling mechanism for electricity demand forecasting of Turkey	Grey Model (GM), ARIMA	Successfully applied Grey model with rolling mechanism, showing superior accuracy in short-term forecasts.	[31]
Industrial electricity demand for Turkey: A structural time series analysis	Structural Time Series (STS)	Demonstrated that industrial electricity demand in Türkiye is strongly influenced by economic activity.	[32]
Sensitivity analysis for models with multiple behavior modes: A method based on behavior pattern measures	ARIMA, Behavioral Models	Applied time series analysis combined with behavior pattern measures to improve forecasting accuracy.	[33]
A review on time series forecasting techniques for building energy consumption	ARIMA, SARIMA, ANN	Conducted a global review and found that ARIMA and SARIMA are widely used for short-term building energy forecasts.	[34]
Temporal Convolutional Networks Applied to Energy-Related Time Series Forecasting	Temporal Convolutional Networks (TCN)	TCN-based models outperformed traditional recurrent networks for forecasting national electric demand and power demand at charging stations, offering superior predictive accuracy.	[35]
Time Series Forecasting with Multi-Headed Attention-Based Deep Learning for Residential Energy Consumption	Multi-headed Attention-based Deep Learning, Convolutional Recurrent Neural Network	The study introduces a deep learning model that significantly improves energy consumption forecasting by extracting complex patterns with multi-headed attention mechanisms.	[36]
Time Series Forecasting for Decision Making on City-Wide Energy Demand: A Comparative Study	LSTM, ARIMA	The study compares various time series models for predicting city-wide energy demand, finding that LSTM models outperform others in terms of accuracy.	[37]
Analysis and Forecasting of Monthly Electricity Demand Time Series Using Pattern-Based Statistical Methods	ARIMA, ETS, Prophet	This study provides a solution for predicting monthly power demand using statistical methods, effectively capturing seasonal fluctuations and trends in the energy demand series.	[38]

Deep Learning for Energy Time-Series Analysis and Forecasting	Deep Learning (DL) Models	This paper explores various DL methods for improving the accuracy of energy time-series forecasting, emphasizing their application in the Greek Energy Market.	[39]

5.2. Machine Learning Techniques

Machine learning techniques are increasingly used in electricity demand forecasting, favored for their ability to handle large datasets and model complex relationships with high accuracy. Among these techniques, artificial neural networks (ANNs) are particularly prominent due to their effectiveness in capturing non-linear patterns within the data. In Türkiye, the application of ANNs has gained attention, especially in the context of forecasting annual gross electricity demand. As illustrated in Fig. 7, ANNs are employed to model the relationship between socio-economic indicators, such as GDP per capita, population, and climatic conditions, to predict electricity demand with high precision [40]. This approach has proven crucial for reliable energy planning in a rapidly developing economy like Türkiye. Moreover, as demonstrated in Fig. 8, the ANN model outperformed traditional multiple linear regression models, showing superior accuracy in forecasting electricity demand for the years 2007-2013, with predictions that closely align with actual observed values [40].

Additionally, fuzzy logic approaches, another subset of machine learning, have shown notable success in short-term electricity demand forecasts in Türkiye, further enhancing the reliability of predictions under varying economic conditions [41].

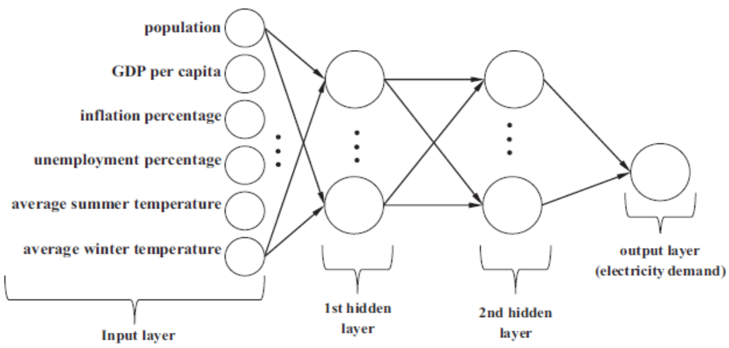

Figure 7. Electricity demand forecasting with artificial neural networks after Ref. [40].

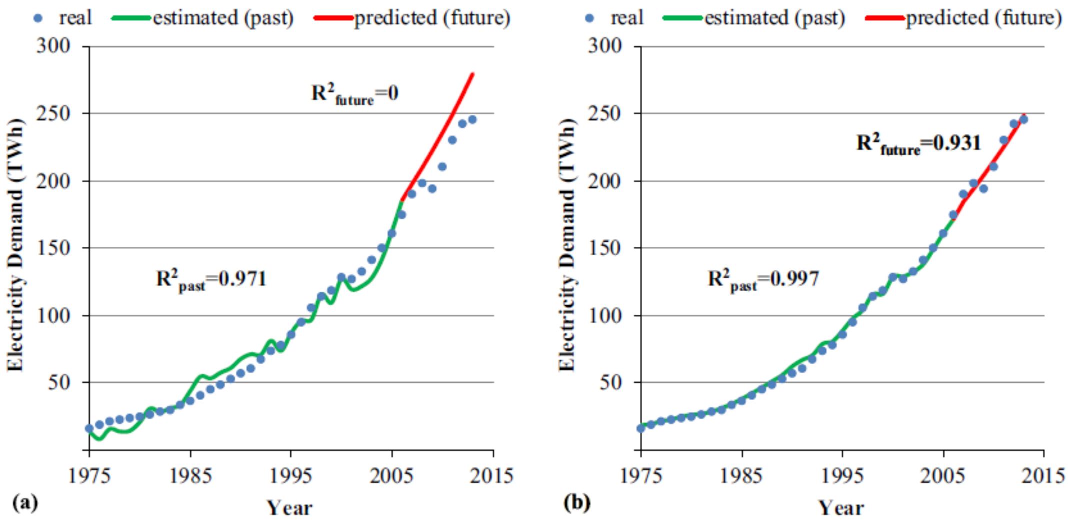

Figure 8. Forecasting the electricity demand for the years between 2007 and 2013 by (a) MLR model and (b) ANN model after Ref. [40].

5.3. Hybrid Models

Hybrid models aim to achieve higher accuracy and reliability by combining different forecasting methods, making them particularly effective in addressing the complexities of dynamic and multifaceted systems like electricity demand forecasting. One such approach, as demonstrated by Ref. [42], utilizes a modulated Fourier expansion to forecast Türkiye's electricity demand. This method captures periodic variations, modulating them with seasonal effects to achieve a high level of accuracy. Their study highlights the capability of this model to fit the data within a 4% margin and predict future demand within 9.8%, demonstrating its effectiveness in a deregulated electricity market [43].

Furthermore, the integration of optimization techniques with machine learning algorithms has been shown to further enhance forecasting performance. Ref. [43] explored this by combining medium neural networks (MNN), the Whale Optimization Algorithm (WOA), and Support Vector Machine (SVM) methods. Their approach effectively modeled Türkiye's electricity demand, using socio-economic data such as GDP, population, imports, and exports as inputs. The results demonstrated that these hybrid methods outperformed traditional models, providing more accurate long-term forecasts and ensuring a robust basis for energy planning and policy-making.

Table 5 highlights the effectiveness of hybrid models in improving electricity demand forecasting accuracy, supporting the previous discussions on their advantages. The table presents key findings from various studies, demonstrating how combining different forecasting methods, such as neuro-fuzzy models and optimization algorithms, leads to more reliable predictions in the energy market. These examples reinforce the notion that hybrid models provide a robust foundation for long-term energy planning and policy-making.

Table 5. Forecasts made with hybrid models.

Title	Model(s) Used	Key Findings	Reference
Mid-Term Energy Demand Forecasting by Hybrid Neuro-Fuzzy Models	Local Linear Neuro-Fuzzy Model, Hodrick-Prescott Filter	HPLLNF hybrid model, utilizing mutual information and HP filter, demonstrates excellent performance in long-term energy demand forecasting for gasoline, crude oil, and natural gas.	[44]
A novel hybrid approach based on Particle Swarm Optimization and Ant Colony Algorithm to forecast energy demand of Turkey	Particle Swarm Optimization, Ant Colony Optimization	Hybrid PSO-ACO model provided the lowest relative estimation errors, with the quadratic form offering better-fit solutions for Türkiye's energy demand forecasting.	[45]
Forecasting the annual electricity consumption of Turkey using an optimized grey model	Optimized Grey Modeling (1,1)	Optimized Grey Model provided superior accuracy in forecasting Türkiye's electricity consumption, with better predictions in a direct approach.	[46]
Forecasting energy consumption using ensemble ARIMA-ANFIS hybrid algorithm	ARIMA, ANFIS	ARIMA-ANFIS hybrid model outperforms single models, particularly with data insufficiency, achieving a low MSE of 0.026%.	[47]
Forecasting of Turkey natural gas demand using a hybrid algorithm	Genetic Algorithm, Simulated Annealing	Hybrid GA-SA algorithm showed better forecasting accuracy for Türkiye's natural gas demand compared to linear regression.	[48]
Forecasting the annual electricity consumption of Turkey using a hybrid model	Multiple Linear Regression, ANN	Hybrid model combining regression and ANN provided an average absolute forecast error of 2.25% in predicting Türkiye's electricity demand.	[49]
Two-phase particle swarm optimized-support vector regression hybrid model integrated with ICEEMDAN	ICEEMDAN, PSO, SVR	Hybrid ICEEMDAN-PSO-SVR model provides superior accuracy in short-term and long-term electricity demand forecasting, outperforming alternative methods.	[50]
A Hybrid Neural Network Model for Power Demand Forecasting	LSTM, CNN	Hybrid LSTM+CNN model provides higher accuracy in power demand forecasting by integrating contextual information like temperature and humidity.	[51]
Machine Learning Based Hybrid System for Imputation and Efficient Energy Demand Forecasting	Extreme Gradient Boosting, Categorical Boosting, RF	Hybrid model significantly improves forecasting accuracy with an R-squared value of 0.9212, effectively handling data gaps through feature engineering.	[52]
Artificial Intelligence Approaches to Estimate the Transport Energy Demand in Turkey	Static & Recurrent Neural Networks, ARIMA	Multiple AI and hybrid models were developed for transport energy demand, with polynomial fitting yielding predictions close to official estimates.	[53]

6. UNDERSTANDING TÜRKİYE'S ELECTRICITY PRODUCTION AND CONSUMPTION TRENDS

In recent years, Türkiye has witnessed a substantial increase in electricity demand, driven by factors such as economic growth, population expansion, and urbanization. This surge in demand has underscored the critical importance of accurate electricity demand forecasting for ensuring energy security and optimizing the use of energy resources.

Ref. [54] emphasizes the importance of precise electricity demand forecasting in low- and middle-income countries, where economic and climatic factors exert a significant influence on demand. Their analysis suggests that incorporating these determinants into Türkiye’s electricity demand forecasting models could improve the accuracy of predictions, thereby facilitating more informed policy decisions and enhancing resource management in the energy sector.

Electricity demand in Türkiye is influenced by a variety of factors, including economic growth, industrial production, technological advancements, climatic conditions, and socio-demographic variables. Studies on electricity demand forecasting in Türkiye have employed various methodologies to analyze the impact of these factors. For example, Ref. [9] utilized econometric models to examine Türkiye's electricity demand, providing valuable guidance on the methods appropriate for energy demand forecasting.

As illustrated in Tables 6 and 7, Türkiye's electricity production and consumption patterns have fluctuated over the years. The total net production from hydroelectric, geothermal, solar, wind, biomass, and conventional thermal sources has increased steadily. The data on net consumption, imports, and exports presented in these tables are crucial for understanding the balance between energy supply and demand.

Table 6. Electricity generation and consumption in Türkiye, 1990–2001 in Billion kWh after Ref. [55]. Generation components may not add to total due to rounding.

Years	Net generation				Net consumption	Imports	Exports
	Hydroelectric	Geo/solar/wind/biomass	Conventional thermal	Total			
1990	22.90	0.10	32.30	55.20	50.60	0.20	0.90
1991	22.50	0.10	35.20	57.80	54.00	0.80	0.50
1992	26.30	0.10	38.20	64.70	60.00	0.20	0.30
1993	33.60	0.10	37.30	71.10	65.70	0.20	0.60
1994	30.30	0.10	44.70	75.20	69.40	0.00	0.60
1995	35.20	0.30	47.40	82.90	76.40	0.00	0.70
1996	40.10	0.20	50.90	91.20	84.70	0.30	0.40
1997	39.40	0.40	59.30	99.10	94.40	2.50	0.30
1998	41.80	0.30	64.30	106.50	102.00	3.30	0.30
1999	34.30	0.30	76.60	111.20	105.50	2.30	0.30
2000	30.60	0.30	88.10	119.00	114.00	3.80	0.40
2001	23.80	0.40	92.40	116.60	112.60	4.60	0.40

Table 7. Electricity generation and consumption in Türkiye, 2002–2022 in billion kWh after Ref. [56]. Generation components may not add to total due to rounding.

Years	Net generation				Net consumption	Imports	Exports
	Hydroelectric	Geo/solar/wind/biomass	Conventional thermal	Total			
2002	33.60	0.30	95.50	129.40	102.90	3.60	0.40
2003	35.30	0.30	105.00	140.60	111.80	1.20	0.60
2004	46.00	0.30	104.40	150.70	121.10	0.50	1.10
2005	39.50	0.30	122.20	162.00	130.30	0.60	1.80
2006	44.20	0.40	131.80	176.30	144.10	0.60	2.20
2007	35.70	0.70	155.10	191.60	155.10	0.90	2.40
2008	33.20	1.20	164.00	198.40	161.90	0.80	1.10
2009	34.40	1.90	150.30	186.60	156.90	0.80	1.60
2010	49.80	3.40	149.90	203.00	172.10	1.10	1.90
2011	49.60	5.20	162.70	217.60	186.10	4.60	3.70
2012	55.10	6.40	166.20	227.70	194.90	5.80	3.00

2013	56.60	8.50	163.90	229.00	198.00	7.40	1.20
2014	38.70	10.40	190.40	239.40	207.40	8.00	2.70
2015	64.10	14.50	171.30	249.90	217.30	7.10	3.20
2016	64.20	20.40	177.40	261.90	231.20	6.30	1.50
2017	55.70	25.70	202.80	284.30	249.00	2.70	3.30
2018	57.20	33.40	199.90	290.50	258.20	2.50	3.10
2019	84.50	38.00	166.60	289.10	257.30	2.20	2.80
2020	74.50	43.70	174.40	292.70	262.70	1.90	2.50
2021	53.40	53.60	212.50	319.50	286.70	2.30	4.20
2022	63.70	60.00	189.30	312.90	286.60	6.40	3.70

The methods used in electricity demand forecasting include various approaches such as statistical models, machine learning techniques, and hybrid models. A study conducted by [30] predicted Türkiye's primary energy demand using ARIMA models. Additionally, machine learning techniques like artificial neural networks and fuzzy logic are widely used to achieve more accurate and reliable forecasts [40]. In addition, hybrid models aim to enhance prediction accuracy by combining different methods [43].

The determinants of electricity demand include economic, climatic, socio-demographic, and technological factors[1] examined the relationship between electricity consumption and economic growth in Türkiye, revealing that these two variables mutually influence each other. This finding underscores the critical role of economic activity in driving electricity demand. Separately, the long-term trend in per capita electricity consumption, as illustrated in Fig. 9, reflects how various factors, including economic growth, have contributed to the steady increase in energy usage from 1990 to 2022. The Fig. 8 highlights the continuous rise in per capita electricity consumption, demonstrating the broader impact of these interconnected determinants on Türkiye's energy needs.

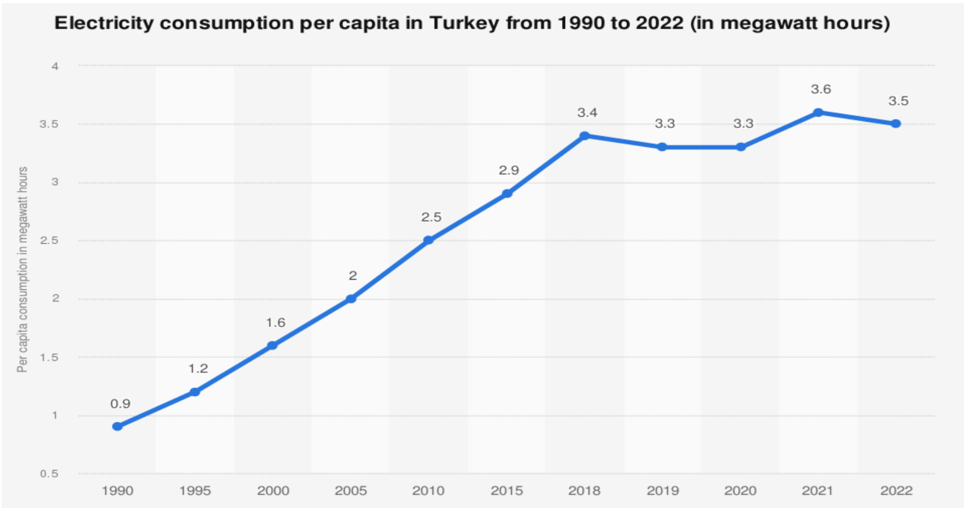

Figure 9. Electricity consumption per capita in Türkiye from 1990 to 2022, in MWh after Ref. [57].

Climatic conditions also have a significant impact on electricity demand. For instance, an increase in temperature raises the need for cooling, thus increasing electricity demand [58]. Population growth and the rise in urbanization rates are other important factors affecting electricity demand [59]. The methods and determinants used in electricity demand forecasting are supported by short, medium, and long-term forecasting strategies. Short-term forecasts are critical for maintaining the balance between energy supply and demand. Medium-term forecasts guide energy investment plans and policy-making. Long-term forecasts are necessary for the strategic planning of energy policies and ensuring sustainable energy supply [60].

This study comprehensively examines the methods, determinants, and forecasting horizons used in electricity demand forecasting in Türkiye. Additionally, specific case studies and policy recommendations for Türkiye are presented, providing a comprehensive perspective for future research and applications [10].

7. DIMENSIONS OF ENERGY FORECASTING: APPROACHES AND IMPLICATIONS

Forecasting horizons play a critical role in the management and planning of energy resources across various timeframes, ranging from immediate operational adjustments to long-term strategic initiatives. This section delves into the different forecasting strategies (i.e. short-term, medium-term, and long-term) that are instrumental in aligning energy solutions with both current and future demands. It also examines the challenges and limitations inherent in forecasting, such as issues related to data quality, model accuracy, external influences, and the impacts of climate change. Furthermore, it provides policy recommendations aimed at enhancing forecasting practices, including the promotion of renewable energy, the improvement of energy efficiency, investment in smart technologies, and the development of long-term strategic plans.

7.1. Forecasting Strategies

Electricity demand forecasting can be categorized into short-term, medium-term, and long-term strategies, each of which serves a vital function in energy management. Short-term forecasts are crucial for ensuring the stability of the grid on a daily basis and optimizing operational efficiency. Medium-term forecasts support tactical planning efforts, such as resource allocation and maintenance scheduling. In contrast, long-term forecasts are essential for strategic decision-making, guiding infrastructure investments and informing policy development to secure a resilient and sustainable energy future.

7.1.1. Short-Term Forecasting

Short-term electricity demand forecasting is typically conducted for daily, weekly, or monthly periods and is crucial for balancing energy supply and demand. These forecasts are particularly important for the operational planning of energy production facilities and pricing in energy markets. Machine learning techniques, such as artificial neural networks (ANNs) and fuzzy logic, are widely used in short-term forecasting due to their high accuracy rates. For instance, forecasts using ANNs have demonstrated significant success in predicting short-term electricity demand in Türkiye, as shown in the study by [61], where the ANN model effectively captured daily and monthly consumption patterns.

Fig. 10 illustrates a multi-layer ANN structure designed for short-term forecasts, as presented by [61]. Fig. 10 exemplifies how ANNs can effectively model complex relationships between various input factors, such as yearly and monthly data, to predict electricity demand. The model's structure, which includes input, hidden, and output layers, allows for the accurate forecasting of electricity consumption, particularly under dynamic conditions like those experienced during the pandemic. This visual representation emphasizes the adaptability and precision of ANN models in capturing the nuances of short-term electricity demand.

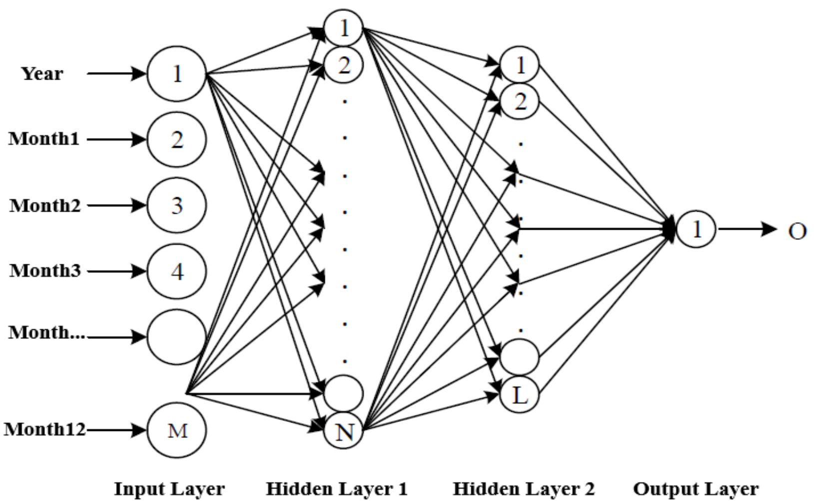

Figure 10. An example multi-layer ANN structure for short-term forecasts after Ref. [61].

During the COVID-19 pandemic, the importance of short-term electricity demand forecasting became even more pronounced. Restrictions imposed during the pandemic and changes in consumption habits led to unexpected shifts in electricity demand. The study by Ref. [62] underscored the necessity for flexible and adaptable forecasting models during this period, highlighting the challenges and adjustments required in short-term forecasting to accurately reflect the altered demand structure.

7.1.2 Medium-Term Forecasting

Medium-term forecasting is generally performed for annual periods and is crucial in energy investment planning, maintenance, and capacity expansion processes. These forecasts are vital for ensuring energy supply security and improving the efficiency of energy systems. Recent studies conducted in Türkiye demonstrate how medium-term forecasts are integral to determining energy policies and planning investments [63]. For instance, Ref. [63] utilized time series and regression models to estimate the gross annual electricity demand in Türkiye, providing valuable insights for medium-term planning.

Table 8 provides an overview of key studies focused on medium-term electricity demand forecasting in Türkiye. The table illustrates the effectiveness of various models, including Optimized Grey Modeling and Artificial Neural Networks (ANNs), in predicting electricity consumption. These models have shown to improve forecasting accuracy significantly, particularly when incorporating socio-economic indicators and climatic conditions, supporting the importance of medium-term planning in the energy sector.

Table 8. Key studies on medium-term electricity demand forecasting in Türkiye.

Title	Model(s) Used	Key Findings	Author(s)
Forecasting the annual electricity consumption of Turkey using an optimized grey model	Optimized Grey Modeling (1,1)	Optimized Grey Modeling technique provided superior accuracy in forecasting Türkiye's electricity consumption compared to other models, particularly when using the direct forecasting approach.	[46]
Estimating Gross Annual Electricity Demand of Turkey	Time Series, Regression, Fuzzy Logic	Time series model showed better forecasting performance; strong correlation with GDP.	[63]
Forecasting annual gross electricity demand by artificial neural networks using predicted values of socio-economic indicators and climatic conditions: Case of Turkey	Artificial Neural Networks (ANN), Multiple Linear Regression	The model accurately forecasted Türkiye's annual gross electricity demand using ANN, outperforming official predictions by incorporating socio-economic indicators and climatic conditions.	[40]
Medium-term electricity demand forecasting based on MARS	Multivariate Adaptive Regression Splines (MARS)	The MARS method outperformed other models such as Multiple Linear Regression (MLR) and Artificial Neural Networks (ANN) in terms of test error and stability in medium-term electricity demand forecasting.	[64]
Vision 2023: Scrutinizing achievability of Turkey's electricity capacity targets and generating scenario based nationwide electricity demand forecasts	Semi-empirical electricity demand model	The study forecasts Türkiye's electricity demand until 2023 under different scenarios, highlighting potential shortfalls in achieving Vision 2023 capacity targets, particularly in wind and nuclear energy.	[60]
Forecasting Turkey's Monthly Electricity Demand by Seasonal Artificial Neural Network	Seasonal ANN, SARIMA	Demonstrated that ANN models effectively capture seasonality and trends, providing accurate monthly electricity demand forecasts.	[65]
Forecasting Electricity Demand in Turkey Using Optimization and Machine Learning Algorithms	MNN, WAO, SVM	The combination of optimization algorithms with machine learning provided highly accurate demand forecasts.	[43]

The study by Ref. [7] employed a time-varying parameter approach to forecast industrial and residential electricity demand in Türkiye, underscoring the importance of methods used in medium-term forecasting. By focusing on how economic variables influence electricity demand, their research provides valuable insights for energy policy and investment decisions.

7.1.3. Long-Term Forecasting

Long-term forecasting, typically conducted over periods of ten years or more, is crucial for the strategic planning of energy policies. It provides policymakers with the necessary insights to ensure a sustainable energy supply and to plan for the efficient use of energy resources in the face of growing demand. Ref. [60] examined Türkiye’s electricity capacity targets for 2023 and provided scenario-based forecasts, highlighting the importance of these forecasts in guiding policy decisions that aim to balance economic growth with environmental sustainability. By analyzing various scenarios, Melikoğlu emphasized the potential impacts of different policy decisions on Türkiye’s future energy landscape, making such long-term forecasts indispensable tools for national energy strategy.

Climate change and technological advancements are significant factors to consider in long-term energy forecasts, as they can drastically alter the patterns of electricity demand. Türkiye's energy projections, extending up to 2050, anticipate the profound impacts of climate change and the integration of new technologies, such as renewable energy and smart grids, on the nation's electricity consumption [66]. Furthermore, long-term forecasting models, like the optimized grey models and hybrid approaches discussed by [46], have been noted for their high accuracy rates in predicting energy consumption. These models allow for more precise adjustments in energy planning, ensuring that future supply meets the anticipated demand even in the face of uncertainty and changing conditions.

Table 9 complements this discussion by summarizing the pros and cons of different long-term electricity demand forecast models, offering a comparative analysis of their performance. For instance, while artificial neural networks demonstrate high accuracy in annual demand forecasting, they may fall short when external factors like population changes are not considered. This table provides a valuable reference for selecting the most effective model for specific forecasting needs, thereby ensuring more reliable and informed energy policy decisions.

Table 9. Pros and cons of long-term electricity demand forecast models.

Model Type	Pros	Cons	Reference Title	Author(s)
Artificial Neural Networks (ANN)	Demonstrated ability to forecast annual electricity demand with under 1% average error.	The model only used time-dependent electrical demand series, excluding factors like population and economy, which might limit accuracy in varying conditions.	Forecasting short-term electricity demand of Türkiye by artificial neural networks	[61]
Semi-empirical Electricity Demand Model	Provides accurate long-term forecasts and effectively evaluates policy impacts, matching up to 94,3% with previous forecasts.	The model’s effectiveness is highly dependent on the accuracy of the underlying scenarios and assumptions.	Vision 2023: Scrutinizing achievability of Türkiye's electricity capacity targets and generating scenario based nationwide electricity demand forecasts	[60]
Artificial Neural Networks + Support Vector Regression	Successfully estimates energy demand with acceptable error rates using multiple influencing factors, including socioeconomic indicators.	Requires extensive data and fine-tuning to achieve optimal accuracy; computationally intensive.	The Estimation of Türkiye's Energy Demand Through Artificial Neural Networks and Support Vector Regression Methods	[67]
Fourier Analysis with Feedback	Provides highly reliable hourly and daily electricity demand forecasts with errors as low as 0,87% for hour-ahead forecasts.	The method may not be effective in capturing unexpected or non-cyclical changes in demand.	Hourly electricity demand forecasting using Fourier analysis with feedback	[68]
Hybrid Model (ARIMA + LS-SVM)	Combines strengths of ARIMA and support vector machines, offering more realistic and reliable forecasts with better handling of unexpected fluctuations.	The hybrid model is complex to implement and requires significant computational resources and expertise.	A hybrid approach based on autoregressive integrated moving average and least-square support vector machine for long-term forecasting of net electricity consumption	[69]
GMDH-type Neural Network (GMDH-NN)	Achieved very close results to actual monthly electricity demand with a low mean absolute percentage error (MAPE) of 2,10%.	The model's accuracy might decrease if applied to significantly different datasets or longer forecasting periods.	GMDH-type neural network-based monthly electricity demand forecasting of Türkiye	[70]
Trigonometric Grey Model (TGM)	Effective for forecasting with a minimal mean absolute error (MAE) in short-term electricity consumption predictions.	May not capture long-term trends accurately due to reliance on short-term data characteristics.	Trigonometric Grey Prediction Method for Türkiye's Electricity Consumption Prediction	[71]

7.2. Challenges and Limitations in Forecasting

Electricity demand forecasting involves various challenges and limitations, which can stem from data quality, model constraints, and external factors such as economic volatility and climate change. Accurately predicting electricity demand is further complicated by the rapid integration of renewable energy sources and the evolving regulatory landscape. This section will examine the primary challenges and limitations encountered in electricity demand forecasting in Türkiye, highlighting how these factors interact to influence the accuracy and reliability of forecasts.

7.2.1 Data Quality

Data quality is a critical factor that directly impacts the accuracy and reliability of electricity demand forecasts. Inaccurate, incomplete, or inconsistent data can significantly compromise the performance of forecasting models, leading to erroneous predictions that can affect energy planning and policy decisions. Ref. [8] emphasized the importance of high-quality data in evaluating electricity supply in Türkiye, particularly in the context of economic growth and the increasing demand for electricity. The study highlighted that errors in data collection, such as discrepancies in historical consumption patterns or inaccuracies in recording economic indicators, can greatly diminish the precision of forecasts. Moreover, inadequate data can result in models that fail to accurately reflect real-world conditions, thereby leading to misguided energy strategies and inefficient resource allocation. Ensuring the integrity and reliability of data is therefore essential for producing accurate and actionable electricity demand forecasts in Türkiye.

7.2.2. Model Limitations

Model limitations are a critical consideration in electricity demand forecasting, as each forecasting approach comes with its own set of constraints. Statistical models, and machine learning techniques, while powerful, often operate under specific assumptions that may not fully capture the complexities of real-world scenarios. These limitations can hinder the accuracy of forecasts, particularly when models fail to account for external variables such as sudden economic shifts, policy changes, or climatic variations. For example, models that rely heavily on historical data may not perform well in rapidly changing environments where past trends do not predict future behavior. Ref. [3] highlighted the challenges of using models that do not fully consider the diverse and unpredictable factors impacting renewable energy sources in Türkiye, noting that these limitations can result in less reliable predictions and potentially flawed energy planning.

Fig. 11 provides a visual comparison of the projected electricity production in Türkiye up to 2050 using different forecasting models, including neural networks, fuzzy logic, and multiple regression [66].

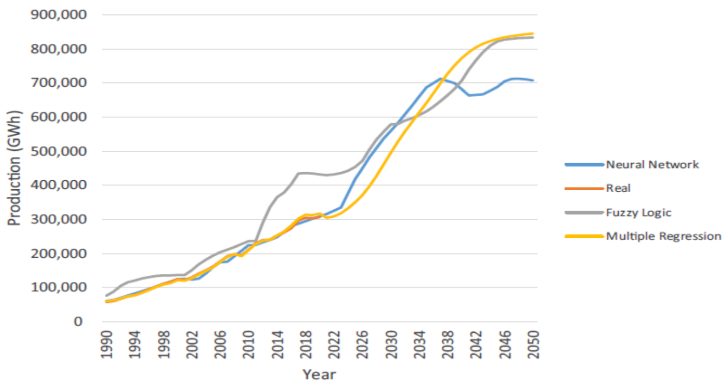

Figure 11. Türkiye's electricity production prediction results [66].

Highlights the discrepancies between these models, showing how various assumptions can lead to different outcomes. For instance, while neural networks might predict a steady increase in production, other models like fuzzy logic may show more volatility depending on their underlying assumptions. The differences illustrated in Fig. 11 emphasize the importance of selecting the right model for the specific forecasting context, as the choice of model can significantly influence the projections and, consequently, the strategic decisions made by policymakers.

As discussed under the long-term forecasting subheading, Table 9 also elaborates on the pros and cons of these different models. The table provides a comparative analysis that is essential for understanding the strengths and weaknesses of each approach, further underscoring the critical role that model selection plays in ensuring accurate and reliable electricity demand forecasts.

7.2.3. External Factors

External factors create significant challenges in electricity demand forecasting. Economic fluctuations, political changes, natural disasters, and global energy market volatility can impact forecast accuracy. For instance the COVID-19 pandemic revealed unexpected effects on electricity demand, highlighting the difficulties of short-term forecasting. Restrictions and changing consumption patterns during the pandemic led to unforeseen changes in electricity demand [62].

Analyzing sector-specific electricity consumption data provides insights into these unforeseen changes. Visuals (see Fig. 12, Fig. 13, and Fig. 14) from the study by [62] illustrate the trends in commercial, industrial, and residential electricity consumption between January and June from 2016 to 2020. The commercial sector experienced a significant decline in consumption during March, April, and May 2020, with only partial recovery in June. Industrial consumption also dropped sharply in April and May 2020 but surged in June as normalization efforts began. Residential consumption spiked in April 2020 but followed historical trends in other months. Figs. 12, 13 and 14 underscores the impact of COVID-19 restrictions on electricity demand across different sectors.

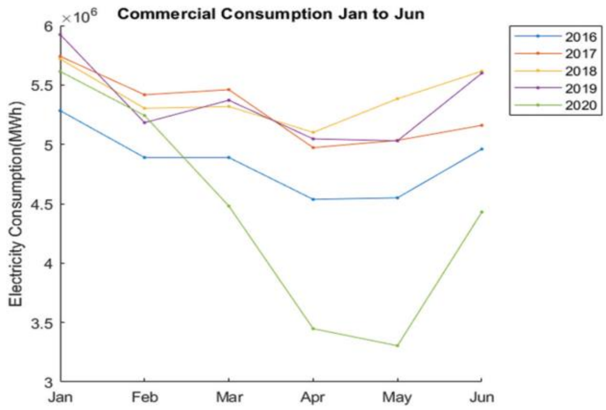

Figure 12. Commercial consumption between January-June 2016-2020 after Ref. [62].

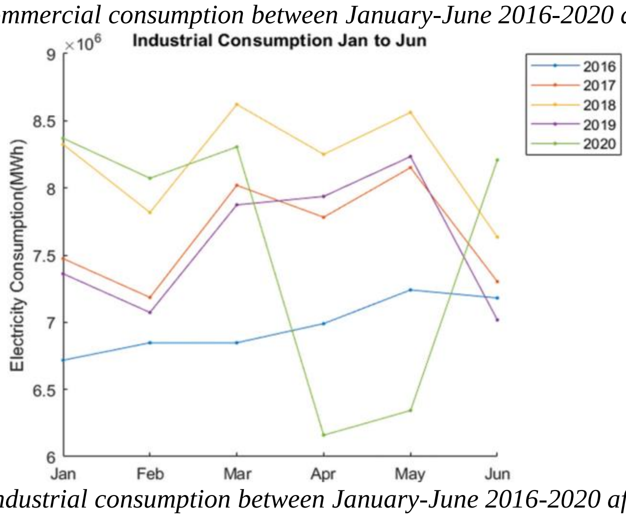

Figure 13. Industrial consumption between January-June 2016-2020 after Ref. [62].

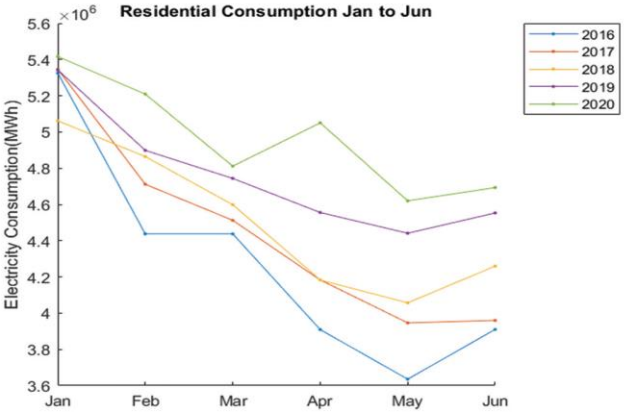

Figure 14. Residential consumption between January-June 2016-2020 after Ref. [62].

7.2.4. Climate Changes

In the Determinants of Electricity Demand section, under the Climatic Conditions subheading, we previously discussed the significant impact of seasonal temperature changes on electricity demand in Türkiye, as explored by Ref. [3]. We examined how varying temperatures influence electricity consumption, particularly the increased demand during the summer months due to the need for cooling. This was further analyzed with supporting data and insights from Table 3, which provided a detailed breakdown of Türkiye's seasonal electricity demand in 2023, showing the reliance on various energy sources throughout different seasons.

Climate change presents a unique challenge due to its potential to alter temperature patterns and, consequently, electricity consumption profiles. The study by Ref. [22] highlights the critical need to incorporate climate change projections into forecasting models to ensure accurate and reliable electricity demand predictions. As temperatures rise, the demand for electricity, particularly for cooling, is expected to increase, which underscores the importance of robust climate projections in energy planning.

By integrating these projections into forecasting models, we can better anticipate shifts in electricity demand driven by climate change, thereby enhancing the resilience of energy systems and ensuring they can meet future demands while maintaining environmental sustainability.

7.3. Policy Recommendations and Suggestions

Electricity demand forecasting is crucial for shaping energy policies, ensuring energy supply security, and promoting sustainability. Accurate forecasts help balance economic growth with environmental protection, guiding the development of energy efficiency measures and the integration of renewable energy sources. In Türkiye, these forecasts are vital for formulating strategies that address the nation's growing energy needs while also considering the impacts of climate change and technological advancements. By improving forecasting methods and data quality, Türkiye can create more effective and adaptive energy policies that support long-term sustainability and security.

7.3.1. Promotion of Renewable Energy Sources

To diversify Türkiye's energy supply and reduce dependency on external sources, the promotion of renewable energy sources is vital. As discussed in the Promotion of Renewable Energy Sources section under the Renewable Energy Potential subheading, the use of renewable energy not only contributes to energy security but also aligns with global environmental sustainability goals. Ref. [3] emphasized the high potential of renewable energy in Türkiye and the necessity of increasing the use of these sources in energy production. They highlighted the significant role of renewable energy in meeting Türkiye's growing energy demand while mitigating environmental impacts. In this context, it is important to increase investments in renewable energy and expand incentives for renewable energy sources to achieve long-term sustainability.

Table 10 provides a detailed overview of the installed renewable energy capacity in Türkiye from 2000 to 2020, illustrating the country's progress in developing its renewable energy infrastructure. The table highlights the growth in various renewable energy sectors, including hydraulic, geothermal, wind, solar, and biomass energy, and their respective contributions to the total installed power capacity.

Table 10. Renewable based installed power in Türkiye (MW) after Ref. [66].

Year	Hydraulic	Geothermal	Wind	Solar	Biomass	Renewables	Total Installed Power	Rate of Renewables in Production (%)
2000	11.175	17	19	-	10	11.221	27.264	41,20
2001	11.672	17	19	-	10	11.719	28.332	41,40
2002	12.240	17	19	-	14	12.291	31.845	38,60
2003	12.578	15	19	-	14	12.626	35.587	35,50
2004	12.645	15	19	-	14	12.693	36.824	34,50
2005	12.906	15	20	-	14	12.955	38.843	33,40
2006	13.062	23	59	-	20	13.164	40.564	32,50
2007	13.394	23	147	-	21	13.586	40.835	33,30
2008	13.828	29	363	-	38	14.260	41.817	34,10
2009	14.553	77	791	-	65	15.487	44.761	34,60
2010	15.831	94	1.320	-	85	17.331	49.524	35,00
2011	17.137	114	1.728	-	104	19.084	52.911	36,10
2012	19.609	162	2.260	-	147	22.179	57.059	38,90
2013	22.289	310	2.759	-	178	25.537	64.007	39,90
2014	23.643	404	3.629	40	227	27.945	69.519	40,20
2015	25.867	623	4.503	248	277	31.520	73.146	43,10
2016	26.681	820	5.751	832	363	34.449	78.497	43,90
2017	27.273	1.063	6.516	3.420	477	38.751	85.200	45,50
2018	28.291	1.282	7.005	5.062	621	42.264	88.550	47,70
2019	28.503	1.514	7.591	5.995	791	44.395	91.267	48,60
2020	30.983	1.613	8.832	6.667	1.105	49.202	95.890	51,30

Fig. 15 further illustrates the increasing rate of renewables in electricity production in Türkiye, showcasing the steady rise in the share of renewable energy in the country’s total energy mix. This visual representation underscores the importance of continuing to invest in and promote renewable energy sources to sustain this positive trend.

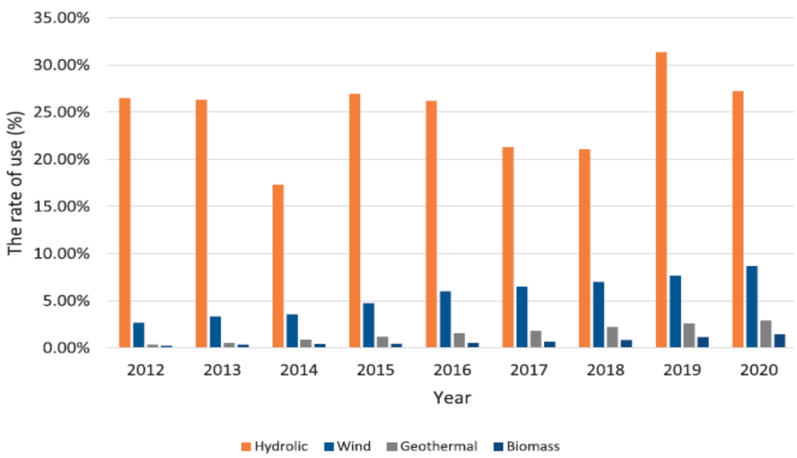

Figure 15. The rate of renewables in electricity production in Türkiye after Ref. [66].

7.3.2. Development of Energy Efficiency Policies

Energy efficiency is a critical component in the effort to reduce electricity demand and promote the more effective use of energy resources. Implementing energy efficiency policies can lead to significant energy savings, thereby positively impacting electricity demand. In Türkiye, the development of such policies is vital to addressing the growing energy needs while also mitigating environmental impacts.

Ref. [8] highlighted the importance of energy efficiency policies in shaping electricity demand forecasting, emphasizing their role in achieving sustainable energy goals and enhancing energy security.

Table 11 provides a detailed overview of various studies that have examined the impact of energy efficiency policies on electricity demand. The table summarizes key findings from multiple research efforts, offering insights into how different energy efficiency policies have influenced electricity consumption across various regions and time periods. For instance, [72] found that demand management programs and energy efficiency policies could reduce electricity demand by as much as 10.5% to 8.8%. On the other hand, some studies, like [73], indicated that certain policies, such as minimum-efficiency standards for energy-using household goods, might actually lead to an increase in energy demand due to rebound effects. These mixed results underscore the importance of carefully designing and implementing energy efficiency policies to maximize their effectiveness.

Table 11. Impact of energy efficiency policies on electricity demand.

Study	Period	Articles Considered	Energy Efficiency (EE) Policy	Effect on Energy Demand
[72]	2000-2020	54	Demand management programs and energy efficiency policies	[-10,5%; -8,8%]
[73]	2010-2019	17	Minimum-efficiency standards for energy-using household goods	Increased energy demand
[74]	2005-2018	30	Electrification policies and energy efficiency in residential sector	[5% - 15% increase]
[75]	2006-2014	19	Environmental regulations and market policies in EU electricity industry	Mixed impacts on efficiency
[76]	2005-2015	29	Energy efficiency incentive programs in U.S.	Smaller effect than expected
[77]	2009-2016	50	State-level energy efficiency policies in the U.S.	No significant reduction
[78]	1980-2015	20	Energy conservation policies in New Zealand's industrial and commercial sectors	Partial rebound effects

7.3.3. Investments in Smart Grids and Technology

As previously mentioned in the Technological Developments subsection under the Determinants of Electricity Demand section, smart grids and advanced technologies play a crucial role in enhancing the efficiency of energy systems and balancing energy supply and demand. As discussed earlier, smart grids optimize electricity distribution by reducing energy losses and increasing demand response flexibility. These technologies enable real-time monitoring and management of electricity demand, leading to more efficient energy use and strengthened grid stability.

In the context of Türkiye's energy strategy, investments in smart grids are particularly significant. Ref. [60] highlighted that such investments are critical for achieving Türkiye's electricity capacity targets. By integrating these technologies into the energy system, the country can better manage its growing energy demands and transition towards a more sustainable energy future. The implementation of smart grids not only improves electricity management but also ensures preparedness for future energy needs.

7.3.4. Long-Term Energy Planning and Strategic Goals

Long-term energy planning is crucial for ensuring energy supply security and developing sustainable energy policies in Türkiye. As previously discussed in the "Determinants of Electricity Demand" section under the "Technological Developments" subheading, the integration of advanced technologies like smart grids is essential for achieving these goals. Academic studies, such as those illustrated in Fig. 16 and Fig. 17, provide projections of Türkiye's electricity production and consumption, highlighting potential future trends that policymakers must consider. Fig. 16 demonstrates the predicted increase in Türkiye's electricity production, while Fig. 17 outlines the anticipated rise in electricity consumption. These projections underscore the importance of setting strategic long-term goals and implementing the necessary policies to balance supply and demand effectively [66].

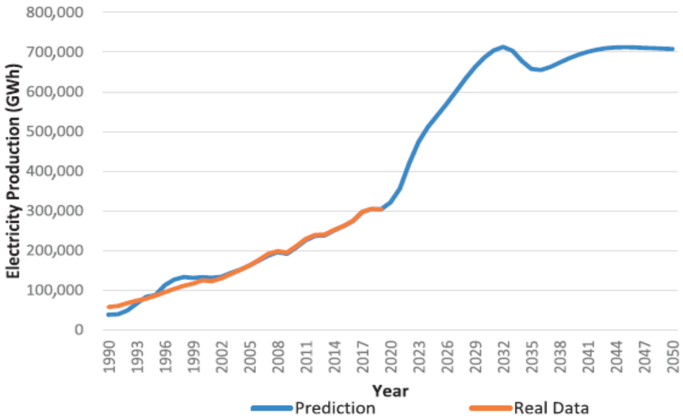

Figure 16. Türkiye's electricity production prediction after Ref. [66].

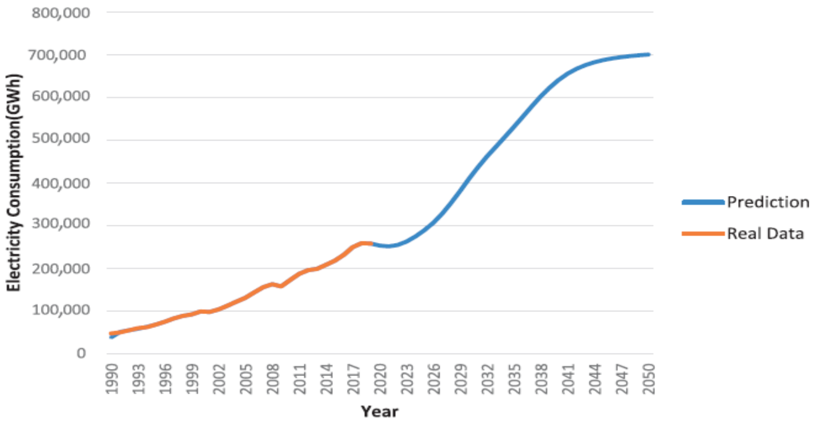

Figure 17. Türkiye's electricity consumption prediction after Ref. [66].

8. CONCLUSIONS

This comprehensive review of electricity demand forecasting in Türkiye has provided valuable insights into the complex interplay of factors influencing energy consumption and the methodologies used to predict future demand. The study set out to address three key research questions, and the findings offer significant contributions to both academic understanding and practical applications in energy planning.

Addressing RQ1, "What are the most significant determinants of electricity demand in Türkiye?", the review identifies several critical factors. Economic growth and industrial production emerge as primary drivers, with a strong bidirectional relationship between electricity consumption and economic development. Climatic conditions, particularly in the context of climate change, play a crucial role in shaping demand patterns, especially for cooling needs. Socio-demographic factors, including population growth and urbanization, also significantly influence electricity consumption. Additionally, technological advancements present a dual impact, with energy-efficient technologies potentially reducing demand while the proliferation of new electric-powered technologies increases overall consumption.

In response to RQ2, "Which forecasting methods are most effective in capturing these dynamics?", the study highlights the growing effectiveness of advanced techniques such as artificial neural networks (ANNs) and other machine learning approaches. These methods demonstrate superior capability in capturing the complex interactions between various determinants of electricity demand. Traditional statistical models, while still valuable, are increasingly complemented or replaced by these more sophisticated techniques. Hybrid models that combine multiple approaches show particular promise in improving forecast accuracy across different time horizons.

Regarding RQ3, “How can these insights be applied to improve future energy planning and policy development?”, the review offers several key recommendations. Integrated modeling approaches that incorporate economic, climatic, technological, and socio-demographic factors should be prioritized to provide more comprehensive and accurate forecasts. Energy policies should be closely aligned with industrial and economic development strategies to balance demand management with economic growth objectives. Continued investment in smart grid technologies and demand-side management tools can enhance short-term forecasting accuracy and optimize electricity use. Long-term planning must incorporate climate change projections to ensure system resilience. Developing sector-specific forecasting strategies and improving data quality and accessibility across different sectors will be crucial for refining models and supporting evidence-based policymaking.

The findings of this review underscore the critical importance of accurate electricity demand forecasting for Türkiye's energy security and sustainable economic growth. By adopting more sophisticated modeling techniques, integrating diverse data sources, and aligning forecasting efforts with broader economic and environmental goals, Türkiye can navigate the complexities of its evolving energy landscape more effectively. This comprehensive analysis provides a solid foundation for future research and policy development in electricity demand forecasting. It highlights the need for continued innovation in forecasting methodologies, improved data collection and analysis, and the integration of forecasting insights into broader energy and economic planning processes. As Türkiye continues to develop its energy infrastructure and pursue sustainable growth, the insights and recommendations from this study will be invaluable in shaping a resilient and efficient energy future.

REFERENCES

[1] Altinay G, Karagol E. Electricity consumption and economic growth: Evidence from Turkey. *Energy Economics*. 2005;27(6):849-56. doi:10.1016/j.eneco.2005.07.002.

[2] Tanugur MM, Zehir MA. Investigation of Residential Demand Response Flexibility Including the Effects of the COVID-19 Pandemic on Energy Usage Habits in Turkey. In: *2022 IEEE 4th Global Power, Energy and Communication Conference (GPECOM)*; 14-17 June 2022; Nevsehir, Turkey. p. 523-528.

[3] Evrendilek F, Ertekin C. Assessing the potential of renewable energy sources in Turkey. *Renewable Energy*. 2003;28(15):2303-2315. doi:10.1016/S0960-1481(03)00138-1.

[4] T.C. Ministry of Environment Urbanisation and Climate Change. Total Energy Consumption by Sectors. 2022. Available from: https://cevreselgostergeler.csb.gov.tr/en/total-energy-consumption-by-sectors-i-86042. Accessed: 16 August 2024.

[5] Turkish Electricity Transmission Corporation. Türkiye Electricity Production-Transmission 2019 Statistics. 2020. Available from: https://www.teias.gov.tr/turkiye-elektrik-uretim-iletim-istatistikleri. Accessed: 16 August 2024.

[6] T.C. Ministry of Environment Urbanisation and Climate Change. Share of Renewable Electricity in Gross Electricity Production. Available from: https://cevreselgostergeler.csb.gov.tr/en/share-of-renewable-electricity-in-gross-electricity-production-i-86048. Accessed: 16 August 2024.

[7] Arisoy I, Ozturk I. Estimating industrial and residential electricity demand in Turkey: A time varying parameter approach. *Energy*. 2014;66:959-64. doi:10.1016/j.energy.2014.01.016.

[8] Yucekaya A. Evaluating the Electricity Supply in Turkey Under Economic Growth and Increasing Electricity Demand. *J Eng Technol Appl Sci*. 2017;2(2):81-89. doi:10.30931/jetas.336840.

[9] Bakirtas T, Bildirici M, Bakırtaş T, Karbuz S. An econometric analysis of electricity demand in Turkey. *ODTÜ Gelişme Dergisi*. 2000;27:23-34. Available from: https://hdl.handle.net/11511/92114.

[10] Balat M. Electricity Consumption and Economic Growth in Turkey: A Case Study. *Energy Sources Part B*. 2009;4(2):155-165. doi:10.1080/15567240701620416.

[11] Çunkaş M, Altun AA. Long term electricity demand forecasting in Turkey using artificial neural networks. *Energy Sources Part B*. 2010;5(3):279-289. doi:10.1080/15567240802533542.

[12] Gungor VC, Sahin D, Kocak T, Ergüt S, Buccella C, Cecati C, et al. Smart Grid Technologies: Communication Technologies and Standards. *IEEE Trans Ind Inform*. 2011;7(4):529-539. doi:10.1109/TII.2011.2166794.

[13] Sovacool BK, Hirsh RF. Beyond batteries: An examination of the benefits and barriers to plug-in hybrid electric vehicles (PHEVs) and a vehicle-to-grid (V2G) transition. *Energy Policy*. 2009;37(3):1095-1103. doi:10.1016/j.enpol.2008.10.005.

[14] Rosenquist G, McNeil M, Iyer M, Meyers S, McMahon J. Energy efficiency standards for equipment: Additional opportunities in the residential and commercial sectors. *Energy Policy*. 2006;34(17):3257-3267. doi:10.1016/j.enpol.2005.06.026.

[15] Lund H, Mathiesen BV. Energy system analysis of 100% renewable energy systems-The case of Denmark in years 2030 and 2050. *Energy*. 2009;34(5):524-531. doi:10.1016/j.energy.2008.04.003.

[16] Zhong RY, Xu X, Klotz E, Newman ST. Intelligent Manufacturing in the Context of Industry 4.0: A Review. *Engineering*. 2017;3(5):616-630. doi:10.1016/J.ENG.2017.05.015.

[17] Sedlmeir J, Buhl HU, Fridgen G, Keller R. The Energy Consumption of Blockchain Technology: Beyond Myth. *Bus Inf Syst Eng*. 2020;62(6):599-608. doi:10.1007/s12599-020-00656-x.

[18] Zhang Y, Ansari N. On architecture design, congestion notification, TCP incast and power consumption in data centers. *IEEE Commun Surv Tutor*. 2013;15(1):39-64. doi:10.1109/SURV.2011.122211.00017.

[19] Hook A, Court V, Sovacool BK, Sorrell S. A systematic review of the energy and climate impacts of teleworking. *Environ Res Lett*. 2020;15(9):093003. doi:10.1088/1748-9326/ab8a84.

[20] Strubell E, Ganesh A, McCallum A. Energy and Policy Considerations for Modern Deep Learning. In: *Proceedings of the AAAI Conference on Artificial Intelligence*; 7-12 February 2020. p. 13693-13696.

[21] Palizban O, Kauhaniemi K. Energy storage systems in modern grids—Matrix of technologies and applications. *J Energy Storage*. 2016;6:248-259. doi:10.1016/j.est.2016.02.001.

[22] Guven D, Kayalica MO, Kayakutlu G, Isikli E. Impact of climate change on sectoral electricity demand in Turkey. *Energy Sources Part B*. 2021;16(3):235-257. doi:10.1080/15567249.2021.1883772.

[23] Li M, Allinson D, He M. Seasonal variation in household electricity demand: A comparison of monitored and synthetic daily load profiles. *Energy Build*. 2018;179:292-300. doi:10.1016/j.enbuild.2018.09.018.

[24] Cassarino GT, Sharp E, Barrett M. The impact of social and weather drivers on the historical electricity demand in Europe. *Appl Energy*. 2018;229:176-185. doi:10.1016/j.apenergy.2018.07.108.

[25] Fonseca FR, Jaramillo P, Bergés M, Severnini E. Seasonal effects of climate change on intra-day electricity demand patterns. *Clim Change*. 2019;154:435-451. doi:10.1007/s10584-019-02413-w.

[26] Eshraghi H, de Queiroz AR, Sankarasubramanian A, DeCarolis JF. Quantification of climate-induced interannual variability in residential U.S. electricity demand. *Energy*. 2021;236:121273. doi:10.1016/j.energy.2021.121273.

[27] Load Dispatcher Information System (YTBS). Electricity Statistics of Türkiye. 2019. Available from: https://ytbsbilgi.teias.gov.tr/ytbsbilgi/frm_istatistikler.jsf. Accessed: 15 August 2024.

[28] Tatli H. Short-and long-term determinants of residential electricity demand in Turkey. *Int J Econ Manag Account*. 2017;25(3):443-464. doi:10.31436/ijema.v25i3.448.

[29] Zhao Y, Wang S. The relationship between urbanization, economic growth and energy consumption in China: An econometric perspective analysis. *Sustainability*. 2015;7(5):5609-5627. doi:10.3390/su7055609.

[30] Ediger VŞ, Akar S. ARIMA forecasting of primary energy demand by fuel in Turkey. *Energy Policy*. 2007;35(3):1701-1708. doi:10.1016/j.enpol.2006.05.009.

[31] Akay D, Atak M. Grey prediction with rolling mechanism for electricity demand forecasting of Turkey. *Energy*. 2007;32(9):1670-1675. doi:10.1016/j.energy.2006.11.014.

[32] Dilaver Z, Hunt LC. Industrial electricity demand for Turkey: A structural time series analysis. *Energy Econ*. 2011;33(3):426-436. doi:10.1016/j.eneco.2010.10.001.

[33] Hekimoğlu M, Barlas Y. Sensitivity analysis for models with multiple behavior modes: a method based on behavior pattern measures. *Syst Dyn Rev*. 2016;32(3-4):332-362. doi:10.1002/sdr.1568.

[34] Deb C, Zhang F, Yang J, Lee SE, Shah KW. A review on time series forecasting techniques for building energy consumption. *Renew Sustain Energy Rev*. 2017;74:902-924. doi:10.1016/j.rser.2017.02.085.

[35] Lara-Benítez P, Carranza-García M, Luna-Romera JM, Riquelme JC. Temporal convolutional networks applied to energy-related time series forecasting. *Appl Sci*. 2020;10(7):2322. doi:10.3390/app10072322.

[36] Bu SJ, Cho SB. Time series forecasting with multi-headed attention-based deep learning for residential energy consumption. *Energies*. 2020;13(18):4722. doi:10.3390/en13184722.

[37] Nooruldeen O, Alturki S, Baker MR, Ghareeb A. Time Series Forecasting for Decision Making on City-Wide Energy Demand: A Comparative Study. In: *2022 International Conference on Decision Aid Sciences and Applications*; Chiangrai, Thailand. p. 1706-1710.

[38] Pełka P. Analysis and Forecasting of Monthly Electricity Demand Time Series Using Pattern-Based Statistical Methods. *Energies*. 2023;16(2):827. doi:10.3390/en16020827.

[39] Tzelepi M, Symeonidis C, Nousi P, Kakaletsis E, Manousis T, Tosidis P, et al. Deep Learning for Energy Time-Series Analysis and Forecasting. *arXiv preprint*. 2023;arXiv:2306.09129.

[40] Günay ME. Forecasting annual gross electricity demand by artificial neural networks using predicted values of socio-economic indicators and climatic conditions: Case of Turkey. *Energy Policy*. 2016;90:92-101. doi:10.1016/j.enpol.2015.12.019.

[41] Kucukali S, Baris K. Turkey's short-term gross annual electricity demand forecast by fuzzy logic approach. *Energy Policy*. 2010;38(5):2438-2445. doi:10.1016/j.enpol.2009.12.037.

[42] Yukseltan E, Yucekaya A, Bilgec AH. Forecasting Electricity Demand for Turkey Using Modulated Fourier Expansion. *Am Sci Res J Eng Technol Sci*. 2015;14(3):87-94.

[43] Saglam M, Spataru C, Karaman OA. Forecasting Electricity Demand in Turkey Using Optimization and Machine Learning Algorithms. *Energies*. 2023;16(11):4499. doi:10.3390/en16114499.

[44] Iranmanesh H, Abdollahzade M, Miranian A. Mid-term energy demand forecasting by hybrid neuro-fuzzy models. *Energies*. 2012;5(1):1-21. doi:10.3390/en5010001.

[45] Kiran MS, Özceylan E, Gündüz M, Paksoy T. A novel hybrid approach based on Particle Swarm Optimization and Ant Colony Algorithm to forecast energy demand of Turkey. *Energy Convers Manag*. 2012;53(1):75-83. doi:10.1016/j.enconman.2011.08.004.

[46] Hamzacebi C, Es HA. Forecasting the annual electricity consumption of Turkey using an optimized grey model. *Energy*. 2014;70:165-171. doi:10.1016/j.energy.2014.03.105.

[47] Barak S, Sadegh SS. Forecasting energy consumption using ensemble ARIMA-ANFIS hybrid algorithm. *Int J Electr Power Energy Syst*. 2016;82:92-104. doi:10.1016/j.ijepes.2016.03.012.

[48] Ozdemir G, Aydemir E, Olgun MO, Mulbay Z. Forecasting of Turkey natural gas demand using a hybrid algorithm. *Energy Sources Part B*. 2016;11(4):295-302. doi:10.1080/15567249.2011.611580.

[49] Aydoğdu G, Yildiz O. Forecasting the annual electricity consumption of Turkey using a hybrid model. In: *2017 25th Signal Processing and Communications Applications Conference (SIU)*; 15-18 May 2017; Antalya, Turkey. p. 1-4.

[50] Al-Musaylh MS, Deo RC, Li Y, Adamowski JF. Two-phase particle swarm optimized-support vector regression hybrid model integrated with improved empirical mode decomposition with adaptive noise for multiple-horizon electricity demand forecasting. *Appl Energy*. 2018;217:422-439. doi:10.1016/j.apenergy.2018.02.140.

[51] Kim M, Choi W, Jeon Y, Liu L. A hybrid neural network model for power demand forecasting. *Energies*. 2019;12(5):931. doi:10.3390/en12050931.

[52] Khan PW, Byun YC, Lee SJ, Park N. Machine Learning Based Hybrid System for Imputation and Efficient Energy Demand Forecasting. *Energies*. 2020;13(11):2681. doi:10.3390/en11132681.

[53] Turgut MS, Eliiyi U, Turgut OE, Öner E, Eliiyi DT. Artificial Intelligence Approaches to Estimate the Transport Energy Demand in Turkey. *Arab J Sci Eng*. 2021;46(3):2443-2476. doi:10.1007/s13369-020-05108-y.

[54] Mir AA, Alghassab M, Ullah K, Khan ZA, Lu Y, Imran M. A review of electricity demand forecasting in low and middle income countries: The demand determinants and horizons. *Sustainability*. 2020;12(15):5931. doi:10.3390/su12155931.

[55] Tunç M, Çamdali Ü, Parmaksizoglu C. Comparison of Turkey's electrical energy consumption and production with some European countries and optimization of future electrical power supply investments in Turkey. *Energy Policy*. 2006;34(1):50-59. doi:10.1016/j.enpol.2004.04.027.

[56] Turkish Electricity Transmission Corporation. Türkiye Electricity Production-Transmission Statistics. 2020. Available from: https://www.teias.gov.tr/turkiye-elektrik-uretim-iletim-istatistikleri. Accessed: 6 August 2024.

[57] Zeynep D. Electricity consumption per capita in Turkey from 1990 to 2022 (in megawatt hours). 2024. Available from: https://www.statista.com/statistics/1370802/turkey-electricity-consumption-per-capita. Accessed: 14 August 2024.

[58] Eskeland GS, Mideksa TK. Electricity demand in a changing climate. *Mitig Adapt Strateg Glob Chang*. 2010;15:877-897. doi:10.1007/s11027-010-9246-x.

[59] Halicioglu F. Residential electricity demand dynamics in Turkey. *Energy Econ*. 2007;29(2):199-210. doi:10.1016/j.eneco.2006.11.007.

[60] Melikoglu M. Vision 2023: Scrutinizing achievability of Turkey's electricity capacity targets and generating scenario based nationwide electricity demand forecasts. *Energy Strategy Rev*. 2018;22:188-195. doi:10.1016/j.esr.2018.09.004.

[61] Cömert M, Yıldız A. Forecasting short-term electricity demand of Turkey by artificial neural networks. In: *2018 International Conference on Artificial Intelligence and Data Processing (IDAP)*; Malatya, Turkey. p. 1-6.

[62] Kök A, Yükseltan E, Hekimoğlu M, Aktunc EA, Yücekaya A, Bilge A. Forecasting Hourly Electricity Demand Under COVID-19 Restrictions. *Int J Energy Econ Policy*. 2022;12(1):73-85. doi:10.32479/ijeep.11890.
[63] Yavuzdemir M, Gökgöz F. Estimating Gross Annual Electricity Demand of Turkey. *Int Bus Res*. 2015;8(4):145. doi:10.5539/ibr.v8n4p145.
[64] İlseven E, Göl M. Medium-term electricity demand forecasting based on MARS. In: *2017 IEEE PES Innovative Smart Grid Technologies Conference Europe (ISGT-Europe)*; Turin, Italy. p. 1-6.
[65] Hamzaçebi C, Es HA, Çakmak R. Forecasting of Turkey's monthly electricity demand by seasonal artificial neural network. *Neural Comput Appl*. 2019;31:2217-2231. doi:10.1007/s00521-017-3183-5.
[66] Cekinir S, Ozgener O, Ozgener L. Türkiye's energy projection for 2050. *Renew Energy Focus*. 2022;43:93-116. doi:10.1016/j.ref.2022.09.003.
[67] Kayakuş M. The Estimation of Turkey's Energy Demand Through Artificial Neural Networks and Support Vector Regression Methods. *Alphanumeric J*. 2020;8(2):227-236. doi:10.17093/alphanumeric.756651.
[68] Yukseltan E, Yucekaya A, Bilge AH. Hourly electricity demand forecasting using Fourier analysis with feedback. *Energy Strategy Rev*. 2020;31:100524. doi:10.1016/j.esr.2020.100524.
[69] Kaytez F. A hybrid approach based on autoregressive integrated moving average and least-square support vector machine for long-term forecasting of net electricity consumption. *Energy*. 2020;197:117200. doi:10.1016/j.energy.2020.117200.
[70] Akkaya AV. GMDH-type neural network-based monthly electricity demand forecasting of Turkey. *Int Adv Res Eng J*. 2021;5(1):53-60. doi:10.35860/iarej.766762.
[71] Tuzemen A. Trigonometric grey prediction method for Turkey's electricity consumption prediction. In: Panagiotis M, Constantin Z, Michael T, editors. *Interdisciplinary Perspectives on Operations Management and Service Evaluation*. Business Science Reference; 2020. p. 136-154.
[72] Labandeira X, Labeaga JM, Linares P, López-Otero X. The Impacts of Energy Efficiency Policies: Meta-analysis. *Energy Policy*. 2020;147:111790. doi:10.1016/j.enpol.2020.111790.
[73] Voss A. *The Adverse Effect of Energy-Efficiency Policy*. 2019.
[74] Otsuka A. Regional determinants of energy efficiency: Residential energy demand in Japan. *Energies*. 2018;11(6):1557. doi:10.3390/en11061557.
[75] Bigerna S, Chiara D'errico M, Polinori P. Environmental and energy efficiency analysis of EU electricity industry: An almost spatial two stages DEA approach. *Energy J*. 2019;40(1_suppl):29-54. doi:10.5547/01956574.40.SI1.sbig.
[76] Sfinarolakis G. *Effectiveness of Energy Efficiency Incentive Programs* [PhD dissertation]. University of Rhode Island; 2018.
[77] Adua L, Clark B, York R. The ineffectiveness of efficiency: The paradoxical effects of state policy on energy consumption in the United States. *Energy Res Soc Sci*. 2021;71:101806. doi:10.1016/j.erss.2020.101806.
[78] Nepal R, Indra Al Irsyad M, Jamasb T. Sectoral Electricity Demand and Direct Rebound Effect in New Zealand. *Energy J*. 2021;42(4):153-174. doi:10.5547/01956574.42.4.rnep.