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Forecasting Turkey's Energy Demand Using Artificial Neural Networks: Three Scenario Applications

Yapay Sinir Ağları Yöntemiyle Türkiye'nin Enerji Talebi Tahmini: Üç Senaryo Uygulaması

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ABSTRACT

Energy has become increasingly crucial for countries as we have experienced high economic growth, increases in population together with rapid urbanization in the globalized world. Turkey's energy demand has grown rapidly and is expected to continue growing. In this context many studies have been carried out to forecast energy demand in Turkey. The energy demand forecasts are officially prepared by the Turkish Ministry of Energy and Natural Resources (MENR). However, MENR forecasts are significantly higher when compared with realized demand and the results of other academic studies. In this study, Turkey's energy demand is forecasted by using artificial neural network technique, a type of artificial intelligence application. For this purpose, three different scenarios are developed. These are: 'static scenarios', where economic growth is assumed to be stable, 'sustainability scenarios', where energy intensities are assumed to be decreasing and finally 'periodic-change scenarios', where the economic growth is assumed to change during five different time periods by 2030. Moreover, both static and sustainability scenarios are further investigated under high, medium and slow economic growth assumptions. Periodic-change scenarios also consist of two sub-scenarios, where energy intensities are assumed to decrease and stay the same. All scenarios are applied to the total energy demand of Turkey. The results of the energy demand estimations found by our models are compared with the official estimations of the MENR. It is concluded that the MENR estimations are significantly higher than what we have found with our models.

Keywords: Energy demand, energy demand forecasting, energy demand modelling.

ÖZET

Küreselleşen dünyada yüksek ekonomik büyüme, nüfus artışı ve hızlı şehirleşme nedeniyle enerji ülkeler için önemi sürekli artan bir konu haline gelmiştir. Türkiye'nin enerji talebi hızlı bir artış seyri göstermektedir ve gelecekte de bu hızlı artışın devam etmesi beklenmektedir. Bu bağlamda, Türkiyenin gelecek enerji talebini tahmin etmeye çalışan birçok çalışma yapılmıştır. Enerji talep tahminlerini ülkede resmi olarak Enerji ve Tabi Kaynaklar Bakanlığı (ETKB) hazırlamaktadır. Ancak, ETKB'nin yapmış olduğu tahminler gerçekleşen talep değerleri ve diğer akademik çalışmaların bulgularından oldukça yüksek çıkmaktadır. Bu çalışmada, Türkiye'nin enerji talebi yapay zeka uygulamasının bir türü olan yapay sinir ağları tekniği kullanılarak tahmin edilmiştir. Bu amaçla, üç farklı senaryo geliştirilmiştir. Bunlar; ekonomik büyümenin istikrarlı büyüdüğünü varsayan 'statik senaryo', enerji yoğunluklarının azaldığını varsayan 'sürdürülebilir senaryo' ve son olarak 2030 yılına kadar ekonomik büyümenin her beş yıllık dönemde değiştiğini varsayan 'dönemsel-değişim senaryo'sudur. Bunun yanında, statik ve sürdürülebilir senaryolar yüksek, orta ve düşük ekonomik büyüme varsayımları altında ayrıca incelenmiştir. Dönemsel-değişim senaryosu enerji yoğunluklarının azaldığı ve sabit kaldığı iki alt-senaryo durumunu da incelenmektedir. Tüm senaryolar Türkiye'nin toplam enerji talebi tahmini için kullanılmıştır. Modellerimizin bulguları ETKB'nin bulduğu resmi sonuçlarla karşılaştırılmıştır. Ortaya çıkan sonuçlara göre, resmi kurum tahminleri bizim tüm senaryo bulgularımızdan önemli derecede yüksek çıkmaktadır.

Anahtar Kelimeler: Enerji talebi, enerji talebi tahmini, enerji talebi modelleme.

1-INTRODUCTION

Energy has become increasingly crucial as we have experienced high economic growth, increases in population together with rapid urbanization in the globalized world. As developing country, Turkey's energy demand has grown rapidly and is expected to continue to grow. In this context many studies has been carried out to forecast energy demand in Turkey. Forecasting of demand for energy has become important in many respects. The first is to assess alternative mitigation policies to climate change caused by greenhouse gas emissions[1] resulting from energy use. In order to correctly determine greenhouse gas emissions in future, energy demand for the same period should be forecasted as accurate as possible. Besides, in order to evaluate economic costs of ghg emission reduction options in realistic way, energy demand has to be estimated. Secondly, demand for energy increases as results of economic growth, increases in population, rapid urbanization and trade. Therefore, it is important to take these changes into account to see how energy demand will be in future.

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Thirdly, as Turkey is net energy importer it is important to calculate the cost of energy for resource allocation and economic development (Lise and Van Montfort, 2007; Unler, 2008). Finally, the specific feature of electricity, which is an important energy type that cannot be stored, requires relatively accurate estimation of future demand for energy.

Studies on energy demand estimations in Turkey have multi-disciplinary structure. Basically, the country's energy policies must be compatible with the global policies and objectives. Therefore, official forecasts of Turkey's energy demand is executed by MENR in coordination with SPO (State Planning Organization) which is responsible for future development plans and macro-economic balances (Orhan, 2007:54).

The most important criticism for the results of Model for Analysis of the Energy Demand (MAED), which is a technology-based model and used for forecasting Turkey's official energy demand, is on its assumptions. The assumptions (economic growth, population increase ect.) used for the MAED are generally built according to objectives of state development plans. Current observations, however, usually show that these assumptions, introduced as the target, are higher than the realized ones. Therefore, the energy demand projection results of MAED for Turkey are always higher compared with all other academic studies (Karakaya, 2008: 357).

2- LITERATURE REVIEW

Studies on future energy demand projections for Turkey were carried out by both scientists and the MENR. In terms of methodological approaches used, these studies, except official projections (MAED) can be grouped in two, namely econometric models and artificial Intelligence models. The following section reviews these studies on energy demand forecast for Turkey under these two groupings.

- Studies Adopted Artificial Intelligence Approach

A number of studies tried to estimate Turkey's future energy demand by using Artificial Neural Networks methodology, which is developed in the field of artificial intelligence. Even though this approach is rather recently applied on Turkish energy sector, there are increasing number of studies focusing on Turkish case and several aspects of the energy issues are analysed. In an earlier study, Hamzaçebi and Kutay (2004) emphasized the importance of accuracy in the demand forecasts and specific feature of the electrical. In this study, the authors compared the traditional econometric models with artificial neural networks using only the electricity consumption and population data. The study sugests that artificial neural networks can be used as a means of estimation of energy demand. Sozen et al (2006) also have developed a model to estimate Turkey's future energy consumption by using the artificial neural networks.. Kavaklioglu et al (2009) have forecasted Turkey's electricity demand by 2025. Sozen and Arcaklioglu (2007) have predicted Turkey's energy demand using three different models by the same method. Murat and Ceylan (2006) using artificial neural networks, have estimated Turkey's energy demand for the transport sector by considering future developments in GDP, population and vehicle mileage. Gorucu et al (2004) have estimated Natural gas demand for Ankara. Gorucu and Gumrah (2004) have carried out this estimation by using multivariate regression analysis.

Genetic Algorithm, a kind of artificial intelligence, is among the new methods being used in the energy demand studies of Turkey. Ceylan et al (2005), Canyurt et al (2005) indicated that genetic algorithm method is used to predict energy demand of Turkey. Ceylan and Ozturk (2004) Using this method, have forecasted Turkey's energy demand between 2002 and 2025. Also Ozturk et al (2005) have forecasted Turkey's eletricity energy demand from 2002 to 2025 with genetic algorithm. Haldenbilen and Ceylan (2005) have predicted Turkey's transport energy demand by 2020 using genetic algorithm.

Toksari (2007, 2009) have used Ant Colony Optimization to forecast Turkey's electricity energy demand between 2007 and 2025. Ceylan et al (2008) have used Meta-Heuristic Harmony Search Algorithm using Turkey's transport energy demand. Unler (2008) have forecasted Turkey's energy demand by 2025 with Particle Swarm Optimization.

- Studies Adopted Econometric Modeling Approach

Yumurtacı and Asmaz (2004) used Linear Regression analysis to estimate Turkey's electricity energy demand by 2050. Say and Yucel (2006), using this method, predicted energy demand of Turkey for 2010 and 2015.

Ediger and Akar (2007) estimated Turkey's future primary energy demand. In this study, Autoregressive Integrated Moving Average was used to estimate energy demand for 2020. Erdogdu (2007) estimated Turkey's electricity energy demand between 2005 and 2014. Tunc et al (2006) estimated Turkey's electricity energy demand in 2010 and 2020 using data which contains oil, coal, natural gas, nuclear energy, hidro energy and renewable energy resources. In this study, Curve Fitting and Optimization methods were used. Ediger and Tatlidil (2002) estimated energy demand in Turkey for 2010 using Cycle Analysis method.

3- METHOD

Artificial neural networks which is used to forecast energy demand, were inspired by the human brain functions. Experimenting with ways of learning and generalization can be done. This method is not linear and gives better results compared to linear methods (Sharda and Patil, 1992). Therefore, this method can perform nonlinear modeling without the need for any assumption (Kaastra and Boyd, 1996). In artificial neural networks, input data and output data is given to the network, so that the relationship between this information to the network is taught through training (Hamzacebi and Kutay, 2004).

Artificial neural networks are mathematical systems that weighted so many processing elements connected to each other. All the artificial neural networks are composed of neurons. This is the first step in design of the neurons. The second phase is clustering these neurons. Clustering process is done in layers. In general, all artificial neural networks have a similar structure. Some neurons are in contact with outer space to receive inputs and to forward output. The rest of the neurons are in hidden layers.

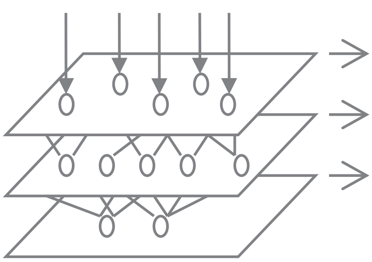

Figure 1: Neural Networks Structure

The next stage is training after configuration of an artificial neural network. At this stage, the weights are determined. In general, the initial weights are selected randomly. There are two methods to training the process. These are supervised and unsupervised training. The supervised training method performs estimation with input and output data. However unsupervised training method estimates using only input data (Yurtoglu, 2005).

Artificial neural networks are divided in terms of direction of information flow on the network. If the information on the network system is moving forward, "feed forward", if the network has back connections, "back propagation" is called an artificial neural network. In addition, if the information is being obtained from instantaneous observations, so the update process parameters are carried out in an instant, it is called the simultaneous (parallel) learning (Piché, 1994; Efe and Kaynak, 2004).

In this study, it is used feed forward back propagation neural network. In this network structure, the information moves from input to output. However, output is estimated by information from the inputs, comparing the estimated output values with actual values are determined the errors. In order to minimize these errors, it is estimated the network again and again. Thus, this process was repeated for each loop until the best network structure is created. In the study, all the networks created an input layer consisting of 5 neurons, forming a hidden layer and output layer, that is composed of a single neuron. In addition, all artificial neural network is formed, trained 20 thousand times.

4- SCENARIOS

In this study, Turkey's total energy demand will be forecasted by focusing on developments in po-

Table 1: Scenarios Example in Literature

Studies		Annual Growth				
	Scenarios	**GDP (%)**	**Population (%)**	**Import (%)**	**Export (%)**	**Export/İmport (%)**
Ceylan ve Öztürk (2004)	1.	5	0.12	5	5	-
	2.	4	0.18	5	5	-
Canyurt et al (2004)	1.	5	0.12	5	5	-
Toksarı (2009)	1.	3.5	0.10	7	-	50
	2.	7	0.12	3.5	2.5	-
	3.	5	0.08	3.5	4	-
Toksarı (2007)	1.	6	0.17	4.5	2	
	2.	5	0.15	5	-	45
	3.	4	0.18	4.5	3.5	-
Ünler (2008)	1.	6	0.17	4.5	2	-
	2.	5	0.15	5	2	-
	3.	4	0.18	4.5	3.5	-

pulation, export, import, energy intensities and GDP data. Past trend data sets cover 1970-2008 periods. This forecasting exercise has three scenario structures. Each scenario structures have different assumptions on GDP growth rates, energy intensities, exports and imports. Before presenting our scenarios, it is useful to see the other studies' assumptions on similar indicators for comparison purposes. The scenarios and assumptions adopted in literature are shown in Table 1.

The three different scenarios developed for this study are: 'static scenarios', where economic growth is assumed to be stable, 'sustainability scenarios', where energy intensities are assumed to be decreasing and finally 'periodic-change scenarios', where the economic growth is assumed to change during five different time periods by 2030.

- Static Scenarios

Static scenarios are assumed to be a steady upward trend in population, exports, imports, energy intensities and GDP. Static scenarios covers the period between 2009 and 2030. Under this scenario structure, the energy demand was forecasted under three different economic growth assumptions (high, medium and low). The assumptions on main drivers for energy demand under this scenario are presented in Table 2;

Table 2: Static Scenarios

	Low Economic Growt	**Medium Economic Growth**	**High Economic Growth**
GDP (%)	3	4.5	6
Population (%)	1.2	1.2	1.2
Export (%)	3	4	5
Import (%)	2	4	6
Energy Intensities (%)	Constant	Constant	Constant

- Sustainability Scenarios

The main feature of this scenario structure is to assume a decrease in amount of energy used for per unit of production by increasing efficiency in energy use by the year 2030. In this context, the energy intensity is assumed to be reduced by 30% in 2030 compared to 2008. That is, annual energy intensity is assumed to decrease by 1.6% on average. The assumptions of this scenario are shown in Table 3;

Table 3: Sustainability Scenarios

	Low Economic Growth	**Medium Economic Growth**	**High Economic Growth**
GDP (%)	3	4.5	6
Population (%)	1.2	1.2	1.2
Export (%)	3	4	5
Import (%)	2	4	6
Energy Intensities (%)	-1.6	-1.6	-1.6

- Periodic-Change Scenarios

In Periodic-change scenarios, the period between 2009 and 2030 are divided into five sub-periods, changes in variables of each period is differentiated. Also using this scenario structure, it is created two different sub-scenarios which are 'Static energy intensity' and decreasing over time called as 'sustainability'. The scenarios are shown in Table 4;

Table 4: Periodic-Change Scenarios

		2009-2012	**2013-2016**	**2017-2020**	**2021-2025**	**2026-2030**
Static Energy İntensity	**GDP (%)**	2	6	5	4	3
	Population (%)	1.2	1.2	1.2	1.2	1.2
	Export (%)	2	5	4.5	3	2.5
	Import (%)	1	6	4.5	3	2
	Energy Intensities (%)	Stable	Stable	Stable	Stable	Stable
Sustainability	**GDP (%)**	2	6	5	4	3
	Population (%)	1.2	1.2	1.2	1.2	1.2
	Export (%)	2	5	4.5	3	2.5
	Import (%)	1	6	4.5	3	2
	Energy Intensities (%)	-1.5	-3.5	-3.5	Stable	Stable

These scenarios are assumed that have the same growth rates in GDP, population, exports and imports for the five different periods. Static energy intensity scenario is assumed to be constant until 2030. In sustainability scenario, it is assumed that energy intensities are decreasing by %1.5 on average annually between 2009 and 2012. it is then assumed to decrease by % 3.5 on average between 2013 and 2020. In the following periods, however, it is assumed to be constant.

5- RESULTS OF THE MODEL

Generated under these scenarios, future energy demand of Turkey using artificial neural networks will be forecasted. The actual forecast is obtained using a feed forward neural network, trained with back propagation algorithm. Data from the period 1970-2008 is divided into three sections for the purposes of training, validation and test. The data between 1970 and 2000 will be used for training, between 2001 and 2004 to validate and between 2005 and 2008 to test.

In this study, before projecting the future energy demand, we will estimate the total energy demand in the past years of 2006, 2007 and 2008 to test the reliability of this method for consistency. The estimated results will be compared with estimates of MENR's energy demand. This will enable us to find out to what extend our and MENR's findings are accurate. The results are presented in Figure 2. According to these results, the artificial neural network estimations found in this study are closer to the actual past trend values. Therefore, the results show that artificial neural networks estimates are reliable.

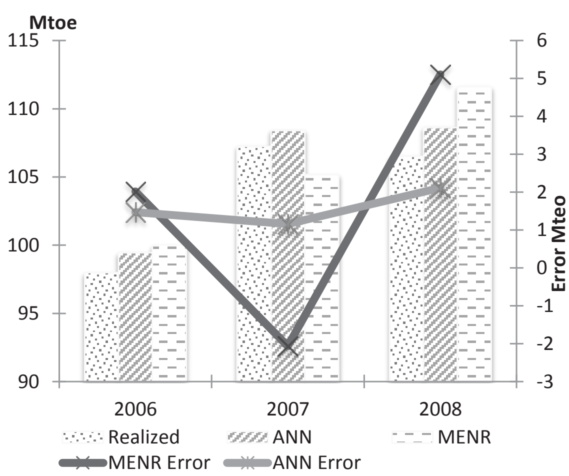

Figure 2: Past Period Estimate

In this section, our future forecast results for three seperate scenarios will be presented. The results are also compared with the official MENR estimates for the same period.

Static scenario estimates are shown in figure 3. The forecasts have been carried out using three different growth rates. Even the highest forecast, Static-high growth scenario, for the energy demand is nearly 30 Mtoe lower compared to MENR forecasts for the same period.

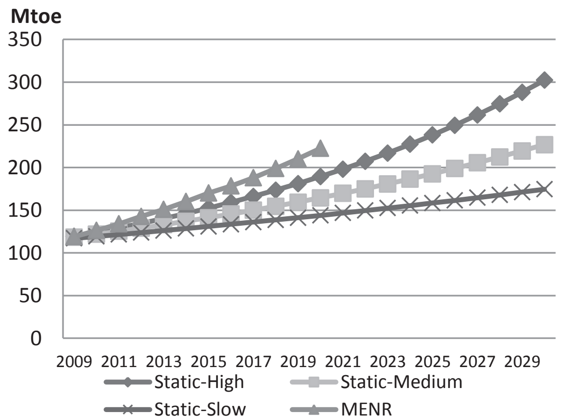

Figure 3: Static Scenarios Forecasts

Sustainability scenario forecasts are shown in Figure 4. Artificial neural network forecasts are consistently lower than the that of the MENR. Sustainability-high economic growth forecast is closest to the MENR forecast. In addition, the Sustainability-low economic growth forecast is about 80 Mtoe lower than the MENR forecast.

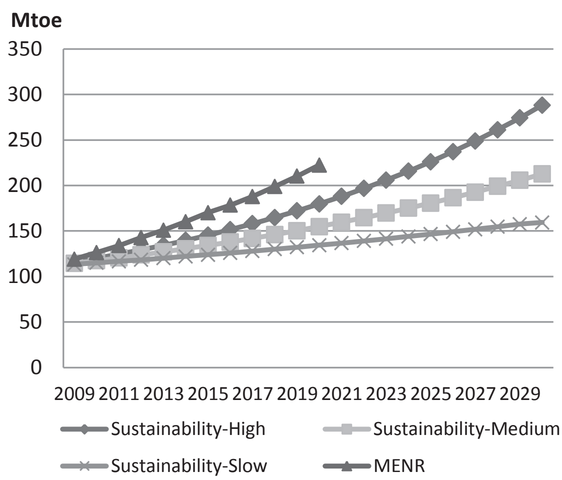

Figure 4: Sustainability Scenarios Forecasts

Periodic Change scenarios forecasts are shown in Figure 5. The Periodic Change-sustainability, assuming to decrease in energy intensities, forecasts are found to be lower than constant energy intensity ones as expected. In addition, it is observed that there is 70 Mtoe difference between our results and MENR forecast.

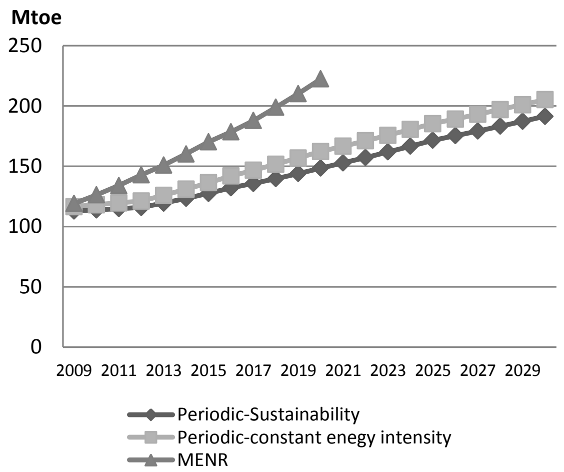

Figure 5: Periodic-Change Scenarios Forecasts

As a result, it is evident that the MENR's energy demand forecasts are consistently higher than forecasts of all scenarios found in this study.

6- CONCLUSION

Countries' energy policies do not reflect only present days' energy situation, they also have to consider how energy resources and use will be shaped in the future. Because of that, energy demand forecast for the future is important in many respects. It is important for investors and energy planners to see how much investment is required and economically sensible in energy field. Increased demand for energy need in the future requires correct determination of the amount of energy. As the amount that will be consumed in the future cannot be determined correctly, there would not be sufficient energy supply, which will result in an energy deficit.

Future energy demand estimations are also important for climate change mitigation actions as the main source of the ghg emissions is due to the burning of fossil fuels. Another reason for reliable energy demand forecasts is due to maintain energy supply security at a sustainable level. In this respect, Turkey is a net importer of energy and the amount of resources paid to energy bill is very high. It is therefore important to know how much energy will be needed and how much resources will be allocated for this sector.

As discussed above energy projections are needed for countries. However, it is equally important to have accurate energy demand estimations.The most important criticism to Turkey's official energy demand forecasts is to use less realistic assumptions on main macroeconomic indicators adopted in the MAED Model. In the official model, socio-economic data used for the future such as economic growth, population growth are formed according to the objectives of governments' development plan. These objectives usually assumes high economic growth and use of more domestic energy resources. Therefore, the exaggerated assumptions have always been resulted in high energy demand forecasts for Turkey. Taking these officially estimated high energy demand forecasts as important parameter in decision-making could mislead the investments required in the energy field.

Because of high energy demand forecasts, high-volume natural gas purchase agreements were signed in the past. The annual amount of natural gas which is covered by these agreements is about 70 billion cubic meters. Moreover, these agreements have both the "take or pay" rule as well as with the long-term contracts (25-30 years). Therefore, Turkey was even obliged to pay for the natural gas that was not consumed (Pamir, 2003). Due to the estimated high demand for energy, future greenhouse gas emissions are also estimated very high. This has resulted in great resistance in among some polciymakers and private sector representatives in Turkey to take a significant action in international climate change negotiations.

Similar to previous academic studies, this paper has found energy demand forecasts significantly lower than the official estimates. In the light of all these studies, it is concluded that Turkey's official energy demand forecasts are overestimated. In future energy planning and policymaking process, it is suggested to take other methodologies and their findings into consideration.

END NOTES

[1] According to the Kyoto Protocol, the attempted control of greenhouse gases are the following: carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), hydro fluorocarbons (HFCs), per fluorocarbons (PFCs), Sculpture hexafluoride (SF6).

[2] This paper is partly based on the first author's unpublished PhD thesis.

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