Turkey's Forecasting of Energy Demand with Artificial Neural-Network

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ABSTRACT

Energy demand is increasing day by day in parallel with economic growth, especially for the rapidly developing countries. In order to achieve a sustainable economic growth, long-term targets are being put to manage the operation of market in a good way. Turkey is an emerging and rapidly developing country so its energy demand has increased rapidly to meet the growing economy. Therefore, forecasting Turkey's energy demand accurately is of great importance to achieve a sustainable economic growth. The main goal of this study is to develop the equation for forecasting energy demand using the backpropagation algorithm which is one of the artificial neural-network models to determine the future level of energy demand. This study presents the predictions for the years 2017-2020. The results of the energy demand estimations found in this study are compared with the official estimations of the MENR. It is concluded that official estimations for Turkey's energy demand are dramatically higher than forecasting value presented in this study.

Keywords: Artificial neural-network, Turkey, Energy demand forecast

1 INTRODUCTION

Turkey's energy demand, one of the world's 20 largest economy[1], increasing day by day because of its expanding population, rapid urbanization and strong economic growth. Turkey's total primary energy supply is 129.7 mtoe[2] as of 2015. Majority of its energy demand is met by natural gas (30%), followed by oil (30%) and coal (27%) [2]. More than half of these primary sources are used for electricity generation. 68% of electricity generation is supplied by fossil fuels which are natural gas, coal and oil. On the other hand, hydropower has significant portion in the electricity generation with 26%. Moreover, industry is the most energy consuming sector in Turkey with 31.974 btoe[3] [3]. Thus, production factors are more involved in the production process with industrialization i.e. rapid urbanization for Turkey. Increasing use of production factors in the production process leads to an increase in energy consumption. Industry is developing, energy investments become more efficient and production and employment increase with increased energy consumption. This process affects GDP in a positive way. Therefore, energy is one of the most important factors for Turkey's growth and it is important to make reliable demand forecasts for the future to sustainably meet the rising energy demand with growing population, increasing industrialization and urbanization in the framework of these developments.

Forecasting of demand refers to the process of organizing and analyzing past period data to determine and anticipate what a firm's or country's sales of products or investments will be for future periods [4]. Population growth, population composition, urbanization, industrialization and

[1] Turkey is the 18th-largest economy in the world in terms of nominal GDP with 735.72 billion dollars in 2016 [1].
[2] Mtoe: Million tons of oil equivalent.
[3] Btoe: Billion tons of oil equivalent.

economic growth are generally accepted as components in the demand forecasting models [5]. Energy should be used more efficiently due to limitations of energy sources in addition to environmental factors. Therefore, demand forecasting is the most important instruments of energy politics. Forecasting methods are divided into two major groups which are qualitative and quantitative methods. Qualitative forecasting methods are based on the opinions and experiences of the individual who is expert on the subject studied whereas quantitative forecasting methods are based on mathematical models [6]. In this study, artificial neural-network (ANN) which is one of the quantitative methods are used.

The main goal of this study is to develop the equation for forecasting energy demand using the backpropagation algorithm which is one of the artificial neural-networks models to determine the energy demand in 2020. Based on our findings, some policy implications related to energy demand are also discussed. In this study, we will evaluate the energy consumption predictions to forecast the energy demand for Turkey for the next four years (201-2020) using the artificial neural networks. The results show that official estimations for Turkey's energy demand are significantly higher than forecasting value presented in this study.

Remaining of this paper is organized as follows. In section 2 literature review about energy demand of Turkey using ANN is presented. In section 3 regression analysis used for determining which variables should be used in ANN modeling is demonstrated. In section 4 ANN approach used in this study is explained and results of the ANN modeling and forecasting are presented. In section 5 conclusions about this study is discussed.

2 LITERATURE

There are many different forecasting techniques in the literature for estimating energy demand. For example, energy demand is forecasted using time series models, regression models, econometric models, decomposition models, cointegration models, ARIMA models, artificial systems (experts systems and artificial neural-network models), grey prediction models, and so on [7]. In Turkey, there are several articles on Turkey's energy demand forecasting. Models established by using artificial neural-network are illustrated in Table 1.

Çunkaş and Altun (2010) estimates the Turkey's long-term electricity demand for the years 2008 to 2014 by using ANN. In the study, they compared the forecasting results of two ANN models, three-layered back-propagation and a recurrent neural network and concluded that the recurrent neural network model produces the best forecasting results. Hotunluoğlu and Karakaya (2011) predicts Turkey's energy demand by using ANN and three different scenarios are developed which are static, sustainability and periodic-change scenarios. They found that MENR estimations for Turkey's energy demand are significantly higher than those presented in this study. Es et al. (2014) predict Turkey's net energy demand up to 2025 for the years 1970-2010. The study compared the prediction performance of built ANN model and a multiple linear regression technique and it is concluded that ANN is superior than the multiple linear regression technique. Bayrak and Esen (2014) analyzes the energy deficit and energy production predictions for Turkey for the years 2012-2020 by using ANN. They concluded that the energy demand is expected to rise at an annual rate of 3.2% with 152.492 thousand toe in 2020, so official estimations of the MENR is dramatically higher than those presented in this study. Yetiş and Jamshidi (2014) predict Turkey's electricity consumption for the years 2012-2023 using ANN and found that net electricity consumption is expected to increase to 373.09 GWh. Birim and Tümtürk (2016) predicts the Turkey's electricity demand for the years 2015-2023 by using multiple linear regression and ANN. Four different models were developed and it is concluded that Turkey's electricity consumption is expected to vary between 337087.4 and 385006.6 Gwh by 2023 and official estimations of Turkish Electricity Transmission Company (TEIAS) is higher than those presented in this study (except model 2).

Table 1 Studies on Energy Demand Forecasting of Turkey Using Artificial Neural Networks

Author(s)	**Variables**	**Years**	**Demand**	**Forecast period**
Çunkaş and Altun [8]	GNP, GDP, population, number of households, index of industrial production, oil price, electricity consumption per capita, electricity price	1981-2002	Electricity demand	2008-2014
Hotunluoğlu and Karakaya [9]	Population, export, import, energy intensity, GDP	1970-2008	Energy demand	2009-2030
Es et al. [10]	GDP, population, import, export, area of the building and vehicles number	1970-2010	Net energy demand	2011-2025
Bayrak and Esen [11]	Real GDP, Population, export, import, energy consumption	1960-2011	Energy demand	2012-2020
Yetis and Jamshidi [12]	GDP, index of industrial production, population	1992-2011	Electricity Consumption	2012-2023
Birim and Tümtürk [13]	GDP, population, import, export, employment, natural gas	1992-2014	Electricity demand	2015-2023

3 METHODOLOGY

3.1 Artificial Neural Networks Models

Artificial neural-networks are a mathematical model that tries to model the information processing capabilities of the biological neural networks [14]. One of the major application areas where ANN is being used is to forecast. "ANNs provide an attractive alternative tool for both forecasting researchers and practitioners". ANNs' features such as being data-driven self-adaptive methods, universal functional approximators, nonlinear and enabling generalize provide valuable and attractive results [15]. ANNs are systems consisted of certain artificial neurons that work together. The structure of an ANN consists of three major layers which are input layer (entry layer), hidden layer (mid layer) and output layer. The structure is illustrated in Figure 1. The information (which are independent variables in this study) is transmitted to the network through the input layer. They are processed in hidden layer, and then sent to the output layer [16].

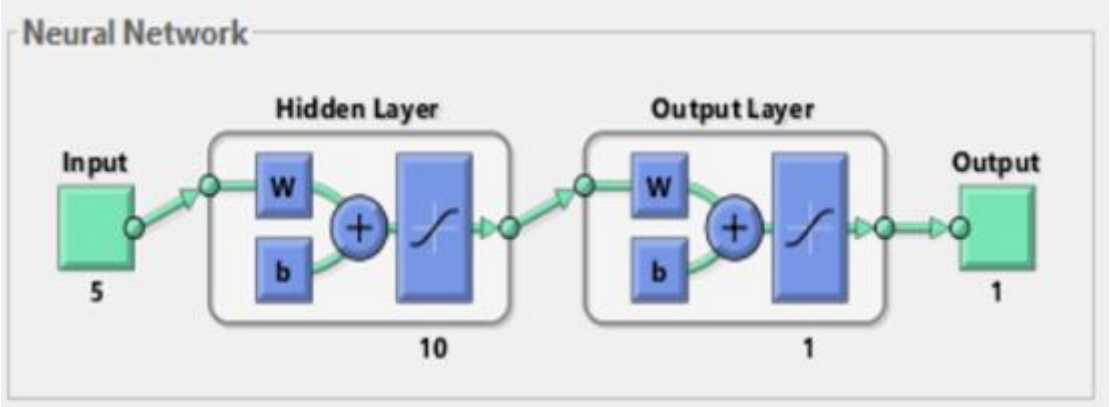

Figure 1 Typical Processing Element of an Artificial Neural Networks

ANNs' models are divided into feed forward and backpropagation neural network. In this study, backpropagation neural network is used because in the backpropagation, historical data is used and "some of the information flows not only in one direction from input to output but also in opposite direction" whereas in feed forward, "information flows from inputs to outputs in only one direction" [17].

4 EMPIRICAL RESULTS

This section provides information on the data set and resources used in this study and evaluates the results of the artificial neural networks used for the data analysis. Besides, predictions are done for target years 2018 and 2020 made by MENR. The numerical analysis software MATLAB 2014 has been used to model the artificial neural networks.

4.1 The Data Set

Independent variables used in this study are GDP, GDP growth, population, export and import whereas the dependent variable is primary energy consumption. Figure 2 shows the values of these variables for 1965-2015. In order to see the fluctuations in the graph more clearly, the data are transferred by normalization. Firstly, the system will be tested with the data from 1965-2015 then; forecasting will be made for the years 2017-2020. The data set used in the analysis is gathered from different sources. The annual data on total energy consumption (million tons of oil equivalents) obtained from BP Statistical Review of World Energy 2016. The data for the GDP (current US dollars), GDP growth (%) and population are taken from World Bank, World Development Indicators. Export and import (thousand dollars) obtained from Turkish Statistical Institute, Foreign Trade Statistics.

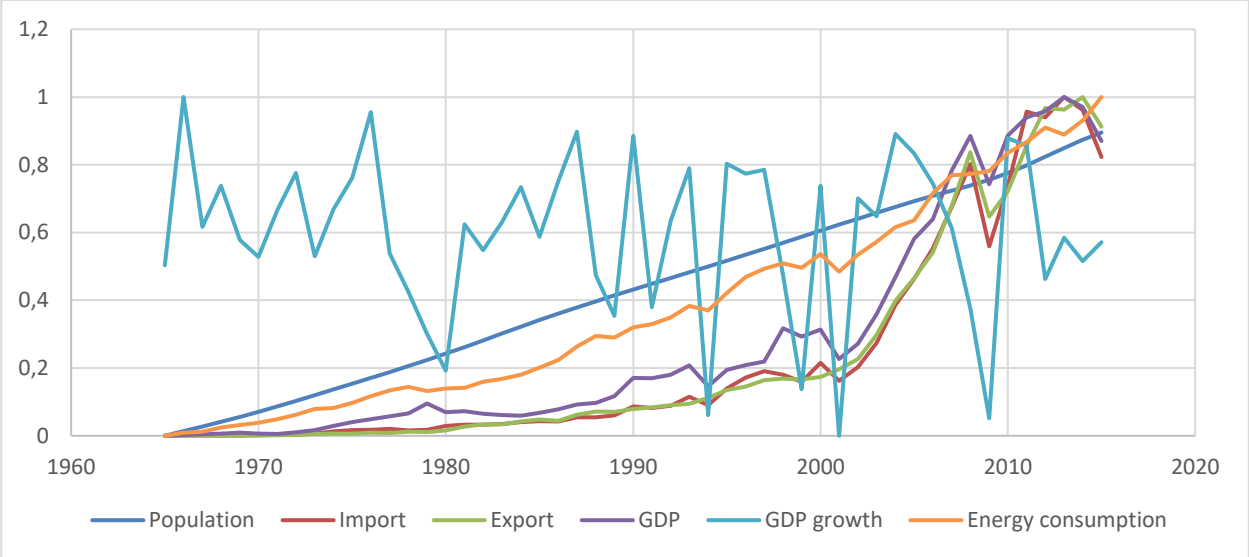

Figure 2 Primary Energy Consumption and Independent Variables (1965-2015)

The raw data to be used in the development of the ANN must be normalized to see the fluctuations more clearly and to prevent the mistakes in the learning process. In this study, simple normalization is used and equation is as follows:

$$X^1 = \frac{X - X_{min}}{X_{max} - X_{min}}$$

X_{min} and X_{max} constitute the minimum and maximum values of the parameters given in the data set whereas X^1 is the normalized counterparts of data X.

4.2 Establishing the Network and Results

GDP, GDP growth, population, export, import and primary energy consumption are used to estimate the energy demand covered the years 1965-2015. Network structure of the model used in the ANN is illustrated in Figure 3.

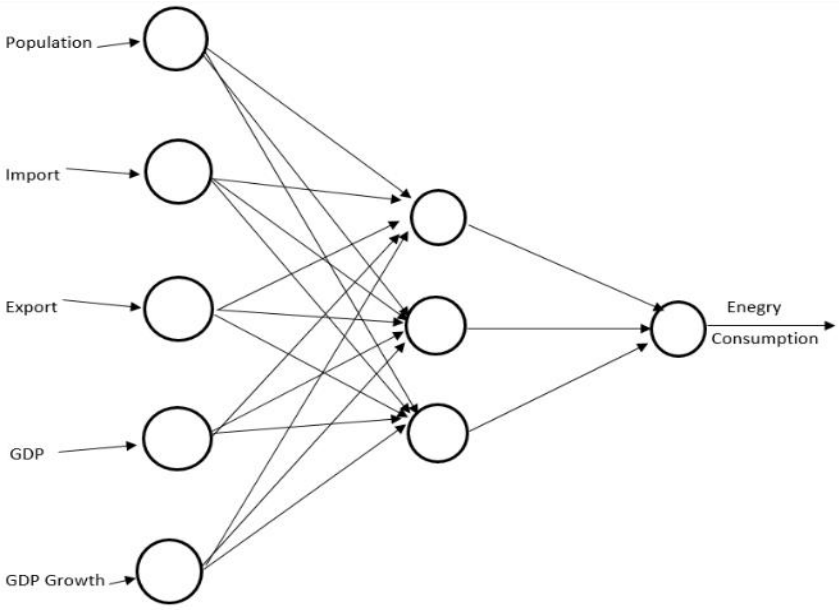

Figure 3 The Artificial Neural Network Model Used in this Study

70% of given data is used for learning, 15% of given data is used for validation and 15% of given data is used for test group. After the algorithm learned the relationship between input and output, it can be estimated for the periods of 2017-2020 using given data. The given data is non-linear.

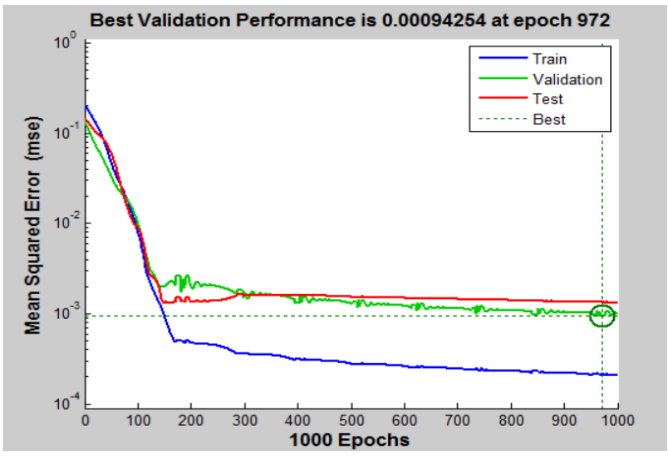

Figure 4 The Performance Curves Designed according to ANN Model

In this study, mean squared error (MSE) is used to determine the performance of the network. At the shown Figure 4 the smallest mean squared error is reached at the 1000th iteration and it is recognized that the best learning occurred at this stage.

Prediction results are shown at the table 2. According to the results the energy demand, which was 131,324 thousand toe in 2015, will increase by 8,1% in total (from 2015 to 2020), reaching 141,971 thousand toe in 2020. GDP growth is estimated as 1,09% in 2020 whereas it was 3,97 % in 2015. Low increase in GDP growth causes the increased energy consumption as lower than estimated value of it.

Table 2 Prediction Results of the ANN

Years	Population	Import	Export	GDP	GDP growth	Energy Demand
2017	82761483	207806312	146924201	725276467699,84	4,072285341	142,3838138
2018	80551266	208378265	155741687	713404969906,57	-0,121815155	140,8231633
2019	81321569	208950218	156194268	712017626049,83	0,456516817	141,4891891
2020	82076788	209522171	156505418	711011598925,64	1,096740456	141,9711002

Figure 5 shows the changes of energy consumption from the year 1965 to 2020. Years between 2016 and 2020 are estimated by using ANN. It can be understood that the value of energy consumption will increase after 2015. This increase in the energy consumption will be higher than 2015 but it is not in the expected level.

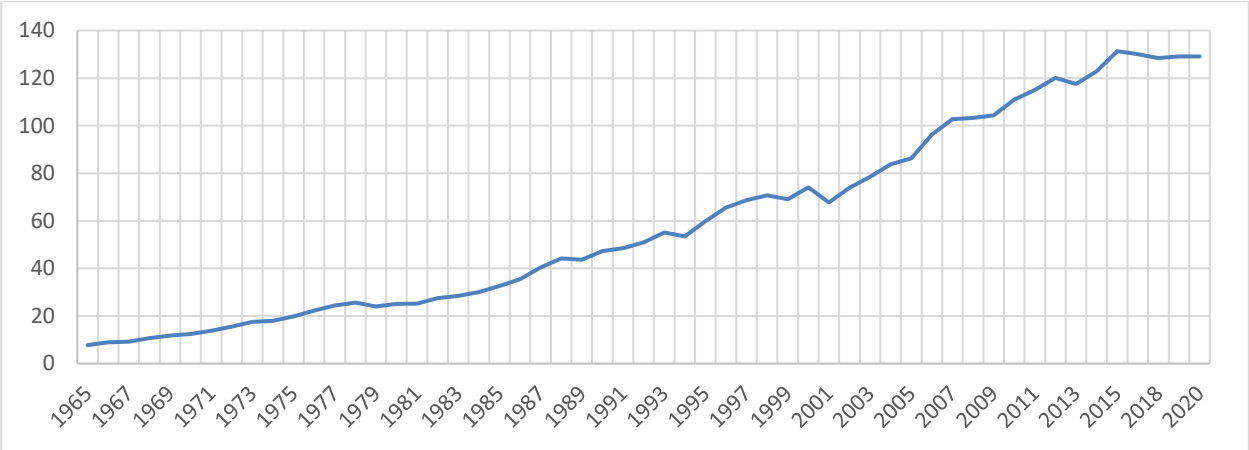

Figure 5 Energy Consumption by the Years

5 CONCLUSION AND POLICY IMPLICATIONS

Turkey's energy policy is based on increasing the share of renewable energy sources, using energy efficiently, enhancing security of supply, meeting the growing energy demand in the sustainable way in terms of economic and environmental and achieving a competitive energy system that strengthens the strategic position of the country in international energy trade. In this regard, Turkey sets long-term targets to make investments properly. The main goal of this study is to develop the equation for forecasting energy demand using the backpropagation algorithm which is one of the artificial neural-networks models to determine the future level of energy demand. In this framework, the predictions of the energy demand for the years 2017-2020 are based on variables for the period 1965-2015. Based on energy consumption predictions made using the given data, the energy demand is expected to increase at 8,1% in total (from 2015 to 2020),

reaching 141,971 thousand toe in 2020. The results show that official estimations for Turkey's energy demand are significantly higher than forecasting value presented in this study.

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