Journal of Scientific & Industrial Research
Vol. 81, December 2022, pp. 1336-1341
DOI: 10.56042/jsir.v81i12.40731

Turkey's Long-Term Electricity Consumption Forecast

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Received 16 September 2020; revised 02 November 2022; accepted 08 November 2022

Demand forecasting is essential primarily for planning. Although it is crucial in many sectors and issues, it has particular importance for electricity. Therefore, the issue of electricity consumption forecasting has recently become a prevalent topic. In light of the above, this study aimed to develop an appropriate model to estimate the long-term electricity consumption of Turkey. The study consists of three steps. In the first step, eight models were developed to separately investigate the effects of eight input variables frequently used in electricity consumption forecasting studies in the literature. In the second step of the study, two models consisting of input variables with high impact in the first step were developed, and the trained performances of the developed models were calculated by using the regression analysis. In the final step, the combined effect of eight variables on electricity consumption forecasting was investigated using regression analysis. It can be conclude that the model in the third step showed significant results, and the model performance was good. Finally, Turkey's electricity consumption forecast for the years 2020–2030 was performed using the model in the third step.

Keywords: Demand estimation, Electricity demand, Forecasting, Regression analysis

Introduction

Although electrical energy is a reliable energy source that can be transmitted quickly, produced, and consumed simultaneously when needed with a very large use area. It has some disadvantages besides being an efficient energy source and harmless to the environment.[1] Some of these disadvantages such as the inability to store on a large scale, the inability to forecast the demand correctly, the effect of geological, geographical, and climatic conditions in production, and the importance of adequacy and dependence levels of countries in terms of primary energy resources can be listed.[2]

The demand for electrical energy, whose share in energy consumption is constantly rising, continues to increase rapidly with the development of industry and technology. Electrical energy is an energy source that must be consumed at the moment it is produced due to the inability to store it. Therefore, it is necessary to produce electricity by considering the supply-demand balance. This increases the importance of demand forecasts.[3]

The purpose of electrical energy demand forecasts is to identify the factors that affect the demand and to forecast future electricity demand with the help of a model. Demand forecasts are of great importance for the successful planning of production, distribution, and transmission systems of electrical energy.[1] To meet the electrical energy needed by the country in a timely and economical manner, supply, demand, transmission, distribution, and pricing policies must be established effectively. The development of these policies increases the importance of demand studies since the reliability of demand forecasting is the most important factor that determines the effectiveness of the policies to be developed.[1]

Electricity consumption in Turkey is increasing every passing day, as is all over the world. Turkey's electricity consumption was 304.2 billion kWh in 2018, while electricity generation was 304.8 billion kWh. At the end of September 2019, Turkey's installed power capacity has reached 90,720 MW. The electricity consumption forecasts in Turkey are officially performed by the Ministry of Energy and Natural Resources of Turkey (MENR). According to MENR's projections, Turkey's electricity consumption in 2023 is estimated to be around 375.8 TWh.[4] The model for analysis of energy demand, which historically has not produced reliable results for Turkey, is used. Therefore, different methods are needed for Turkey's electricity consumption estimation.[5]

In this context, the main purpose of this study is to determine the most appropriate model to estimate

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electricity consumption in Turkey. The study consists of three steps. In the first step, eight models were developed in order to separately investigate the effects of eight input variables (Gross Domestic Product (GDP), Population (P), Installed Power (IP), Export (E), Import (I), Gross Electricity Generation (GEG), Year (Y), The Number of Consumers (NC)), which were determined as a result of a comprehensive literature review. On the electricity consumption forecasting these eight models were trained using the Regression Analysis in MATLAB. In the second step of the study, two models consisting of input variables with high impact in the first step were developed, and these models were also trained using the Regression Analysis in MATLAB. Finally, in the third step, a model including eight input variables was trained using the Regression Analysis in MATLAB. According to the findings, it can be suggested that the model in the third step showed significant results and the findings contribute to the area of energy consumption estimation.

There are many studies conducted on electricity demand forecasting, and many different methods have been used in these studies. Some of these methods are as follows:

Panklib *et al.*[6] used an ANN and a regression model to forecast long-term electricity consumption in Thailand. Barak and Sadegh[7] developed a hybrid ARIMA–Adaptive Network based Fuzzy Inference System (ANFIS) algorithm, and then the developed algorithm was applied to energy consumption data obtained from Iran. Toksari[8] presented a hybrid algorithm of Ant Colony Optimization and Iterated Local Search in order to forecast domestic electricity consumption. Yuan *et al.*[9] proposed a hierarchical Bayesian approach to forecast China's regional energy demand. Chung[10] developed an NN-based grey forecasting approach. Yan *et al.*[11] designed a hybrid deep learning NN framework by combining long-short term memory NN with convolutional NN to deal with the forecasting problem of a single household electricity consumption. Mahdiraji *et al.*[12] designed a novel singular spectrum analysis-fuzzy regression model to forecast electricity consumption.

Guleryuz[13] used different methods to estimate energy demand for industrial sectors in Turkish. The results showed that the PSO-ANFIS model has a better prediction ability than MLR and ANFIS models. Leite Coelho da Silva *et al.*[14] compared different models for electricity consumption estimation. It has been shown that the model that makes the best prediction of the results obtained is a multi-layer perceptron. Kuskapan *et al.*[15] developed five different models to estimate railway energy consumption in Turkey. The developed models were run using the ANN method. The research results showed that the best estimation model was Model 3.

Some of the studies on energy consumption/demand for Turkey are given in Table 1. There is always a need for alternative models and methods that offer better results to predict electricity demand in Turkey. Therefore, this paper focused on new models.

Materials and Methods

Regression Analysis

Regression analysis can generally be defined as finding a connection or connections by explaining the relationship between the dependent variable and the independent variables with mathematical models. Regression analysis is one of the most used techniques to make predictions. Regression analysis divides into two simple and multiple regression analyses according to the number of independent variables. In simple regression analysis, there is an independent variable and a dependent variable, and

Table 1 — Some of the studies on energy demand in Turkey

Forecasting	Input variables	Method used
Net energy consumption[16]	GDP, import, export, population, and employment	ANN technique
Basic energy sources and net electricity consumption[17]	Population, import, export, gross generation, net energy consumption, and installed capacity	ANN technique
Total electricity consumption[18]	Gross national product (GNP), population, import, and export	ANN technique
Net electricity consumption[19]	Gross generation, years, population, and installed capacity	ANN technique
Net electricity consumption[20]	GNP, GDP, installed capacity, population, gross generation, export, and import	ANN technique
Sectoral consumption[21]	The industrial sector, residence, transportation, and agriculture	ANN technique
Annual electricity[22]	Data on total Electricity consumption	Optimized grey
Total electricity consumption[5]	Years, GNP, import, export, and population	SVR
Electricity demand[23]	Population and energy consumption increase rates per capita	Linear Regression
Electricity demand[24]	GDP, import, export, and population	Particle swarm optimization
Electricity demand[25]	GNP, population, import, and export	Genetic Algorithm approach

there is a cause-effect relationship between them. Multiple regression analyses have one dependent variable and at least two independent variables. The criterion for understanding the relationship between variables in a regression equation is the regression coefficient (R^2). This coefficient makes it possible to understand the accuracy of a regression equation and the effect of an independent variable on the dependent variable.[26]

In this study, the Regression Analysis was performed by using Regression Learner App, which is available as a ready tool in MATLAB. The methods in Regression Learner were run for each model presented in the study. For each model, the method with the lowest Root Mean Squared Error (RMSE), Mean Squared Error (MSE), and Mean Absolute Error (MAE) values were selected, and forecasting was performed by taking the method with low RMSE, MSE, and MAE values into consideration.

The reasons for the use of the regression analysis method, which is applied in all fields of science, in the study are as follows[27]:

- Regression Analysis is a statistical method.
- Regression analysis helps model the relationship between variables.
- Regression analysis helps model the relationship between variables in the future. In other words, it is a method to be used to forecast the future data

Performance Criteria

There are various statistical tests that can be used to evaluate the performance of the models proposed in the study. These tests are MSE given in Eq. 1, and RMSE given in Eq. 2, and MAE given in Eq. 3, respectively.

$$MSE = \frac{1}{N}\sum_{t=1}^{N}(r_t - p_t)^2 \quad \ldots (1)$$

$$RMSE = \left(\frac{1}{N}\sum_{t=1}^{N}(r_t - p_t)^2\right)^{1/2} \quad \ldots (2)$$

$$MAE = \frac{100}{N}\sum_{t=1}^{N}\left|\frac{r_t - p_t}{r_t}\right| \quad \ldots (3)$$

where, N is the number of observations, r_t is the actual electricity consumption in the t^{th} time period, while p_t is the forecasted electricity consumption in the t^{th} time period.

Case Study

In this study, the appropriate model to be used to forecast the long-term electricity consumption of Turkey was investigated using Regression Analysis (RA) in MATLAB. The evaluation was performed in three steps to find the appropriate forecasting model. In the first step of the study, eight models were developed to separately investigate the effects of eight input variables (GDP, P, IP, E, I, GEG, Y, NC) on electricity consumption forecasting. The training performance of these eight models was examined by using the Regression Analysis method in MATLAB. The schematic view of Step 1 is shown in Fig. 1. In the second step, two models were developed based on the variables that had good training performances in the first stage; Model 9; Y, P, GEG, and Model 10; Y, P, GEG, and IP models were developed. The schematic view of Step 2 is shown in Fig. 2. Finally, in the third step, a model was developed using all eight input variables, and the schematic view of the model developed in Step 3 is shown in Fig. 3.

Turkey's current information was taken into account while investigating the appropriate model to be used in order to forecast the electricity consumption in Turkey. The GDP data for the years between 1990 and 2018 were obtained from the official international official website of World Bank Data.[28] The data relating to the population for the years between 1990 and 2018 were obtained from the population Internet website.[29] The data on the installed power capacity of Turkey for the years between 1990 and 2018 were obtained from the official website of the Turkish Statistical Institute.[30] The export and import data for the years between 1990 and 2018 were obtained from the official website of Turkey Electricity Transmission Corporation.[31] The GEG data for the years between 1990 and 2018 were obtained from the official website of the Turkish Statistical Institute.[30] Lastly, the data related to the number of consumers for the years between 1990 and 2018 were obtained from the activity report provided on the official website of Turkey Electricity Distribution Company.[32]

Results and Discussion

In this study, 11 models were developed using eight different input variables to forecast long-term electricity consumption in Turkey, as mentioned in thecase study; the study consists of three steps. In the first step of the study, the effect of eight different inputs variables on electricity consumption forecasting was investigated. In this regard, eight different models were developed, and forecasting was performed for each model by using the Regression Analysis Method in MATLAB. The performance values of the models after training are given in Table 2.

As shown in Table 2, the input variables with the lowest RMSE, MSE, MAE values are year, population,

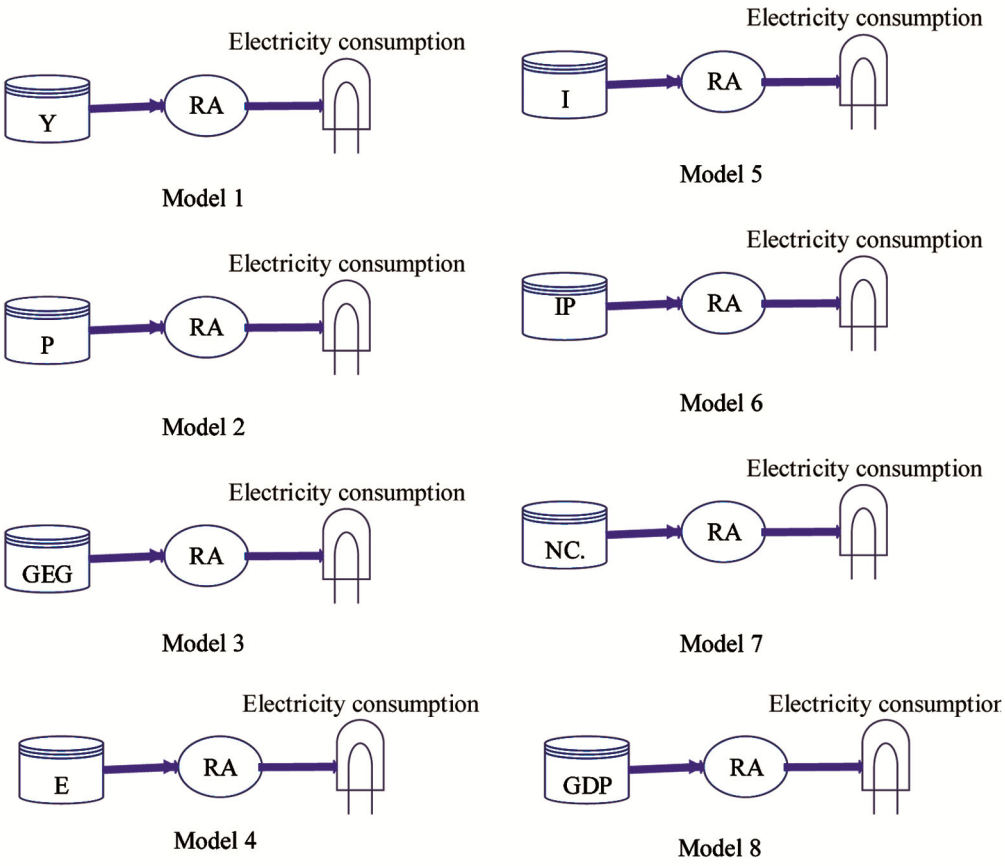

Fig. 1 —The schematic view of Step 1

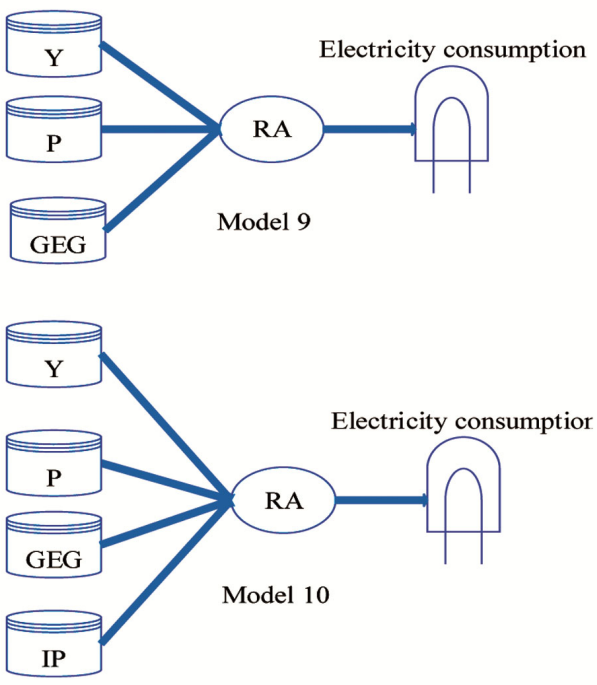

Fig. 2 —The schematic view of Step 2

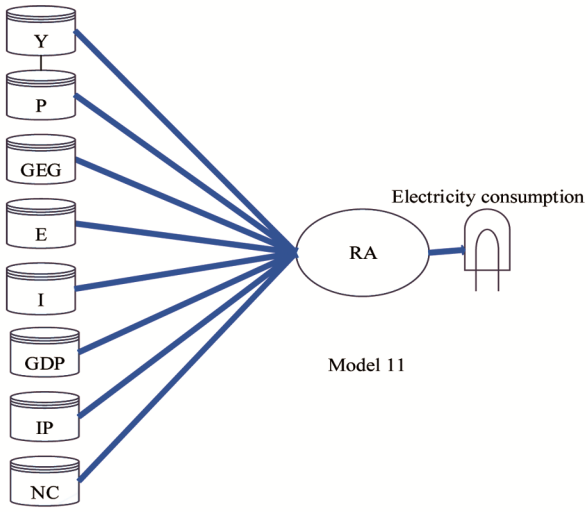

Fig. 3 —The schematic view of Step 3

GEG and installed power. Therefore, Model 9; year, population, GEG, and Model 10; year, population, GEG, and installed power models were developed in the second step. The performance values of Model 9 and Model 10 after training are given in Table 3.

Table 2 — The performance values of the models after training in the first step

Models	Input	RMSE	MSE	MAE
Model 1	Year	4.58	20.976	3.4365
Model 2	Population	4.0793	16.64	2.9189
Model 3	GEG	1.4467	2.0928	1.0361
Model 4	Export	41.655	1735.1	32.65
Model 5	Import	62.749	3937.4	53.694
Model 6	Installed Power	8.9432	79.98	7.0208
Model 7	The Number of Consumption	15.253	232.65	10.521
Model 8	GDP	24.523	601.39	19.382

Table 3 — The performance values of Model 9 and Model 10 after training

Models	Input	RMSE	MSE	MAE
Model 9	Year, population, GEG	1.4284	2.0402	1.0562
Model10	Year, population, GEG, Installed Power	1.6688	2.7848	1.1277

Table 4 — The Performance values of the Robust Linear Method

Results (trained)	Value
RMSE	0.63815
R-Squared	1.00
MSE	0.40724
MAE	0.45123
Prediction speed	~310 obs/sec
Training time	5.7632 sec

As shown in Table 3, the RMSE value of Model 9 is 1.4284, MSE value is 2.0402 and MAE value is 1.0562, the RMSE value of Model 10 is 1.6688, MSE value is 2.7848 and MAE value is 1.1277, respectively. According to the results obtained, it can be said that the performance of Model 9 is better compared to Model 10. Finally, in the third step, Model 11 was developed in order to examine the combined effect of eight input variables on electricity consumption forecasting. Regression methods included in Regression Learner Tool in MATLAB were run in order to determine the most suitable regression method for Model 11. The Robust Linear method gave the best forecasting with a RMSE value of 0.63815. The performance values of the Robust Linear Method as a result of the training are shown in Table 4.

Considering the results obtained, the best forecasting performance was given by Model 11. The RMSE value of Model 11 is 0.63815, MSE value is 0.40724, and MAE value is 0.45123, respectively. In this regard, it can be said that Model 11, which is proposed within the knowledge of the author, gives better results compared to the studies of Kankal *et al.*[30] Kavaklioglu[2], Kavaklioglu *et al.*[32], Hamzacebi and Es.[36]

As shown in Table 5, the electricity consumption of Turkey between the years 2020–2030 was forecasted by using Model 11.

Table 5 — Future electricity consumption forecasting of Turkey

Years	Electricity Consumption (TWh)
2020	312.206
2021	324.718
2022	337.581
2023	350.718
2024	364.145
2025	377,859
2026	391.837
2027	406.097
2028	420.635
2029	435.431
2030	465.844

Conclusions

The obtained results showed that the proposed model outperformed many studies in the literature. In this context, it is thought that the proposed model will show successful forecasting performance in Turkey's long-term electricity management. This study's limitation is that some input variables' monthly values are not reached. For this reason, the annual electricity consumption estimation has been made. However, it is thought that the model's performance will be more successful since there will be more data when the monthly values of the input variables are used. Future studies may establish a demand forecasting model using different input variables and investigate the usability of the model. They can also compare the forecasting results obtained with different methods, such as ARMA, ANFIS, and ANN, using the same input and output variables.

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