Hacettepe University Graduate School of Social Sciences

Department of Economics

ELECTRICITY DEMAND FORECASTING METHODS USED IN TURKEY AND THEIR EFFECTS ON INVESTMENTS IN ELECTRICITY SECTOR

Ertan TAŞKIRAN

Ph.D. Dissertation

Ankara, 2021

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ABSTRACT

TAŞKIRAN, Ertan. Electricity Demand Forecasting Methods Used in Turkey and Their Effects on Investments in Electricity Sector. Ph. D. Dissertation, Ankara, 2021.

Electrical energy is one of the most critical elements for accessing applications that are related to modern life. Due to the nature of electricity as a commodity that cannot be stored on a large scale, demand management should be handled with particular care. For this reason, realistic demand forecastings must guide investment decisions. This is also an essential element for the balance of payments and investment planning. Thus, electricity investments are also essential to determine accurately associated with unsaturated electricity demand in Turkey. Furthermore, many tools and materials used in the electricity sector are requiring high technology imported goods. Besides, the fuels used in electricity generation and the planning of the power plants that use these fuels affect all economic activity. As a result, planning is the most important factor for power plants. For this purpose, some energy models and forecasting methods have been developed for use in many countries worldwide. Some of these models and methods have also been used in Turkey, but high rate deviations have been observed up to 85% in long-term official forecastings. Even though rapid developments of computer and software technology ensure to enhance forecasting accuracy in many countries, such a deviation ratio is an unacceptable subject in Turkey. In this thesis, as a common and high forecast accuracy rate, the ARIMA Model and Artificial Neural Networks (ANN) have been used for future 10-year demand forecasting in Turkey. These forecasting results have been compared with the actual amounts and official forecasting. Then, the relationship between these results and power plant investments in Turkey has been discussed. Accordingly, it is analyzed that existing investments and future investments can meet the electricity demand. Finally, the proposals for investment in Turkey in the international developments and practical guidance and solutions have been introduced.

Keywords: Electricity Market, Electricity Demand Forecasting, ARIMA, Artificial Neural Networks.

ÖZET

TAŞKIRAN, Ertan. Türkiye’de Kullanılan Elektrik Talep Tahmin Yöntemleri ve Yapılan Tahminlerin Elektrik Sektörü Yatırımlarına Etkileri. Doktora Tezi, Ankara, 2021.

Elektrik enerjisi modern insan yaşamına dair bütün uygulamalara ve hizmetlere erişebilmek için en önemli araçtır. Doğası gereği büyük ölçekte depolanamayan bir mal olduğu için talep yönetimi özel bir özenle yürütülmelidir. Bu nedenle gerçekçi elektrik talep tahmin projeksiyonları elektrik sektörü yatırım kararlarına yol gösterici olmalıdır. Böylelikle, elektrik sektör yatırımları Türkiye’de henüz doymamış olan elektrik talebi ile uyumlu yürütülmelidir. Zira, elektrik sektöründe kullanılan pek çok malzeme ve araç-gereç yüksek teknolojili ithal mallardır. Ayrıca, elektrik üretiminde kullanılan yakıtlar ve bu yakıtları kullanan santrallerin de planlanması ülkenin bütün ekonomik faaliyetini etkilemektedir. Bu amaçla, pek çok ülkede bazı enerji modelleri ve tahmin yöntemleri geliştirilmiştir; ancak bu yöntemlerin de kullanıldığı Türkiye’de uzun dönemli resmi tahminlerde % 85’e varan oranlarda sapmalar görülmüştür. Bilgisayar teknolojileri ve yazılımlarındaki gelişmelerin, Dünya’nın geri kalanında yapılan tahminlerde kesinlikler sağladığı görülmekteyken, Türkiye’de yapılan tahminlerde bu denli yüksek sapma oranları görülmesi dikkatle ele alınması gereken bir husustur. Bu tezde, Türkiye’nin gelecek on yıllık elektrik talep tahmini için, yaygınlığı ve tahmin isabeti yüksek olan zaman serisi modellerinden ARIMA Modeli ile Yapay Sinir Ağları (YSA) kullanılmıştır. Yapılan bu tahminlerin sonuçları ile resmi tahminler karşılaştırılmış, sonrasında tahmin sonuçları ile özellikle elektrik güç santralleri yatırımları arasındaki ilişki irdelenmiştir. Böylelikle, mevcut yatırımlar ve gelecekte planlanan yatırımlardan elde edileceği öngörülen elektrik enerjisi üretiminin, elektrik talebini ne ölçüde karşılayıp karşılayamayacağı da tartışılmıştır. Ayrıca Türkiye’de yapılan elektrik sektörü yatırımlarıyla ilgili olmak üzere uluslararası gelişmeler ve uygulamalar ışığında bazı öneriler getirilmiştir.

Anahtar Kelimeler: Elektrik Piyasası, Elektrik Talep Tahmin Yöntemleri, ARIMA Modeli, Yapay Sinir Ağları.

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INTRODUCTION

Many services and applications related to modern human life can be accessed with electrical energy. To carry out these services continuously and without interruption, the interconnected electrical system must work flawlessly. It is very important to ensure the supply-demand balance of electricity, which is considered a public good in many countries due to this function. Electricity can be generated simultaneously with consumption, and for this reason, system balance must be perfectly maintained. If the balance cannot be achieved, many services related to modern life are interrupted: Metro and train transport, household appliances, communication, health services, enlightenment, etc. Thus, it is vital to plan electricity generation to meet the electricity demand, and it can be ensured only by accurate demand forecasting.

There are many studies related to electricity demand forecasting, though many of them concerning engineering and electrical industries in Turkey, there have not been any academic studies on the effects on investment. In this scope, the relationship and interaction between investments and demand forecastings will be examined and aimed to contribute to the literature.

In many developed countries, where electricity demand is saturated, electricity investments have concentrated more on renewable energy sources and energy efficiency with the effect of both free-market dynamics and the regulatory-interventionist role of the state. Although electricity demand has increased an average of around 10% in Turkey in the last 50 years, power plant investments have reached such a level far above the electricity demand in recent years. The renewable power plants have outstandingly increased, but investments in other conventional resources have also increased rapidly. For this reason, in the electricity sector, which is a capital-intensive sector, it cannot be denied that rapid technological developments and highly import-dependent sector. Therefore, investments should be carefully planned in this sector. For good planning in the efficient investments in the electricity sector, demand forecastings are among the most critical indicators. But, demand forecasting studies carried out in Turkey for many years have not shown a good indicator of their high rate of deviation.

Demand forecasting studies were not elaborated properly during the vertically integrated state monopoly period due to the high increase in unsaturated demand and cross-subsidies of TEK. The Turkish electricity sector had been operated under the state monopoly for many years, and it has turned into private-sector domination with the liberalization efforts after 2001. In this period, the idea of supplying electricity to every village of the country caused demand forecasts not to be needed or was not taken seriously. However, when the share of the private sector in the installed capacity increased, its’ effects on distribution and transmission sub-sectors also increased.

However, the results of demand forecasts made in Turkey have deviated greatly over the years. Although there are a slight deviations in the demand forecastings carry-out in the World, the deviation rates in Turkey are unfortunately too high to be ignored. On the other hand, the reason for the need for investments in the electricity generation sector in Turkey is the forecastings that the electricity demand will be very high in the future. For this reason, generation investments made by the private sector in Turkey continued to increase. However, the increase in the amount of demand remains quite below the production capacity.

Since it is seen that the installed power has doubled in comparison to peak-load demand in recent years, forecastings should be made very precisely in terms of financing and investment efficiency. Generation planning, in other words, how much electricity will be produced, how the generation will be met from which power plants and the financing and amortization of the investments to be made are estimated by considering the forecastings data. If forecastings are not carried out properly, contracts and obligations signed before will cause severe problems in the industry.

In addition, electricity investments in the world are realized according to the principles of profitability and efficiency, taking into account the unique characteristics of electricity. Although renewable energy investments increase in Turkey, as in the rest of the World, with various support mechanisms, other resources are also supported. Purchases at guaranteed prices with support mechanisms cause negative effects on end-user welfare in terms of price.

Thus, it is clear that the competitive environment, which is stated to be created by the increase in investments, could not be achieved, that market efficiency in the electricity market, which was liberalized in 2001, have not realized, and that no benefit could be provided for the final consumer. In this process, public power plants were privatized, and the share of the private sector in electricity generation reached 80%. This rapid transformation experienced in the sector, especially starting from 2010, caused new investors to enter the market and the transferred funds from other sectors. These investors used foreign credit resources as much as they used their own resources for electricity sector investments. Today, the rate of loans used by the sector has reached around 50 Billion USD. This situation leads to the realization of idle investments above the needs and the exclusion of loan resources from the needs of other sectors.

In the current situation, the gross demand amount in the electricity generation sector is around 304 TWh, while the available generation capacity is calculated as 490 TWh. Also, electricity demand in Turkey is being saturated gradually, it is predicted that the increase in licensed and unlicensed power plants will increase this idle capacity. Although many energy forecasting models and methods with international validity are used for estimation electricity demand, the high demand forecast amounts of MENR and other public institutions still have been announced, and huge deviation rates have been observed too.

Forecasting studies carried out in many countries, the models and methods, the variables and coefficients of these models, calculation tools and justifications are disclosed to the public in detail, but in Turkey, only the amounts are disclosed by the MENR. Due to this non-transparent process, precise determinations cannot be made regarding the reasons for forecasting deviations. Nevertheless, it is understood that it is desirable to declare the amount of demand to be high by using overly optimistic demand growth amounts. The desire to make a generation investment by making high electricity demand forecasts cannot be analyzed because the basic principles of public administration, transparency, accountability and openness, are not followed and the details of the calculations are not known.

In this dissertation, it is aimed to calculate the state of electricity supply and demand balance, based on why official demand forecasts deviate at such high rates, and electricity generation investments are realized according to these demand forecasts. the high-rate deviations in the gross electricity demand forecasts are examined by periods and the reasons for the deviations are examined. In addition, the electricity generation plant investments realized from the past to the present and the amount of production and available capacity are calculated, and the energy that the plants planned to be put into operation could produce in the future according to their capacity ratios are calculated.

To forecast electricity demand, energy-electricity forecasting models and methods used in the world and Turkey are examined briefly and tried very accurate results predicted by ARIMA. The increase in investments and the optimum investment level are tried to be determined using these forecastings. Then, ARIMA model results are compared with the ANN model by using economic and social variables. These results are analyzed with actual demand and official forecasts. As a result, calculations made by these two methods show demand quantities far below the official demand forecasts. Since the models and variables used for official demand forecasts and the considerations are not disclosed to the public, the real reasons for the deviations cannot be revealed. However, it has been observed that high annual demand growth rates have been determined without considering the slowdown in electricity demand growth rate in recent years. It has been observed that the rate of increase in demand has decreased since the 2000s in the periods separated into sub-periods since 1923. However, official estimates use higher growth rates without considering these declining rates.

In the light of these explanations, in this dissertation, which consists of seven chapters, firstly energy and electricity are dealt with as a commodity, and accordingly, the stages of the electricity market in the world and in Turkey are discussed. In the Second

Chapter, electricity demand and forecasting are examined and electricity demand forecasting models and methods used in the world and in Turkey are briefly explained. Then, demand forecasts in Turkey starting with the Planned period and actual demand were compared and electricity demand forecasts for Turkey were mentioned.

In Chapter 3, electricity demand forecasting literature review is made and explanations are made about the established model. In Chapter 4, electricity investments and the constraints for making investments are discussed, and current and future electricity generation possibilities in Turkey are calculated.

In Chapter 5, forecasting has been made with the model established with ARIMA and ANN and the results were compared with the actual demand amounts. Finally in the Chapter 6 with Conclusion, in the light of the forecastings of model, electricity generation investments and demand projections in Turkey are discussed and suggestions are presented.

CHAPTER 1

ENERGY, ELECTRICITY, AND MARKET

1.1 ENERGY

Although energy is generally referred to as the ability to do work or the power to generate heat, the word energy was first used by the Greek Philosopher Aristotle as *energeia*, the meaning of this word remained uncertain at that time. This uncertainty continued for almost two thousand years between experimental philosophy and theological debates. Throughout the entire Middle Ages and then even in Galileo, Torricelli and Newton, there was no clear definition of energy. Later, in 1717, Bernoulli defined energy roughly as "the product of force times the (virtual) way in its direction" (Kümmel, 2011).

The conservation of energy was first described in terms of *vis viva*. According to Leibniz, vis viva was the sum of the mass, and squares of velocity formed the force ($p = mv^2$) (McDonough, 2019). This concept was later called kinetic energy and was also described as a "*living force*" for mechanical energy conservation. Then, Albert Einstein designated ($E = mc^2$) the relation between energy (E) and mass (m), and energy is equivalent to multiplied of mass and square of the speed of light (c^2) (Kümmel, 2011).

The energy process can be divided into three parts: Bulk material allocation from the natural environment, separation of the raw material, and revealing the energy stored in the raw material (Niemes and Schirmer, 2010). The materials needed to produce energy are found in proportionally low amounts in the natural environment. This low amount of material is separated from the environment where it is located, and then energy is released by passing through certain processes.

While the energy is obtained, all the energy in the material is not revealed. This is "*anergy*." Anergy is called energy that does not turn into another type of energy or work under certain thermodynamic conditions. As free disposal costs are inevitable for by-products, this is precisely the situation in which we encounter with anergy. Also, here we see the diminishing marginal production assumption for each additional output, and production is a decreasing function of its inputs. This assumption also means an increase in anergy for the by-product because all forms of energy are still constant (Niemes and Schirmer, 2010).

Considering these concepts in the context of energy production, it is necessary to explain the concept of *thermodynamics*. The term thermodynamics was first used by Lord Kelvin in his publication in 1849. Thermodynamics is derived from the Latin words "*therme*" (heat) and "*dynamis*" (power). It can be defined as the branch of science that deals with the energy and the deformation of energy. Even today, thermodynamics is defined as energy, heat, work, and entropy science (Akdağ, 2009).

In the mid and late 19th Century, although many scientists adhered to the idea that heat is a weightless fluid, empirical evidence supporting the heat-work energy equivalent became dominant. Thus the expression of equivalence formulated the First Law of Thermodynamics. About the First Law of Thermodynamics, energy (generally heat) is conserved in its quantity (including energy equivalent of mass). It can be neither created nor destroyed. The total energy in the universe remains constant (Michaelides, 2012).

The Second Law of Thermodynamics, which is the main principle for converting heat into work, states "no free lunch" (Kümmel, 2011). The meaning of this point for life is that plants, people, and animals maintain their lives, and facilities related to modern life need additional energy (Hall, 2017). It is implied that if there is not any input, there is not production. The second law of thermodynamics states that heat always flows from the hot body to the cold body. Not all energy used as input is included in the output because some pass to another place in the process (or space).

As energy turns into another useful form, this process is created through an external intervention or a converter. For example, automobile motors are used to provide motion energy, heaters, and air conditioners are used for heating or cooling, and machinery used in production is a kind of converter. The aim here is to explain how this transformation works according to the laws of thermodynamics rather than how transducers work (Martínez et. al., 2018). Thus, according to the first law, input energy is equal to output energy, while according to the second law, input energy is equal to output energy plus wasted energy.

Energy is potentially contained in water before flowing into turbines, coal, natural gas, oil before burning, or in radioactive elements before reacting. Kinetically, it manifests itself in the form of rivers, streams, and waves in the sea, the wind itself, the radiation of the sun. Accordingly, to create a movement other than man's muscle power, creating energy by using the substances in nature directly or indirectly is performed under the laws of thermodynamics. Thus, primary energy can be obtained as motion energy from wind and stream or as heat energy from burning a substance directly. As a result, secondary energy can be produced by converting the movement or heat to another energy.

1.2. CLASSIFICATION OF ENERGY

Although the most common classification of the energy resources is fossil resources, nuclear energy, and renewable resources, considering the category of primary and secondary energy resources, another classification of energy resources in this dissertation. However, it is helpful to explain here one of the standard classifications: (*i*) Fossil sources and nuclear sources called "*non-renewable*" energy sources. Non-renewable resources, once passed through the production stages, are resources that disappear in nature and cannot be directly used in energy production again. (*ii*) "*Renewabl*e" energy sources are resources that can be used as long as they exist in natural processes that do not disappear due to production stages. (Aydın, 2018)

1.2.1. Primary Energy Sources

The primary energy sources are divided into fossil fuels, nuclear sources, and renewable energy sources. While oil, natural gas, and coal are counted in fossil fuels, hydraulic energy, solar energy, wind energy, geothermal energy, biomass energy, and marine energy are among renewable energy sources.

Apart from human muscle and animal power, they are primary sources such as oil, coal, natural gas, water, wind, solar and geothermal energy obtained from nature. As some of these can be used directly, such as coal and natural gas, some are offered for direct use after various very few physical and chemical processes, such as petroleum.

1.2.2. Secondary Energy Sources

Secondary energy sources are energy sources obtained by applying substantially chemical and physical processes to primary energy sources. Besides the sources obtained by passing through chemical processes such as fuel-oil coke coal and coal gas, the most common secondary energy source is electrical energy. Electrical energy is generally obtained by producing motion energy by primary energy sources through nuclear reaction or physical transformation. In order to obtain products such as gasoline, LPG, diesel oil, crude oil must be distilled in refineries (Aydın, 2018).

Apart from these classifications, a classification can also be made according to whether the energy is tradable in the market, whether it is renewable or not, and whether its technology is old or new.

Table 1. Classification of the Energy

Energy Classification (Tradable or Conventional/Renewable)		**Renewable or not**	
		Renewable	**Non-Renewable**
Conventional	**Commercial**	Large Hydraulic Geothermal Nuclear	Fossil Fuels
	Conventional / Non-Commercial	Animal and Plant Waste Windmill & Watermill Wood (Sustainable)	Wood (Non-sustainable)
	New- Innovative	Solar Small Hydraulic Wave	Rock Oil Rock Gas Rock Coal

Source: Aydın (2018)

1.3. ELECTRICITY

Electricity is a physical event caused by charged particles that are stationary or moving. The basic element in electricity is the accumulation of negatively charged electrons, one of the particles of the atom, in one direction or moving in another direction. Electricity is the most convenient way of transferring energy. Simply, electricity is the flow of electrical charge.

Most materials are electrically neutral, and these materials have an equal amount of positive and negative electrical charges. When an electric field is applied to such materials, the positive and negative charges are displaced into the electric field and the current direction. As a result, a pair of positively and negatively charged dots with a small distance between them occur, called electric dipoles (Matsushita, 2014).

As is known, particles with the same sign (plus or minus ends) repel each other, while particles with different signs attract each other. A positive particle in an atom is a proton, and a negative particle is an electron. Neutrons and protons that are uncharged are located in the nucleus of the atom, as electrons are free in the orbit of the nucleus. The separation of free electrons in many metal materials from their atoms and transporting them through a free conductor towards another atom creates electricity. To obtain the high amount of electrical energy required in the industry, it is necessary to rotate the electric generator connected to the turbine shaft in any power (heat, hydraulic, gas, or nuclear reaction) with mechanical energy. The principle of the operation of an electric generator is based on the movement of a conductive wire, usually copper, made of a material from which electrons are released in a magnetic field. The electric generator generates the electric current that is moved from the atom to the atom by rotating the wound conductor wires called stator rotating in a magnet called the rotor. The electron movement that occurs in this way is transmitted by the movement power called voltage.

The properties of electricity as good can be mentioned as follows:

- Electricity is an unique homogenous commodity. Its frequency measures the quality of electricity as good in Hertz, and it’s continuous supply. Although 60 Hz frequencies are used in some countries, most countries supply electrical energy at 50 Hz to end-users. There are also offered to the final consumer of electricity at 220 V and 50 Hz in Turkey. Therefore, if it is supplied uninterrupted, everyone can use a uniform good of the same quality.

- Electricity is not consumed directly, and it is used with some appliances and equipment. The generated electricity is transmitted at 380 kV or 154 kV voltage levels in Turkey, and the substations lower the voltages. After that, a low voltage level (220-380 V) is used by the industry or households with distribution lines.

- Although it is similar to other goods, electricity has its characteristics. Electricity fluctuates demand by day, hours of the day, seasons, years, and regions.

- The important feature here is that it cannot be stored economically with current technologies. As it cannot be stored economically, it must be used as soon as it is generated.

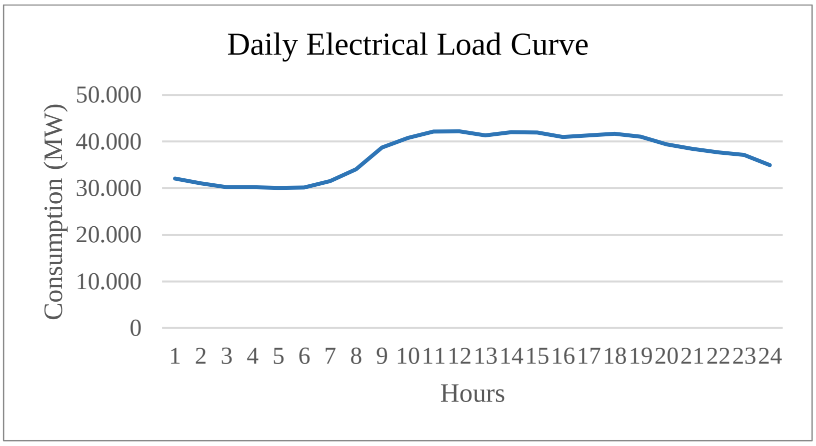
- One of the most important features of electrical energy is that it can be divided into desired amounts. The amount passing through the meters can be easily transmitted in kWh units. If technical requirements are met, electricity can be used immediately.

- It does not directly create environmental pollution.

- Electricity is transmitted to the end consumer through lines; due to thermodynamic laws, technical losses increase as the distance between the place where it is generated and consumed is longer. This causes large investment expenditures.

- One feature that distinguishes electricity from other goods is the sudden changes in demand within hours or even seconds. Electricity consumption, also generation fluctuate every second of the day. Since the electricity demand is extremely volatile, it is a source of energy produced when consumed, requiring perfect planning. After the base load is provided, the meteorological events, social events, holidays, or non-workdays affect electricity demand.

Figure 1. Daily Electrical Load (Demand) Curve



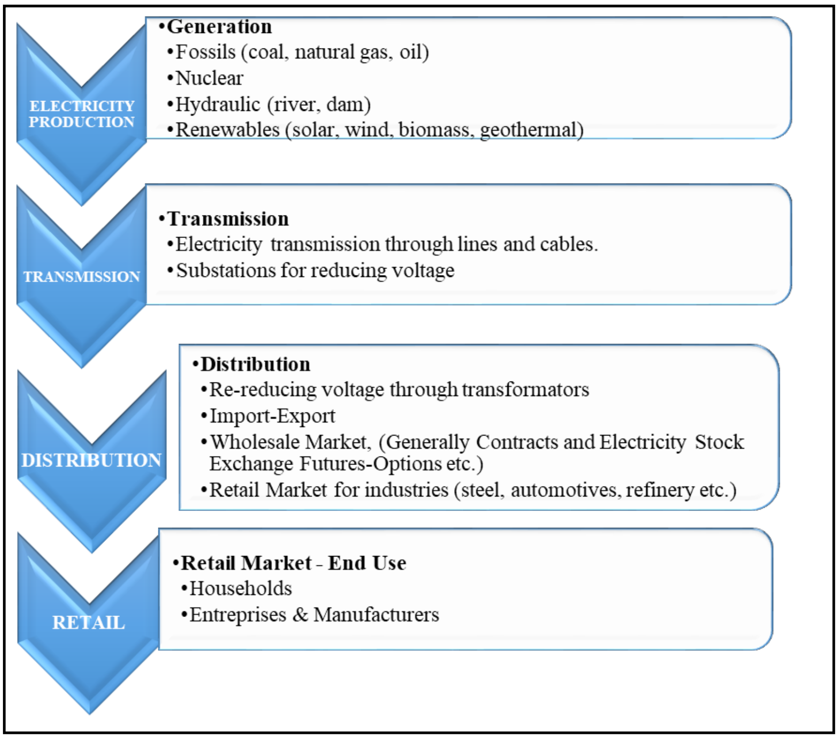
Source: TEIAS, Turkey Daily Electrical Actual Load Curve of 06.01.2021

It is stated here that the *baseload* is required for the system to be in balance at minimum usage. Baseload is generally provided by thermal power plants such as coal-fired and nuclear power plants, which have slow activation and deactivation times. Increasing or decreasing consumption, rapidly activated or deactivated power plants use natural gas, hydraulic, and wind power plants. This balance is entirely planned by the transmission system operator (TSO - TEIAS in Turkey), and the increase and decrease in a generation are provided instantaneously with the signals given to the remote system-connected plants.

Since electricity generation plants are diverse, they are activated according to the order called *merit order*. Therefore, the current energy sources are listed according to the capacity to be activated in the entire electrical system simultaneously in balance (IEA, 2001). With the introduction of smart-grid technologies, the effective balance of increasing and decreasing generation is analyzed demand changes through real-time communication tools and control panels. In particular, when demand reaches its peak level in minutes and seconds, instant supply-demand balance can be achieved thanks to smart grid technologies (Pratt et. al., 2010). Thus, as stated above, the continuous supply of electricity is guaranteed to be readily available if demand increases per second. To ensure this continuity, the following four phases are generally mentioned in electricity: Generation, transmission, distribution, and retail.

The electricity generation sub-sector is a highly capital-intensive sector. Economies of scale are limited, and coordination economies are seen. In general, many companies in this sub-sector show competitive market characteristics. The transmission and distribution sub-sectors show natural monopoly properties and have high sunk costs. Here there is no competition, or a limited number of actors are empowered. The retail sector, where the end-user is located, can generally show competitive features (IEA, 2001).

Figure 2. Traditional Electricity Sector Stages from Generation to Consumption



1.4 FEATURES OF THE ELECTRICITY MARKET

Energy using is an important factor in economic development and is considered one of the conditions of development. This relationship which continues with economic development, also increases the demand for better energy services.

In this context, fossil fuels, renewables, alternative energy sources, energy efficiency, energy independence and security, and climate changes are also factors to be considered. These issues require good planning to ensure continuity as the energy supply, and demand balance is related to the energy source where produced or extracted and where consumed is a different area (Dorsman et. al., 2013). The energy sector requires interdisciplinary cooperation as well as regions, countries, and locally with special attention because of its technical requirements and capital intensity. Besides, it should not be ignored as much as its social dimension also contributes to production (Bhattacharyya, 2011). However, there has been more interest in environmental and social concerns of development in recent years when markets were established, and energy policies were determined. These restrictions impose several obligations, particularly under the Kyoto Protocol and the Paris Agreement and civil society pressure for decreasing greenhouse emissions.

Environmental effects are inevitably occurring in all energy production areas. There are some critical environmental reactions (about air pollution, climate change, waste and water pollution, loss of biodiversity, etc.), especially in power plants using coal and oil and nuclear, because the reactions of many people who are interested in environmental events other than electricity generation or economics create public pressure (Harris, 2006). However, energy is an indispensable element for production, such as labor and physical capital, and affects economies heavily when there is a supply shortage. Also, energy infrastructures include long-term planning, investment, and operation phases. If this process does not harmonize with the economic environment and the social environment, it is inevitable to experience supply or demand problems in the long run. Zweifel et. al. (2017) explain briefly;

- Since energy infrastructures involve long-term planning, investment, and operation phases, this process should harmonize with the economic and social environment. Therefore, the political effects and regulations of public authorities are more dominant than other sectors.

- As the processes of producing (or extracting), transmitting, and transporting energy are the most pollutant factors of water, air, and soil, it is one of the sectors where negative externalities are most common. Due to these externalities, it is not Pareto Optimum since it does not reflect the actual prices of the energy product. But electricity does not directly affect the environment.

- Many energy markets exhibit monopoly or oligopoly characteristics rather than full competition. Especially the existence of natural monopolies, lack of competition, or being too difficult necessitates a public authority to regulate these markets.

After addressing these issues, energy services considered one of the basic human needs such as shelter, food, economic, social, and environmental aspects are all related to human development (IEA (c), 2005).

1.4.1 Electricity Economy

The electricity economy is mainly divided into two categories: The first is called the electricity demand economy, and it concentrates more on the simultaneous balancing between production and consumption. The second deals with the optimal allocation of resources and electric power source also called the “electricity supply economy” or the “electrical energy economy” or “power system economy” (Hu, 2013).

This dissertation dealt mainly with the demand economy in the first category. Because the power systems economy is mostly related to technology, especially production technology for electricity generation and the use of resources, it is useful to state that the electricity demand occurs simultaneously with the electricity supply. That is, electricity is an exceptional commodity that can be produced when it is used synchronously. In economic theory, it is quite difficult to find another good that can be used in this way, except for free goods. It should be noted here that it is important for electricity to increase its prevalence and usage in every field in modern society.

According to the supply and demand theory, price is the main determinant for the demand for a good. Consumers can increase or decrease their demands according to the price of the goods within the scope of substitution possibilities. However, electricity is a compulsory facility used to access all amenities of modern life such as IT, heating, cleaning, cooking utensils. In this respect, substitution for electricity consumption is very difficult, sometimes impossible to compare with other goods. Therefore, it is seen as a sector that needs to be carefully managed and regulated.

Especially the advantage of electrical energy is its widespread use in many sectors and households, and it is difficult to substitute for other energy sources. While it is possible to replace the electricity used for some purposes, for example, heating, hot water, and cooking, it is still not fully substituted in many areas. Because electricity is the most important element in many consumptions and production fields, such as electrical appliances, air conditioners, and even cars, this is related to the electrical infrastructure and how widely used it. This substitution is directly related to the non-widespread electrical infrastructure, the habits of use, and, most importantly, the level of income.

The low price and income elasticity of electricity demand confirm this situation. Due to the low price and income elasticity of electricity, consumers cannot react in a short time when the price increases or decreases. Also, using it's widespread, it is difficult to substitute easily in the long term. Accordingly, electricity is a compulsory good (inelastic demand) in terms of economic theory.

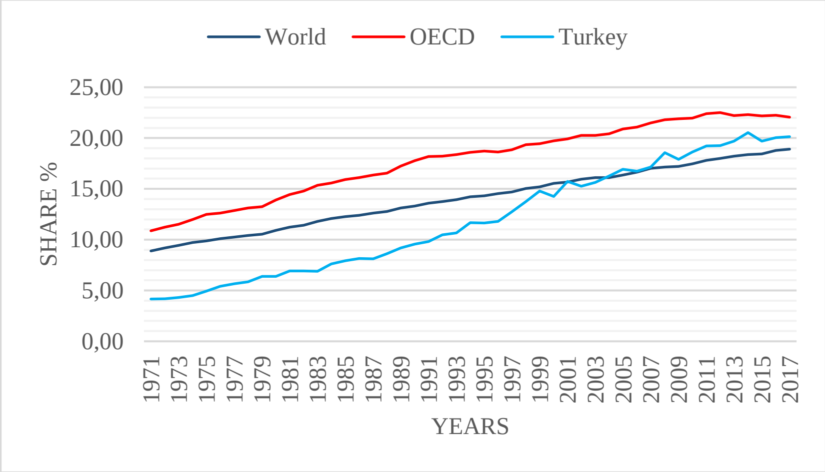
Table 2. The Share of Total Final Energy Consumption by Energy Sources (1971-2018)

Share of Final Energy Consumption by Source	**1971**			**2018**		
	World	**OECD**	**Turkey**	**World**	**OECD**	**Turkey**
Coal	14,96	12,64	14,87	10,01	2,68	10,26
Oil	47,02	55,06	44,88	40,64	46,39	38,03
Natural Gas	13,71	17,58	0,00	16,21	20,97	24,23
Electricity	**8,89**	**10,87**	**4,16**	**19,31**	**22,10**	**21,29**
Other (Biofuels and waste)	13,81	3,14	36,09	3,03	1,62	0,97
Geothermal+ Solar+Wind etc.	1,61	0,70	0,00	10,80	6,23	5,22
Total	100,00	100,00	100,00	100,00	100,00	100,00

Source: IEA, Key World Energy Indicators 2020

It can be understood from the table above that the share of electricity doubled worldwide in 2017 compared to 1971, whereas the share of electricity in Turkey has quadrupled in the same period. Based on the increase in Turkey, there is also the impact of rural-urban migration and great electrification efforts in the 80s. Mainly, the investments made for village electrification corresponded to an average of 16.30% of the electricity investments. Likewise, electricity consumption increased 22 times in the industry, while there was a 36 times increase in household consumption in this period.

Figure 3. The Share of Electricity on Total Energy Consumption (1971-2018)



Source: IEA, Key Indicators of 2019.

1.5 THE HISTORY OF THE ELECTRICITY MARKET

1.5.1 World Electricity Market

The electricity industry was organized in a multi-part structure since the first power plant was established in 1882 and continued this structure until the 1920s. There was intense competition between electricity producers and sellers, which are largely privately owned. It is observed that electricity was widely organized as an auto-producer for the needs of manufacturers necessities in this first period. Besides, electricity was mostly used in the lighting of the street and public buildings.

The electricity market in the World indicated a monopolistic market behavior from production to sales mainly invested by the private sector in this first period. Once again, regional and national monopolies became active in the sector. In short, the prominent feature of this period can be expressed as a private property dominant structure, scattered facilities, and the absence of the national network yet. Meanwhile, cartels have started to appear in the market. Even electricity was still considered a luxury goods by governments.

Later, the public sector intervened dominated the market started from the 1930s and continued until the end of World War II, in the second period. The prominent feature of this period was the widespread confiscation and nationalization efforts. Starting from these years, the idea that electricity was a “public good and service” is a common idea until the 1970s. National networks developed rapidly, and large-scale power plants for various sources started to be established.

Meanwhile, many European states were structured in the form of a completely vertical integrated natural monopoly (Thomas Edison also proposed such an organization), and a large number of small producers were organized nationally as a single monopoly or a large regional monopoly. In this period, electricity companies have tended to combine structurally as a single company.

Vertically integrated power companies own transmission and distribution lines as well as generation facilities. A company established in this way is a monopoly to generate, transmit and distribute the electricity over a specific geographical area with the privilege granted to it by law or with its privileges (Kirschen and Strbac, 2004).

This third period shows that monopolistic structures owned by the public are preferred to the monopoly run by the private sector. France established EDF in 1946, and Italy constructed ENEL as a monopoly with a vertically integrated structure owned by the state in 1962 (Varley, 1999). Turkish Electricity Association (TEK) was established a vertically integrated model of EDF in 1971. Also, ECGB (Central Electricity Generating Board) in the UK was one of the largest vertically integrated companies between 1958 and 1990. Following the functional unbundling in the 1990s, sub-companies were sold through privatization.

Only a different model has been applied in the USA, and special monopolies subject to state regulation and control have been formed. These monopolies have been constantly and tightly controlled by the State, such as tariffs and service quality (Atiyas, 2006). One of the most important features of this period is the economic completion of the vertical integration between small-scale power plants and production and transmission due to oil shocks. After the 1970s, especially oil shocks, the period of intensive unbundling (vertical separation), competition, regulation, and privatization activities began in the electricity sector. The last stage of convergence and globalization resulting from technological innovations in electricity is now considered other commercial goods (Jentsch, 2001).

The debate over whether electricity should be treated as a pure public good that requires special treatment at the long-term protection, or should be evaluated other goods in competitive markets according to supply and demand condition, has continued until today (IEA, 1994).

The following five factors related to private sector dominance are essentially a matter of debate (Berrie, 1992):

1- Especially since the transmission and distribution sectors show strong monopoly features, those who use these stages compulsorily do not have a choice. This can cause these monopoles to behave arbitrarily.

2- Thanks to the increased efficiency, where decreasing costs are often seen in the electricity sector, this decreasing cost is generally not reflected on the final consumer.

3- The electricity generation sector cannot be held responsible for environmental impacts and public impacts of transmission-distribution networks. Except for a few simple administrative regulations, an effective responsibility method cannot be established in the private sector-dominated sector.

4- When consumers utilize public services such as direct lighting, they are not directly involved in their billing. As this is indirectly contributed, it cannot be easily seen how much of a burden is placed on consumers.

5- People cannot easily understand what the high standard is in the electricity industry. While other goods and services can easily be compared, this possibility is almost nonexistent in electricity. Still, keeping the voltage constant and uninterrupted electricity supply may be the criteria here.

There has been intense debate ever since liberalization work began on whether electricity is a public good. Electricity has been defined as a public service in continental Europe. For example, about the German Electricity Law, from 1935 to 1998, electricity was defined as “*Daseinsvorsorge*” (public service) in Germany, and it was stated that consumers could reach it at a reasonable price. (Tehrani et. al., 2013)

Advocates of the first opinion believe that electricity is an integral part of modern life and it must be used to access all other home and industrial applications so that it can be provided to the users without any distinction, such as distant and near, poor and rich. That is, it should be organized as a specific sector that includes protective measures.

The supporters of the second opinion argued that, although it has unique characteristics, electricity should be considered as other energy sources traded in competitive markets such as gas, coal, and oil, only because of the complex nature of this market, there should be a competitive structure by providing system and supply security (IEA, 1994).

However, these intense debates in the electricity market have recently focused on whether electricity grid security is in the public domain or not. Network security in the transmission industry is often seen as a public good. The basis of this is that a network is a tool that must be used and that the users cannot be excluded from consuming these goods or services and cannot be competitive (Kiesling, 2009).

Nevertheless, unlike this view, there is a transition and institutionalization towards a competitive market dominated by the private sector in many countries around the world. In this context, starting from Chile in 1982, there has been a transition to market-oriented approaches in the electricity industry in Argentina, Norway, England, Wales, Australia, Spain, and California-USA.

Norway is the first European country to create liberalization electricity markets in 1991. The market operator, which was established as an independent company in

Norway, was named Nord Pool with the partnership of Sweden. Later, Finland and Denmark also joined this company. Thus, starting from Scandinavia, with the Netherlands following these countries, restructuring occurred in the electricity market in almost all of Europe (Dorsman et. al., 2013).

The European Union also issued many directives for the regulation of the electricity market on the creation of a competitive market and the separation of monopolies financially and administratively. Expressed here, the electricity market in Turkey in 2001 with Electricity Market Law No. 4628 has started to join the free market transformations without a European Union member because even the member of the Union, France, did not have any activities in this regard until 2007.

1.5.2 Electricity Market of Turkey

Before the Republican Era, electricity-producing efforts began in 1902 in Tarsus in Turkey with a water mill at 2 kW and accelerated after the concessions were granted to foreign subsidiaries in 1910. Electricity, which was considered as public goods and services in the Ottoman State, was produced and distributed by giving privileges as in many other public goods and services. In this period following the II. Constitutional (II. Meşrutiyet), privileged foreign companies were established for production and sales in some major Anatolian cities.

After the declaration of the Republic in 1923, the implementation of the privilege of foreign companies was continued until the 1930s, and then nationalization and confiscation were implemented. The market structure, which operated in this way through some state-owned companies, ETIBANK, and municipalities, continued until World War II. A new phase that continued until 1960 manifested itself as regional privileges given to domestic companies and public companies.

During the Planned Economic Period, a vertically integrated state-owned monopoly Turkish Electricity Authority (TEK) was established in 1971. Except for a few domestic privileges given in the 1950s, electricity production transmission and distribution facilities were gathered in a single company in Turkey. The widespread form of organization in the world has been vertically integrated public companies, and TEK was organized vertically integrated in the same way by taking the EDF structure established in France.

In the period starting from 1980, it was seen that the laws giving the privilege of electricity generation to the organizations outside the TEK were enacted for the removal of the TEK monopoly. These applications started as Build-Operate, Build-Operate, and Transfer and Transfer of Operating Rights, resulted in the enactment of the law for the privatization of TEK as a whole in 1993. However, this law was annulled by the Constitutional Court since electricity had strategic importance for national security and the possibility of such an arrangement causing cartels. During this period, as the increase in electricity consumption could not be met by production, TEK had to make regional and hourly mandatory power cuts. After direct privatization was failed at this stage, TEK subdivided into two public companies in 1994, and it has been separated from generation- transmission (TEAS) and distribution (TEDAS) sectors as two parts. Then TEAS (integrated structure of production and transmission) was eliminated and three new public companies TEIAS, EUAS, and TETAS, were established by the Council of Ministers on 05.02.2001. At this date, also EMRA (EPDK) was founded, and the electricity market, and later the natural gas, oil, and LPG market, were restructured through regulation.

Also, the separation in the electricity sector was carried out in two stages. In the first stage, the TEK was divided into two, and in the second stage, which started by dividing TEAS into three in 2001, the distribution companies affiliated with TEDAS were also privatized and separated. Thus, public companies in the electricity sector in Turkey were divided into four separate structures.

The latest market structure is organized as a state monopoly in transmission (TEIAS), privileged private oligopoly for distribution, a large number of public (EUAS) and private power plants in production, and a large number of retail companies. EPIAS operates the wholesale electricity market at any hour of the day in a market organized as an exchange. All these institutions and companies operating in these sectors are all on the market by obtaining a license from EMRA. In this market, tariffs for distribution companies and retail companies in Turkey are regulated by the EMRA. These tariffs, which are updated every three months, are applied in a uniform standard at the national scale by sector. For example, there is an arrangement called a "revenue cap" in the transmission sector. Accordingly, after the financing and investment needs required by the transmission company are determined, they are carried out with the approval of EMRA. As a result, the transmission tariff for generation, distribution companies, and companies directly connected to the transmission line are determined.

However, EPIAS, which is organized as an exchange in the wholesale market, determines the system marginal price and market clearing price with future transactions for the next day or future. Besides, distribution companies, retail companies, or free consumers directly connected to distribution and transmission systems can buy and sell electricity at the agreed price with bilateral agreements of electricity producer firms. Again, it makes day-ahead agreements with generation companies to ensure the system balance for the capacity and ancillary services (Balancing Power Market) required by TEIAS. At present, the share in the installed capacity is approximately 68% of private companies, 22% of EÜAŞ, 3% of Build Operate and Build Operate Transfer, and the rest is the share of unlicensed power plants. Thus the share of the public in the installed capacity has decreased to 22% due to privatizations and an increase in private sector investments in the last decade.

Table 3. Plant Ownership in Turkey in March 2021

Plant Ownership	Installed Power (MW)	Share (%)
Private Power-Plants	65.675,80	67,66
EÜAŞ Plants (State)	21.426,60	22,07
Transferring Operating Rights	2.831,30	2,92
Build-Operate-Transfer Plants	126,80	0,13
Unlicenced Plants*	7.007,30	7,22
TOTAL	97.069,70	100,00

Source: TEIAS

* Unlicensed power plants are below 1 MW, do not require any operation license from EMRA

CHAPTER 2

ELECTRICITY DEMAND AND FORECASTING

2.1 ELECTRICITY DEMAND

As a result of the support of Israel by most of the Western states in respect of the Arab-Israeli War, the first oil shock had been experienced with the export embargo of oil producer Arabic countries**.** Until then, energy consumption, which took shape according to the increasing supply situation, evolved to another dimension with the increase in oil prices 3–4 times. Energy supply security has become more critical for countries (Laitner et. al., 2003). Energy supply security and increasing reactions and restrictions against global warming, and changes in the transactions in competitive markets affect the operation of energy markets (Bhattacharyya, 2011). Moreover, the increase in energy efficiency affects the demand side of the energy markets and thus the supply sector.

Before 1973, abundant and cheap oil caused no need or little need for local or national planning, not only in the oil but also in the electrical, gas, and coal sub-sectors. Nevertheless, as there is not a large and cheap oil as in the 1960s, planning has become necessary at the national level, whether the market mechanism is working or not. Even in the 1990s, in terms of pricing, energy management, and investment, the capacity of the country to deal with energy shocks was difficult in the energy and its sub-sectors since there was no institutionalization (Berrie, 1992). Like other energy sources, electrical energy was also affected by the bottlenecks created by these supply shocks. According to this new situation, demand forecasts have to be made with more precise and accurate methods to meet the electricity demand.

In non-OECD countries, electricity using is increasing highly in residential and commercial buildings due to income and population growth and spreading access to electricity. Also, the use of electricity is growing in the industrial sector as a result of the expansion in production and the transportation sector with the broadening of electric vehicles and electricity-powered subways, and other vehicles (EIA, 2019).

Demand management changed its’ focus due to various events such as technological developments, breakthroughs in communication, improvements in production processes, development of better quality with lower costs in the 1990s. The importance of demand management has shifted to commercial and industrial demand management rather than household consumption. Demand management has also promoted energy efficiency for sustainable development due to the industry’s search for lower costs (Suganthi and Samuel, 2012).

As known, the electricity demand is handled much differently than demand for other goods, as it cannot be economically stored. Although balance is achieved through subsidies or the differences in balance are met by the public in a market dominated by state monopolies, there may be some volatility in balance, such as financial problems and power outages in a market dominated by the private sector (Cugliari and Poggi, 2018). A striking example of power outages occurred in California-USA, which started in 2000 and continued until 2001. As a result of many market manipulations for electricity companies on the stock exchange, deregulations and price quotas, prolonged blackouts, and astronomical price increases in the wholesale market were observed (Weron, 2006).

Energy demand management is an important issue for future electrical energy planning, selection and prioritization of energy resources, optimization of energy use, policy decisions for improvement in energy efficiency, and carbon emission reduction (Suganthi and Samuel 2012). However, some difficulties can be seen in developing and less developed countries. Bhatia (1986) lists the following problems with forecasts in developing countries: (a) using traditional energy is still widespread, (b) many poor people not to reach the commercial energy source (c) unsaturated demand pattern and (d) height in energy loss-leakage rates.

All of the characteristics above of developing countries largely also possible to see in Turkey. Although consumption of traditional primary energy resources is seen in rural areas, its share is very low. The slowdown in the demand growth rate compared to 10 years ago indicates an improvement in saturation. As loss-leakage rates, one of the most significant factors affecting electricity demand, tends to decrease, the rate of increase in the number of demand decreases.

Electricity losses-leakages may be due to the technical operation of the system and the electrical theft, which is called "electricity pilfered." This phenomenon is seen especially in developing and under-developing countries. Except for technical losses, final consumption losses are high due to prevalent reasons such as meter manipulation, non-registered connections, and measurement or calculation error, unfortunately, for many years in distributing the theft-loss rates at very high levels in Turkey. In this losses-leakage rate, also called electrical pilferage, is quite high. Although the loss in distribution tends to decrease in recent years, it is still well above the rates of developed countries. Regarding losses in electrical energy distribution, it is accepted as reasonable loss rates by the American Public Power Association (APPA). APPA takes the values in Table-3 as reference.

Table 4. Reasonable Electricity Grid Losses and Leakage Rates

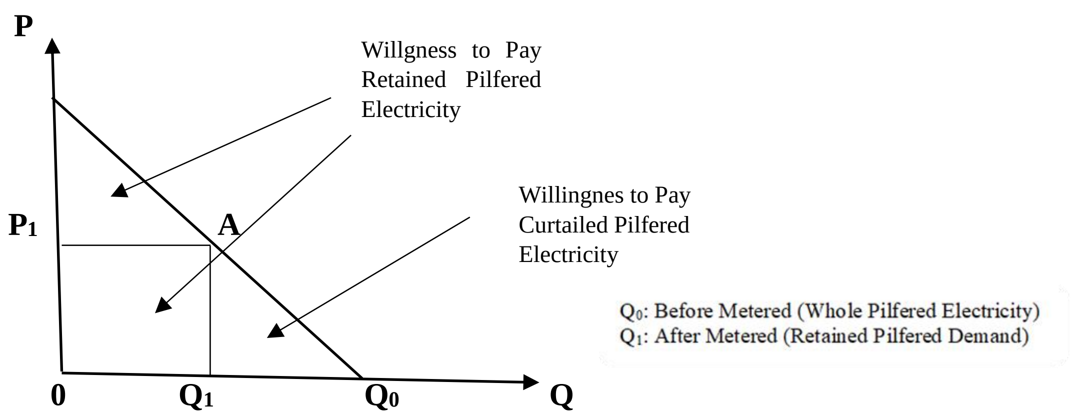
System	**Losses/Leakages (%)**
High/Low Voltage Link	1
Medium Voltage Link	3,5
Medium/Low Voltage Link	2,5
Low Grid and Link	2
Total	9

Source: American Public Power Association (APPA)

Pilfered electricity demand is higher ratios in both metered and non-metered consumption. Although consumers have meters, they prevent meter control or low consumption by interfering with the meters by consumers. Also, usage without meters is a common situation, especially in agricultural irrigation.

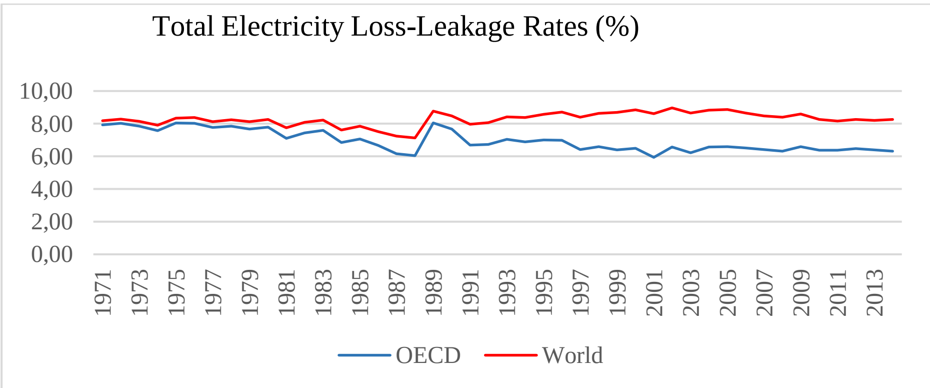
According to the Figure 4., consumers are accustomed to consuming electricity free of charge. In this situation, they consume electricity up to Q0. When these consumers start to be charged, their consumption habits will change (lower consumption). They will be willing to pay some price (P1), and they will consume lower amounts. Electricity providers will save some (Q1-Q0) of the electricity that is already used for free, and they will charge a part up to (0-Q1).

Figure 4. Pilfered Demand of Electricity



Source: Lim and Jenkins (2000)

Figure 5. Total Electricity Loss-Leakage Rates 1971-2014)



Source: Worldbank Electric Power Transmission and Distribution Losses [1]

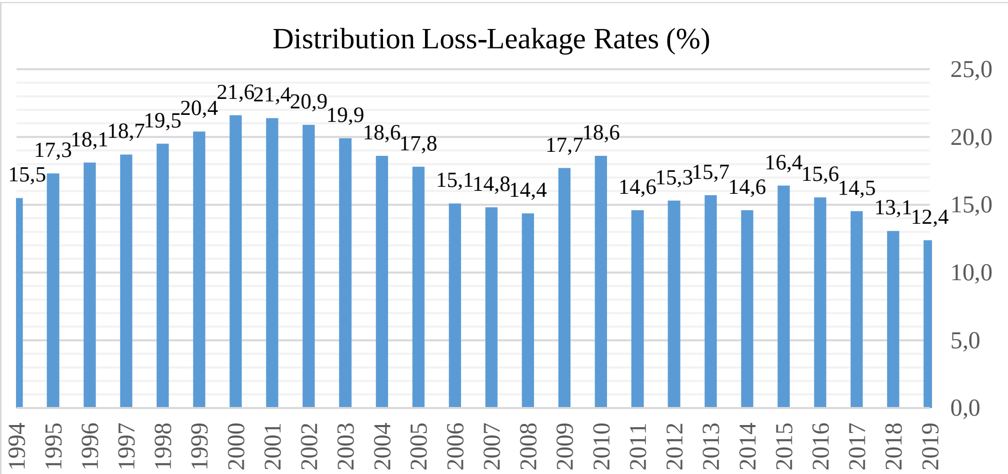
While the world average of both distribution and transmission losses is around 8%, this rate is around 6% on average in OECD countries. As two points in these rates arise

[1] Among the OECD countries, lowest total losses-leakage ratio is in Greece, the highest rates, respectively, are in Turkey, Mexico and Canada. Losses in Canada mostly occur as a result of the length of transmission and distribution lines due to the large area of the country.

from the transmission system, the remaining amount is realized at the distribution and sales stages. However, this situation reaches incredible dimensions in some countries and regions at the distribution stages, and this problem also creates a serious inconsistency in terms of correct pricing and real demand. Smith (2004) states that, in a developed country such as the USA, it reached 3.5% (approximately $ 10 billion) in 1999 and it reached 35% in a less developed country like Bangladesh that same year. (Smith, 2004)

The losses-leakages in the transmission system, which has high design standards depending on Turkey's population density and geographical conditions, are at the level of 1.75-2% by international performance levels, even if it is better than world averages. Also, since the electrical voltage in the transmission system is very high, electrical theft or pilfered is almost impossible; losses occur at this stage for technical reasons.

Figure 6. Distribution Loss-Leakage Rate in Turkey (1994-2019)[2]



Source: Annual Reports of EMRA and TEDAS

However, it reaches very high rates due to leakages and illegal use during the distribution phase. Because this rate in distribution and retail stages has reached of two

[2] The Loss-Leakage Ratios were compiled from TEDAS Annual Reports until 2011, the rest were compiled from EMRA Annual Reports. However, due to the privatization of TEDAS's subsidiary companies, there are many deficiencies especially in the accuracy of the rates between 2008 and 2012. The loss leakage rates published by TEDAS in 2008 and 2009 are around 25%. Moreover, the rates published by EMRA are not exactly correct, since calculations made by taking the averages of the percentage rates, The amount of loss and total amounts on the basis of the distribution company are not published. Because, while the share of total loss-leakage amount in the electricity offered to total consumption should be calculated, EMRA publishes the arithmetic average of the percentages of all distribution companies. (https://www.epdk.gov.tr/Detay/Icerik/3-0-24/elektrikyillik-sektor-raporu)

times the world average and three times the OECD average, it is a big problem for Turkey's electricity demand. Nevertheless, as the loss and leakage rates have been decreasing in recent years, it has a decreasing effect on gross demand through meter controls and pricing.

The electricity demand has many aspects, such as consumers' income and production level, the prices of electricity, and the number of electrical appliances. However, it is also affected by many temporary factors: changes in weather conditions, power outages, and the number of new customer contacts (Lim and Jenkins, 2000). Besides, energy demand is not much different from other commodities dealt with in microeconomics.

Nevertheless, the consumer knows and sorts his own preference sets, shows these preferences in the utility function, and makes rational choices. That is, the consumer depends on his Utility Maximization Problem (UMP). Likewise, producers refer to their production function when determining the factor demand required for production: Cost Minimization Function (CMP) (Bhattacharyya, 2011).

However, while the household and industry -services and manufacturing sector, consume electricity as a commodity, they also give some reactions. Naturally, both households and business sectors pursue economic interests. This interest forms the optimum consumption pattern for the household to maximize utility satisfaction in line with its income and market prices. Here, the consumer observes her income and alternative prices of the goods in her basket. Accordingly, electricity can be replaced with natural gas or alternative fuels (for example heating), in areas other than those that must be used.

Additionally, electricity demand is affected by the behavior of consumers and their expected income. However, these two factors are very slow to change. Therefore, past income and consumer behaviors are important. In other words, consumers react to their demands for electricity with a delay (Lim and Jenkins, 2000).

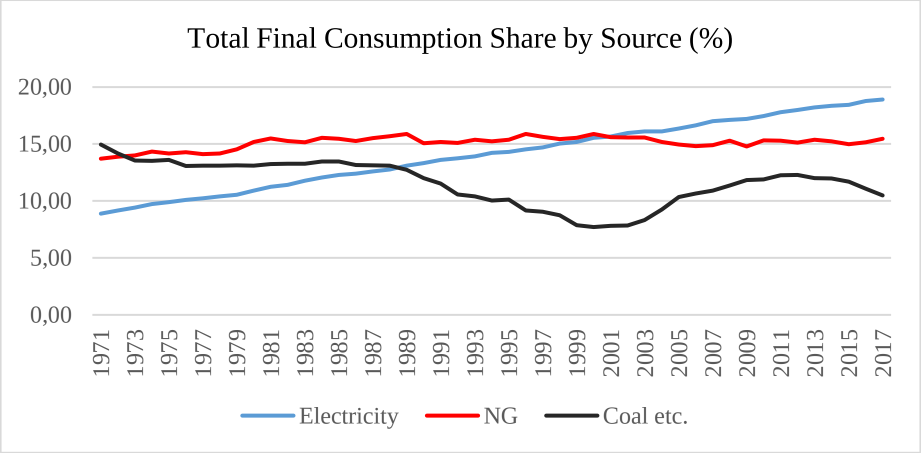
Similarly, companies pursue profit maximization by making choices between the production factors and the raw materials that make up the cost item according to their production technologies. One condition of profit maximization is provided by cost minimization. (Naturally, if productivity growth is kept at least constant). As the share of energy costs in total costs is also relatively high, companies prefer energy sources according to the prices of the inputs they use and their availability.

For this reason, energy consumption can vary according to energy demand, input prices, income, and output levels in general. It should be noted here that the rate of electricity-powered machinery and equipment in companies' production processes and the substitution of electricity. Although the theory of economics emphasizes profit maximization according to the tastes of households and production technologies of firms, it is limited by psychological and physical factors. Thus, it is not very easy to substitute due to the increasing use of modern transportation, home applications, and easy access. Therefore, we can say that utility maximization is a bit more important than cost minimization.

While some socioeconomic, demographic factors and climatic conditions affect the consumption pattern, and the building architecture, engineering features of the building, power appliances and tools existing at the residence, and energy infrastructure of the building may not allow direct substitution effects on consumer preferences (Gellings, 1996). Because, if there is an electric stove installed in the house, and there is no natural gas infrastructure, for example, heating is provided only with electric heaters. On the contrary, in a house with both the electric stove and natural gas infrastructure, it changes the consumer position according to price fluctuations. Typically, while changes in income level and prices of goods affect the consumer's bundle of choice, this is not so easy and speedy with electricity. In this frame, it can be even said that electricity is not a flexible commodity.

As can be seen from the table below, the share of electricity consumption has increased in the last 50 years, while the consumption of coal, which is an alternative product, has decreased, and natural gas consumption has remained stable at 13-15%. In this phenomenon, besides the peculiarities of electrical goods, the widespread use of electrical appliances and equipment and efficient technologies have a significant role. The increasing use of electricity will expand, and it will become a final product for which substitution is almost impossible in the long run.

Figure 7. The Share of Selected Energy Sources in World Total Consumption



Source: IEA, Headline Global Energy Data, 2019[3]

2.2 ELECTRICITY DEMAND FORECASTING

In fact, since electricity was widely used in lighting for the first time, there was not much need for load and demand estimation. Because the number of lighting lamps in the network was known, it was also known how much load would be in the evening hours. However, the widespread use of electrical appliances and the use of electricity in the industry made this work a little more complicated. Especially in the 1940s, the prevalence of air conditioner use caused jumps in daily load curves due to the increase in air temperatures and humidity in the USA. Since then, one of the most essential tools for electricity demand forecasting has been weather forecasting. (Hong and Shahidehpour, 2015)

Throughout the 1950s and 1960s, interest in demand forecasts was not very common. After World War II, which was still growing steadily, the high demand has led many

[3] Although the share of coal in the world has decreased by 2000, the increase in the consumption of coal after 2000 has a great role in the increase in China's coal demand. In 2017, 65% of the World's coal consumption is made by China alone. The demand for coal in the cement and steel industry is still high.

to think that the extrapolation methods were largely sufficient for planning purposes. While the over-estimation for the future was quickly corrected in the next period due to rapid demand increases, underestimating was ignored because the new baseload power plants were activated due to cheap oil and gas (Électra, 1986).

Forecasting, which we encounter in all areas of economics and finance, occurs in terms of the value that households or firms can take one or more future variables. As known, households determine their labor supply according to their expectations of wages and savings, while firms decide on their future investment decisions according to expected cash flows and interest rates. Similarly, large infrastructure investments in public finance are also important to achieve the expected income flow and the targeted goal throughout the project's life. (Elliot and Timmermann, 2008). It can even be said that forecasting is at the heart of planning for both the power sector and the actors on the electricity demand side (Berrie, 1992).

Many different organizations can make both generation (supply) and consumption (demand) forecasting of electrical energy. Industrial companies that consume large amounts of electricity, electricity generation, transmission, distribution, or retail companies can also make predictions for their own purposes. Forecastings are used for various purposes ranging from the real-time operation of power generation plants to determining required long-term generation, transmission, and distribution development plans.

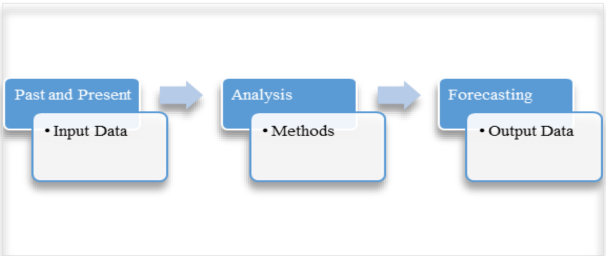
Thus, forecasting in the electricity sector is important not only for generation decisions and transmission-distribution capital investments but also for financial forecasting, fuel purchasing-storing, and using in production, capacity, and reserve planning and implementation. Therefore, forecasting is important for electricity generation, transmission, distribution, and retail sales companies to make precise and accurate predictions (Electra, 1992).

Electricity generation, transmission, and distribution sub-sectors need high capital requirements. Also, since the projects in these sectors are very large, the projects take a long time. Again, since many years pass from the planning to the construction of these projects, it takes a long time to start production too. Therefore, unclear and non-indicative demand forecasts create a cost regarding making and timing investment decisions (CIGRÉ, 2006). Since electricity investments are long-lasting investments that depend on technology and need great financing, good planning is required. Whether in the public or private sector, good planning depends on making the forecasts correctly and meeting the needs.

Two different types generally make demand forecasting in the electrical industry of organizations. The first type of organization is vertically integrated or discrete distribution and transmission system operators, generation companies, and electricity market actors. Demand forecastings can be range from very short to long term, are used for system requirements and network capacity, and operational purposes. The second type of organization provides data and information to actors in the first group, such as regulators and government agencies (CIGRÉ, 2016).

The first step in prediction studies is to reach past and present data. Accordingly, outputs are obtained by determining the most suitable analysis method. It is necessary to establish the right model, which is mandatory to find the lowest deviations in the energy or specifically electricity demand forecast process. This process, which does not differ much from the stages of the model that we encounter in econometric models, increases the reliability of the model.

Figure 8. Basic Stages of Forecasting



Source: Debnath and Mourshed (2018)

Gellings et. al. (1996) lists in order of seven steps for forecasting as follows;

- The correct definition of the goal: This first step involves defining the intended purpose of the forecasting. Accordingly, the purpose and objectives of the model can be classified systematically in the economic framework.

- Identification of the model: In the nature and structure of the economic analysis, it is necessary to obtain access data to achieve the purpose of the model established and to produce the assumptions desired.

- Data compilation and review: Careful review of the data to be used in the model and order by purpose occurs at this stage.

- Choice of forecasting method: Since there are many models for energy demand forecasts, it is necessary to analyze which model should be chosen well. The developing technology and literature also diversify the methods to be used and for the intended purpose.

- Forecast Development-revisions: This phase includes the processes such as control of the data, whether alternative data should be used, and reviewing the data. Thus, after this, the model can be verified and evaluated.

- Model Evaluation and Verification: Statistical and parametric tests are used at this stage. Forecast errors are calculated accordingly.

- Forecast Documentation: this stage is important to explain and understand the stages we have mentioned above in the future.

Besides, it will be necessary to consider factors such as electric vehicles, roof panel systems that can cause radical changes in electricity consumption because the changes in battery technology may affect the consumption amounts as well as the consumption patterns.

CIGRÉ C1-32 Working Group states that the following conditions should be taken into account for forecasting electric power and demand (Electra 290, 2017):

- Electricity price elasticity for consumers
- New production possibilities such as rooftop solar panels

- Government incentives for energy efficiency

- Identifying very small pre-existing power generation facilities for actual demand

- Government or regulatory agency effects on tariffs: such as ceiling price- price limit or instant pricing

- Uncertainty in economic variables; changing the demand pattern of exchange rates, growth rates, households, or industries that use electricity

Naturally, those that can be measured among these elements can be included in a demand forecast model. At the same time, externally non-measurable variables are tried to be included in the model according to their effects, although it is not clear.

Electricity demand forecasting can be made for a certain time interval (short, medium, and long term) as well as for countries, regions, and the whole world in a certain geographical area (Debnath and Maurshed, 2018).

Electricity demand forecastings are divided into three parts in terms of time horizon: (i) Short-term, (ii) Medium-term, and (iii) Long-term forecasting (Al-Alawi,1996).

i. Short-term Forecasting: The short-term forecast includes electricity demand estimates from the one-hour to one month. Hourly and daily forecasts are mostly related to electricity transmission system operation and production planning (such as fuel and resource preference). Although some sources also take a “very short time” separation from minutes to a few hours, I think it would be useful to have this distinction under the short time heading.

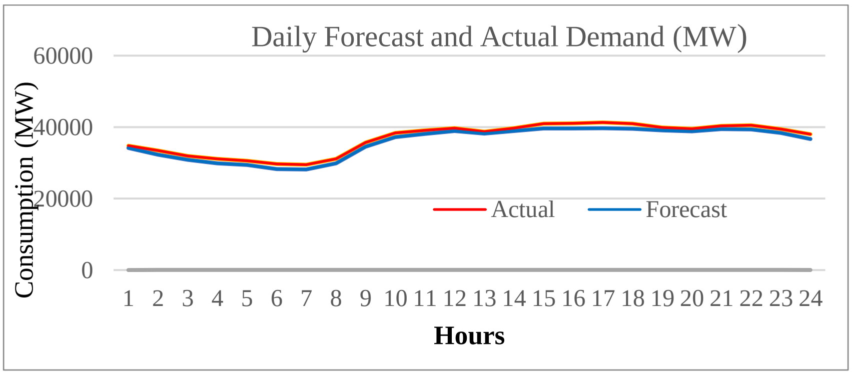
ii. Medium-term Forecasting: The medium-term forecast lasts from monthly to a few years’ forecasts. It includes some social activities and socio-economic factors such as sports events (Olympic games etc.), religious or national holidays, and also covers generation planning and plant maintenance.

iii. Long-term Forecasting: This period requires a forecasting mechanism, from 5 to 25 years, to cover all processes from electricity generation to distribution.

As mentioned in the definitions of short-term and mid-term forecasts, these are important for demand fluctuations that may occur mostly due to meteorology and random effects such as social events, holidays, and some sports events. Instantaneous electrical system balance and working order of the power plants (even maintenance and repair activities) are important in these periods. Transmission service organizations (TSOs) perform these balancing tasks. That is, technically, balancing electricity supply and demand is carried out by TSO.

Meteorological, economic, cultural, and some special factors affect electricity consumption and estimations can be made with an average of 1.5-2% error hourly by using very complicated forecasting techniques (Kirshen and Strabac, 2004). But, the main concerns of this dissertation are long-term demand forecasts and their impact on the market and investments because their effects on investments and the market emerge in the long term. Already, short and very short-term deviations of predicted demand in Turkey are very low.

Figure 9. Daily Electricity Load: Actual and Forecasting by Hours



Source: TEIAS, Data of Demand of 12.07.2020

2.2.1 Electricity Demand Forecasting Models and Methods

There is a very confusing concept in the literature and practice when making energy demand forecasting generally and electricity demand, particularly: Energy forecasting models and forecasting methods. The “model” is a comprehensive and systematic approach to assessment and evaluation in light of its theoretical principles, whose objectives, methodological stages, and specifications are a characteristic combination of specific procedure sequences and techniques. On the contrary, the “method” is specific tools and systems used to analyze and interpret the collected data.

Energy models work by calculating each module, working with many modules separately with lots of data, and then collecting the modules. Major energy agencies around the world have used and recommended these models. On the other hand, forecasting methods are more simply a set of less complex operations that make predictions based on data.

2.2.1.1 Electricity (Energy) Demand Forecasting Models

2.2.1.1.1 WASP Model

The WASP (Wien Automatic System Planning Package) was developed in the USA in 1972 and was first used by the International Atomic Energy Agency (IAEA) in market research in developing countries. Later, in this program, some modifications were made by IAEA, and second and third versions were prepared and used in electrical system improvement in Latin American countries with rich hydraulic resources. As a result, the WASP Model has been an effective tool used by electrical system planners for electrical system expansion planning (IAEA (a), 2001). As mentioned in the previous section, since this dissertation is about the electricity demand economy, it will not go into too much detail regarding the supply-side of electricity.

2.2.1.1.2 MAED Model

Model for Analysis of Energy Demand (MAED), recommended by the World Bank and distributed to more than forty countries, uses some parameters to estimate electricity demand per hour annually with some modules included in it. While the first version was DOS-based, then MAED was added in EXCEL format. MAED is a program that works by dividing agriculture, energy, mining, manufacturing, construction, and service sectors into sub-sectors determined as end-users. The model makes estimates based on resources and sectors, including medium and long-term electricity demand, taking into account social, economic, and technological factors (IAEA (b), 2006).

In the MAED model, starting with the determination of the energy demand in the base year, the base year is adjusted with the energy balance due to collecting the data required by the model and calculating the input variables. This model considers the annual growth trend of electricity demand, seasonal changes in demand, holidays, working days, and special days, as well as calculating daily electricity consumption. (Aydın, 2014)

To run the program, approximately 170 data entries are required each year, with basic data such as GDP, per capita income, population, sectoral energy consumption, energy density. Considering that it is compulsory to enter 1200 data for a 5-year estimate, which is the base year and the control year, it is a labor-intensive task. By running the model, outputs related to primary energy demand, electricity demand, energy demand, and load curves of each sector are obtained (Keleş, 2005).

2.2.1.1.3 LEAP Model

While LEAP formerly an abbreviation of Long-Range Energy Alternatives Planning System, after 2020, it has been changed name as “Low Emissions Analysis Platform.” Developed by the Stockholm Environment Institute (SEI), many institutions in 190 countries use this model, but 37 countries take LEAP results as decision-makers for their commitments under the Paris Agreement. LEAP’s main topics of interest are future energy needs, carbon emissions, and climate change (SEI, 2020).

2.2.1.1.4 NEMS Model

NEMS (National Energy Modeling System) is an energy economy model designed for the US Department of Energy. This model includes projections such as economic indicators, world energy situation, production and consumption levels, access to raw material, raw material costs, population, and price. Performing general balance analysis, NEMS generates data on the target country's energy market's safety, environmental and economic impacts (EIA, 2018). In this model with a modular system structure, four supply modules (oil-gas, natural gas transmission-distribution, coal, and renewable energy), two conversion modules, electricity generation, and refinery, and four demand modules residential, commercial, transportation, industry (Aydın, 2018).

This model, which also considers behavioral factors, is a complex program. It can be operated in developed countries where the formal economy is widespread, depending on a lot of sectoral data and the consistency of the data. Therefore, it requires a lot of labor and costs. This model does not yield consistent results in developing or underdeveloped countries where the informal economy and loss-leakage are broader.

Besides these models mentioned above, ENPEP, IMPACTS, BALANCE, PRIMES, WEM, ERASME, MARKAL, MESAP, POLES are energy models used in the world were designed according to both sectoral and holistic estimates, generally working with modules and collecting all independent modules.

2.2.1.2 Electricity Demand Forecasting Methods

Future electricity demand forecasting is an important issue for infrastructure planning, development trends, and development indices of the country. In the early periods, these forecastings were made with some mathematical techniques. Aftermath, some tools developed with the advancement of technology have provided opportunities for more effective demand forecasts (Singh et. al., 2013).

Load or demand forecasting methods can be classified as qualitative and quantitative methods (CIGRÉ 670, 2016). Qualitative methods are subjective according to the thought and value judgments of those who know the subject. These techniques can be used when historical data cannot be accessed.

Quantitative techniques, on the other hand, include forecasts of future data as a function of historical data. Forecasts are made with the assumption that historical data will be available and will continue similarly in the future. Multiple linear regressions models, ARMA models (Autoregressive Moving-Average Models), artificial neural networks (ANN), and deterministic methods are counted in quantitative techniques (CIGRÉ 670, 2016). The companies can use either self-developed programs or package programs for these calculations.

In line with these issues, qualitative and quantitative methods are discussed in the classification of traditional-simple and advanced models, a more detailed and appropriate classification. Therefore, forecasting methods can be classified as traditional-simple methods and advanced methods.

2.2.1.2.1 Simple or Traditional Methods

Simple methods generally include simple economic data such as growth rate, population growth rate, per capita income and trend analysis, and simple research. However, these techniques do not take into account demand factors or technology, it can also be used for commercial or traditional energy sources and developed or developing countries (Bhatctacharia, 2011). Extrapolation, trend analysis, and direct surveys are taken in this context. Energy intensity calculations, which are defined as the energy requirement for a unit of output, are also within simple approaches. Additionally, the elasticity calculations of electricity demand for various variables can be considered within this scope.

As well, if some developed econometric models are not counted, econometric models are also among the traditional-simple methods: multiple regression, exponential smoothing, and least-squares technique.

2.2.1.2.1.1 Extrapolation or Simple Economic Indicators

In order to make future predictions through extrapolation, past economic values such as past electricity consumption, growth rates, and income growth are based on. Also, the correlation between explanatory variables for electricity demand can be calculated with some statistical methods (Gellings, 1996). Although these forecastings made in the past do not include the technological progress and consumption pattern, they do not explain exactly, even if they provide information about the development of the demand. These simple techniques show the direction and increase-decreases of the demand with simple data in the forecasting, which will not give much information in a complex and integrated market.

2.2.1.2.1.2 Trend Analysis or Time Series

Trend analysis shows the trend of the data over time based on the past growth rates of the target variable. In this way, with the trend calculated from historical values, the future values of the variable can be estimated. It is the simplest analysis for forecasting future values of energy demand. Trend analysis in electricity demand is mostly estimated in three separate calculations: low, medium, and high scenario estimate.

The time series model used for many years in the world has many advantages and disadvantages. Although it is an advantage that this method is simple to use, it also has many disadvantages (Bhatctacharia, 2011): Forecastings cannot be obtained from historical data, it does not include structural changes, variables such as price and income included in demand cannot be observed, and are not suitable for policy analysis. Also, cause-effect relation cannot be defined in this model.

As can be seen in the ARMA model example, the data to the right of equality can turn into a dependent variable in the time series analysis. In this way, time series analysis does not need to collect data on multiple variables, unlike econometric analysis (Gellings, 1996).

Time series models are the simplest models for trend analysis in energy forecasting. Like traditional statistical models, moving average, exponential smoothing, and ARIMA are linear prediction methods in time series. ARIMA is one of the most widely used time series models and is more efficient than other time series models (Barak and

Sadegh, 2016). Since the ARIMA model is used for forecasting in this dissertation, it will be discussed in more detail in the Fourth Chapter.

2.2.1.2.1.3 Direct Surveys

Direct surveys (questionnaires) sent to organizations in the electricity sector are also used to make electricity demand forecastings. They are carried out by combining the data collected from these surveys. Direct surveys are sent to the power generation companies, distribution system operators (DSO), and transmission system operators (TSO) by public or private institutions dealing with electricity, and they include targets related to the electrical load, parameters affecting the load, their evaluations, regional and geographic analysis.

Although the institutions and companies participating in the survey expressed their subjective evaluations in the surveys and the companies refrain from providing accurate information or provide incomplete information, healthy results cannot be obtained, but this method provides some information at least in terms of the direction of the electricity estimates.

2.2.1.2.2 Advanced Methods

Advanced models are models that enable forecasting by processing more data and information, such as complex econometric models, input-output models, hybrid models.

2.2.1.2.2.1 End-Use Method

After the second half of the 1980s, there was a shift in energy demand forecastings from aggregated models to disaggregated models. Disaggregation or end-use models analyze for what purpose consumers use electricity. Firstly, electricity consumption is divided into sectors or consumers, and the electricity consumption of each sector is estimated, and then combined with these, total electricity demand is estimated (Gellings, 1996). The main idea of the end-use model is the proportion between electricity demand and the rate of electricity consumption, and the input variable. Electricity demand is associated with structural changes in the economy (Sowiński, 2019).

Thus, the consumption of each divided sector is categorized as, for example, construction, transportation, residential use, or intended use, heating, lightning, service, and their electrical demands are achieved. This model is a labor-intensive model that requires a lot of data to be collected and processed.

2.2.1.2.2.2 Advanced Econometric Models

Econometric models used in energy demand forecasting are used to analyze the relationship between energy demand and other macroeconomic variables. Although econometric models have been used for electricity demand estimation for a long time, simple techniques in the early days have evolved to more advanced models with the development of econometric models as well as software advances in parallel with technological development. Models based on understanding the relationship between energy and other economic variables in the 1970s were further developed by testing models established in the 1980s and 1990s. Co-integration, stationary tests have been measures applied in all econometric models. Thus, the reliability of the established econometric models started to increase.

Bhattacharyya and Timilsina (2009) particularly cite the panel data and trans log developments. While widely used econometric models examining electricity demand generally analyze variables such as GDP, fuel price, and population, they cannot explain factors such as technology very well.

2.2.1.2.2.3 Input-Output Model

Input-Output Analysis, proposed by Wassily Leontief in 1936, is a static analysis used in production planning. Energy equivalence is achieved by processing the energy exchange in energy units into matrices related to the product of the original units (BTU or kW) and the quantity (Aydın, 2018).

Input-output analysis is also used to show the relations between economic sectors. Thus, direct or indirect energy demands between sectors are tried to be measured. Incomplete, inaccessible, improperly compiled, and non-accurate timely data cause problems in the implementation of this model (Bhattacharyya and Timilsina 2009). This model requires a lot of data, and it cannot be revealed non-monetary or technological development, input-output relationship, urban-rural differences.

2.2.1.2.2.4 Scenario Method

There are many energy scenarios involving social, economic, and technical issues for policymaking. Although these scenarios, which vary from country to country and according to time, do not give definitive results, they do show a projection.

Although the first examples were seen in the 1960s, it was known for the planning of Royal-Dutch Shell company employees. But, the scenario method in energy was discussed at length in the Intergovernmental Panel on Climate Change (IPCC) in 2000. In a report presented in this panel, energy consumption and CO_2 emission over 20 years were examined in three different scenarios (Ghanadan and Koomey, 2005).

Future scenarios provide policymakers with the opportunity to prepare by presenting various combinations of effects in situations to be encountered. The advantageous use of this approach depends on the ability of sudden and unexpected developments to adapt to predetermined pathways. It is not an easy task for the established model to include structural changes, the emergence or disappearance of economic activities (Bhattacharyya and Timilsina 2009).

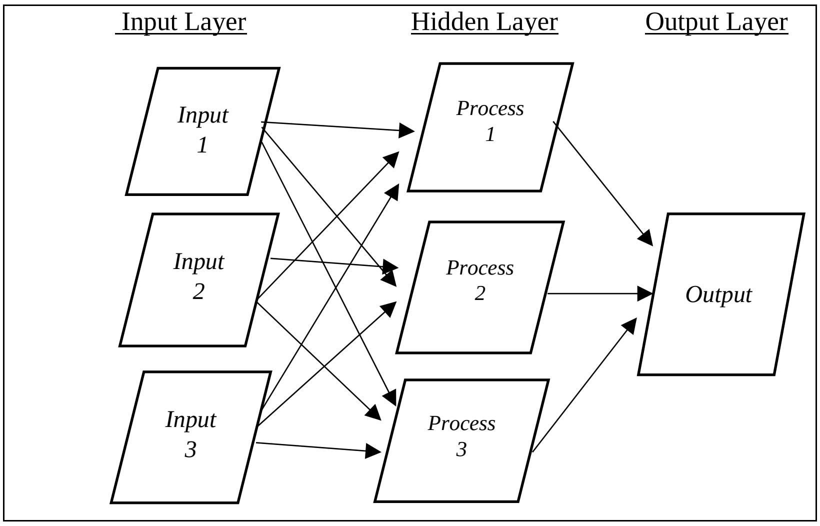
2.2.1.2.2.5 Artificial Neural Networks

The term artificial intelligence, first introduced in the 1950s, is also called intelligent systems. The essential features of these systems are making decisions about events and solving problems, learning the available data and information, and making decisions for the following years. ANN models that duplicate the work of the human brain create predictions for the future through machine learning with data obtained from the past.

Technically, the goal of a neural network is to determine a set of outputs that can correspond to a set of inputs shown to it. To do this, the network reaches the ability to generalize by training with the examples of the relevant event, that is, by learning. Process elements are called input sets, hidden layers, outputs, and lines between processes called connections (Öztemel, 2003).

Accordingly, after n inputs are defined to the model, a result is obtained after operations are performed by the machine on hidden layers as many as the input number. ANN, which can produce different solutions for each problem, can achieve successful results. However, it also has some disadvantages. First of all, the behavior of the established network cannot be explained. Artificial neural networks are hardware-dependent. A network structure suitable for the problem should be established. There is no rule on how the network should be created. In other words, there is no standardized structure regarding the process elements and the number of layers and how the connections between them will be established. The network structure is usually found by trial and error. If the correct network is not established, it can be difficult to reach the optimum solution. Also, there is no advanced method of when the network will be terminated.

Figure 10. A Classical ANN Schema



Nevertheless, one of the most frequently used electricity and energy demand forecasting methods in recent years is machine learning models, namely the artificial neural networks (ANN) method. As can be seen in the following chapters, demand forecasting is made using an artificial neural network in this dissertation.

2.2.1.2.2.6 Hybrid Methods

Two or more methods are generally used to avoid inconsistencies in results from using a single method. For this reason, the results are tried to be optimized by using the methods described above together or in a separate model. For example, ANN models generally use to take advantage of econometric methods. On the other hand, the end-use method can improve itself with the assumptions of the scenario model. NEMS Model can use econometric models and trend analysis. Similarly, econometric methods use trend analysis broadly.

Thus, this dissertation tries to predict future electricity demand by using an artificial neural network model and ARIMA model, which is an advanced form of trend analysis. By comparing the estimated electricity demand amounts with the electricity sector investments, the optimum amounts are tried to be explained in Section 4.

2.3 ELECTRICITY DEMAND FORECASTING IN THE WORLD

Since energy-economy models were used in the post-war periods and 1960s, these models showed they underestimate results during high GNP times. On the other hand, generation projections in the early 1970s caused overestimated results and excessive demand forecastings based on past production and consumption data. Even though the energy quantity forecastings became more precise, even short-term energy prices remained unpredictable by the 1980s. Moreover, given the standard confidence intervals associated with such estimates, a wider range of results and surprises emerged than expected. All these changes in forecasting indicate technological change as well as inadequate evaluation of producer and consumer behavior. (Laitner et. al, 2003).

In the previous sub-section, electricity demand forecasting models and methods were listed and briefly mentioned of their properties. These methods have spread to the World through international-national energy associations of Europe and the USA.

They can be made very fast and reliable calculations in parallel with technological development. Although simple calculations and regression equations are used independently, forecastings are mainly made by energy models. The models can give different results depending on the development levels of the countries and for which sub-sectors they will be used. In other words, the conditions applicable in a specific country may not be valid for other countries.

Along with the technological development, the usage areas and scope of the forecasting model and methods used since the 1960s have also expanded. Increasing processor speeds in computers and rapid development of memory and storage capacities have also made the operation of models and application methods much easier.

ENPEP, WASP, MAED, IMPACTS, BALANCE, PRIMES, LEAP, NEMS, WEM are energy models used in the world and designed according to both sectoral and holistic estimates generally working with modules and collecting all independent modules later. Countries or international cooperation organizations can develop these models for themselves, as well as through academic studies. For example, MAED was developed by IEA for OECD countries and recommended to countries. Again, WASP was developed in America and used by IAEA. The Swedish Environment Institute developed LEAP.

Naturally, these models are suitable for the subjective characteristics of the developed countries or academies and can only be operated with some modifications in other countries because the development level of the countries and the correct access to the data affect the accuracy of these models and methods.

Thus, the models and methods discussed in the previous subsection and briefly explained include the evolution of the models used in energy demand forecasting in the world. In the next section, while the literature survey is explained, the models and methods used in the world today will be briefly referred to.

2.4. ELECTRICITY DEMAND FORECASTING IN TURKEY

Starting in 1902 with a 2 kW water mill in Mersin-Tarsus, the electricity adventure in Turkey has now reached 97.000 MW. The methods of electricity generation and the type of electricity consumption have considerably varied in Turkey for almost 120 years. Also, the liberalization of the electricity market, privatization, decreasing in the share of public production power plants in electricity production, the planning of electricity has made it important for social cost in the structure dominated by the private sector.

In fact, as a vertically integrated monopoly, The Turkish Electricity Authority (TEK) used stochastic forecasting methods based on their own generation decisions. Still, these methods may lead to market disturbances in a market dominated by the private sector. Even though some econometric models were applied, the state monopoly of the electricity market had difficulties in monitoring these models through a single institution for production, transmission, distribution, and sale to the end consumer. These estimations performed perfunctorily rather than technical necessity and guidance because of political aims, electrification campaigns of the villages, existing political environment, irrational subsidies, and investments. In particular, factors such as costs of fuels used in electricity generation structure, climatic conditions, social events cause many fluctuations in market demand. Therefore, it is important to establish forecasting models that provide more consistent and precise results than traditional (stochastic) demand forecasting methods.

Thus, because of unsaturated electricity demand in Turkey, investments in the electricity sector are also important to determine accurately. Considering that many of the tools and materials used in electricity generation, transmission, and distribution are imported goods requiring high technology, the realistic estimation of demand forecasts that will guide investment decisions is essential in the balance of payments and investment planning.

Since electrical energy use was too low, there were no demand forecasts in Turkey’s pre-planned period. With the establishment of the SPO, it is understood that the first estimates started to be made in the 1st Five-Year Development Plan Period (1962-1967). In this plan, it was emphasized that 69% of the population could not benefit from electricity. Also, the fact that the electricity facilities were under the responsibility of ETIBANK, Municipalities, and privileged companies, which have no relations with each other, has led to the absence of forecasting studies.

Thus, random forecastings (best fit curves) were made by the State Planning Organization[4] (SPO) in 1961, 1966, 1967, 1972, 1977 and 1979; by the MENR in 1973, 1975, 1977 and 1978 (Ediger and Tatlıdil, 2002).

TEK estimated the electricity demand and generation forecastings with random methods from the 1970s until the mid-1980s, then it was used the MAED model proposed by the International Energy Agency (IEA). Holding the generation, transmission, and wholesale market before 2001, TEAS (separated from TEK) made medium and long-term electricity generation estimations using the WASP model.

Electricity demand forecasts were made some calculations with several methods in 1977, 1989, 1990, 1993, 1997, and 1999 in Turkey. Although the forecasting for 1999 was the calculation included in the Electricity Specialization Commission Report of the SPO, huge deviations occurred due to the fluctuations in the GNP data in all these studies. For example, the average deviation of the estimates made in the 1989 Demand Forecasting Study (excluding 1989) was on average 15.54% between 1990-2000.

MAED was used in most of the eight separate forecasting studies mentioned above. Except for the low scenario of the last study, deviations in all estimates were increasing after the first few years. Hence, in some years, deviations reached around a rate of 85%.

However, MAED is not an econometric model that calculates the general energy demand; rather than creating a dynamic energy consumption equation by considering

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[4] SPO was re-structured as the Ministry of Development in 2011, and with the abolition of this Ministry in 2018, its duties were transferred to the newly established Strategy and Budget Directorate.

the past energy demand and the indicators that make up this demand with a time series approach, the coefficients of its parameters are determined mainly by trial and error method. It is a deterministic model operated by an iteration approach (Keleş, 2005).

MAED model was recommended for use in Turkey in 1984 by the World Bank, and it has been abandoned today. Hence it was used for calculations in 2003 and 2004. When liberalization efforts started in the electricity market, it was seen that the search for a more methodical model for electricity demand forecasting was determined by legislation.

According to the regulation in the Electricity Market Law No. 6446, "*Covering the next twenty years Turkey Electricity Demand Projections Report prepared and published by the Ministry of Energy and Natural Resources every two years, also received the opinions of Ministry of Development and EMRA (EPDK)*." (Law No. 6446)

This Law also states: "*Following the publication of Turkey Electricity Demand Projections Report, TEIAS prepares Long-Term Electric Power Generation Development Plan and submits it for approval of Ministry of Energy and Natural Resources for the determination of its policies. This Plan contains a future demand forecast covering twenty years, current supply potential, potential supply facilities, fuel supply, transmission and distribution system structure and development plans, import or export opportunities and taking into account the resource diversity policy*." (Law No. 6446)

To demonstrate the implementation of these provisions of the Law, Electricity Market Demand Forecasting Regulation was published by EMRA in 2016. About this regulation:

(1) Data set of demand forecasting; based on economic, social, demographic, climatic, environmental variables and the realization of the described variable.

(2) Official data published by the relevant institutions and organizations and user/consumer data of OIZ or related companies will be used in the data set based on demand forecasting.

(3) How the data used in the data set required by the demand forecasting model affects the demand forecasting outcome is justified by statistical and logical approaches.

As a result of these regulations, recent forecastings made by the Ministry of Energy and Natural Resources (MENR) and this forecasts are published by arithmetically averaging the estimated results by following five different methods with three scenarios: (1) Econometric Model, (2) ARIMA Model, (3) Comparison Model, (4) Regression Model and (5) Flexibility Model.[5]

Although forecastings were carried out with establishing with three-scenario five forecasting models, the deviations are still very high. As shown below, the deviations of forecastings are higher than before forecasting models such as MAED. That is, the deviations became higher after these technical calculation methods were used. As will be explained in the following sections, the estimation of the data used in the models with over-optimistic approaches causes huge deviations even in the lowest scenario.

The inelaborate preparation of the models and the compilation of data without transparency have led to the overestimation of demand forecasts. These projections caused serious resource allocation problems in Turkey which is a dependency on foreign energy and technology (Keleş, 2005).

2.4.1. Official Forecasting Studies

2.4.1.1 Forecasting of Development Plans

The first resource for electricity demand forecasting is 1st Five-Year Development Plan in Turkey. Although this plan was published in 1963, forecastings started in 1962. In

[5] MENR-General Directorate of Energy Affairs: 2019 Turkish Electricity Demand Projections Report

addition, only the forecast in the last year of the plan was announced in the 2nd Five Year Development Plan.

Table 5. Electricity Demand Forecasting of 1st and 2nd Development Plans

1961 and 1967 Demand Forecasting of SPO			
Years	Forecasting (GWh)	Actual (GWh)	Deviations for Actual (%)
1962	3.550	3.559	-0,25
1963	4.011	3.983	0,70
1967	6.539	6.217	5,18
1972	11.850	11.242	5,40

Source: SPO, 1st and 2nd Five Year Development Plan (1963-1967; 1968 -1972) and TEIAS

The third electricity demand forecasting of the Planned Period was made by the State Planning Organization (SPO) in 1972 and announced in the 3rd Five-Years Development Plan.

Table 6. Electricity Demand Forecasting of 3rd Development Plan

1972 Demand Forecasting of SPO			
Years	Forecasting (GWh)	Actual (GWh)	Deviations for Actual (%)
1977	20.330	21.057	-3,45
1982	35.430	28.325	25,08
1987	59.500	44.925	32.45
1992	95.000	67.217	41,33
1995	125.000	85.552	46,11

Source: SPO, 3rd Five Years Development Plan (1973-1977) and TEIAS

In the context of the Fourth Five-year Development Plan preparatory, the Turkish Electricity Authority (TEK) has started electricity demand forecastings since 1977. This plan calculated that the growth in demand for electricity will be 14.4% on average for five years (4. Five-Year Dev. Plan,1977).

Based on these basic criteria, consumer-based forecasting values are subject to a second evaluation of two phases in this plan calculations. For this purpose, the forecasting values made in four different ways and the SPO estimation amounts other than the trend method were also evaluated. A common series of forecasting values were reached. Thus, for the period up to the end of the 4th Five-Year Plan Period, the averages of the forecasting values presented in five different ways were taken, and the values obtained by the trend method were accepted as the basis for the years after 1983.

In 1977, electricity demand was estimated in the 4th Five-Year Development Plan. Thus, for the period up to the end of the Fourth Five-Year Plan Period, the averages of the estimated values presented in five different ways were taken, and The values obtained by the trend method were accepted as the basis for the years after 1983.

Table 7. Electricity Demand Forecasting of 4th Development Plan

1977 Demand Forecasting Study of SPO (Trend Analysis)			
Years	Forecasting (GWh)	Actual (GWh)	Deviations for Actual (%)
1977	20.200	21.057	-4,07
1978	22.700	22.347	1,58
1979	25.400	23.566	7,78
1980	28.300	24.617	14,96
1981	31.540	26.289	19,97
1982	35.150	28.325	24,10
1983	39.600	29.568	33,93
1984	43.750	33.267	31,51
1985	48.350	36.361	32,97
1986	53.430	40.471	32,02
1987	59.040	44.925	31,42
1988	64.900	48.430	34,01
1989	71.400	52.602	35,74
1990	78.500	56.812	38,18
1991	86.300	60.499	42,65
1992	95.000	67.217	41,33
1993	104.000	73.432	41,63
1994	114.000	77.783	46,56
1995	125.000	85.552	46,11
1996	135.000	94.789	42,42
1997	146.000	105.517	38,37
1998	158.000	114.023	38,57
1999	170.000	118.485	43,48
2000	185.000	128.276	44,22

Source: SPO 4th Five Year Development Plan

The amounts in the demand forecasting study in the 1999 Electric Energy Specialization Commission Report used by the SPO in the 8th Five-Year Development Plan studies show the highest deviation rates in previous demand forecasts. Although the impact of the 2001 crisis is ignored, deviations in the following years rise to 86%. The average deviation in this study was 37.64%.

Table 8. Demand Forecasting of 8th Development Plan Preparation Committee

Years	Forecasting (GWh)	Actual (GWh)	Deviations for Actual (%)
2000	128.322	128.280	0,03
2001	139.753	126.871	10,15
2002	152.203	132.553	14,82
2003	165.762	141.151	17,44
2004	180.528	149.239	20,97
2005	196.610	160.794	22,27
2006	213.162	174.637	22,06
2007	231.108	190.000	21,64
2008	250.564	198.085	26,49
2009	271.659	194.079	39,97
2010	294.530	210.434	39,96
2011	313.890	230.306	36,29
2012	334.523	242.370	38,02
2013	356.513	246.357	44,71
2014	379.947	257.220	47,71
2015	404.558	265.724	52,25
2016	431.151	279.286	54,38
2017	459.492	296.702	54,87
2018	489.695	304.167	61,00
2019	521.885	303.320	72,06
2020	555.690	304.836*	86,47

Source: TEIAS and SPO 8. Five-Year Plan Electrical Energy Special Report

2.4.1.2 Other Studies

Except for State Planning Organization and TEK or TEAS, forecasting studies of some congress of organizations such as the Turkish National Committee of WEC have been realized and published by the MAED model. These studies are carried out by the Ministry of Energy and Natural Resources (MENR) and TEK-TEAS. 1989, 1990, 1993, 1997, 2003 and 2004 studies are known to demand forecasting studies of these official institutions.

Table 9. 1989 Demand Forecasting Study

Years	Forecasting (GWh)	Actual (Gwh)	Deviations for Actual (%)
1989	51.335	52.602	-2,41
1990	61.760	56.812	8,71
1995	101.210	85.552	18,30
2000	156.515	128.280	22,01

Source: WEC-Turkish National Committee 1988 Turkish Energy Report

Similarly, in the 1990 study carried out by MENR, the forecasted demand of the actual demand deviated by an average of 27.11%. The deviation between 2006-2010 was 44.46% on average.

Table 10. 1990 Demand Forecasting Study with MAED

Years	Forecasting (GWh)	Actual (GWh)	Deviations for Actual (%)
1990	57.100	56.812	0,51
1991	68.180	60.499	12,70
1992	75.260	67.217	11,97
1993	83.080	73.432	13,14
1994	91.785	77.783	18,00
1995	101.210	85.552	18,30
1996	110.610	94.789	16,69
1997	120.640	105.517	14,33
1998	131.375	114.023	15,22
1999	143.505	118.485	21,12
2000	156.515	128.280	22,01
2001	167.955	126.871	32,38
2002	180.231	132.553	35,97
2003	193.404	141.151	37,02
2004	207.541	149.239	39,07
2005	222.710	160.794	38,51
2006	239.945	174.637	37,40
2007	258.514	190.000	36,06
2008	278.519	198.085	40,61
2009	300.073	194.079	54,61
2010	323.295	210.434	53,63

Source: TEIAS and WEC-Turkish National Committee Papers of 5. Turkey Energy Congress, 1990

In 1993, in the demand estimation study conducted by MENR with the MAED Model, the deviations that occurred at reasonable rates until 2000 gradually increased up to 43% after this date. The average deviation in this study was 18.40%.

Table 11: 1993 Demand Forecasting Study with MAED

Years	Forecasting (GWh)	Actual (GWh)	Deviations for Actual (%)
1993	71.700	73.432	-2,36
1994	80.375	77.783	3,33
1995	88.375	85.552	3,30
1996	96.800	94.789	2,12
1997	106.000	105.517	0,46
1998	116.100	114.023	1,82
1999	127.200	118.485	7,36
2000	139.280	128.280	8,57
2001	150.720	126.871	18,80
2002	163.175	132.553	23,10
2003	176.660	141.151	25,16
2004	192.555	149.239	29,02
2005	207.060	160.794	28,77
2006	224.190	174.637	28,37
2007	242.690	190.000	27,73
2008	262.745	198.085	32,64
2009	284.460	194.079	46,57
2010	307.970	210.434	46,35

Source: TEIAS and WEC-Turkish National Committee 1992

Again, in the 1997 demand estimation study conducted by MENR with the MAED Model, similar to the previous study, the deviations that occurred at reasonable rates until 2000 but gradually increased up to 80% after this date. The average deviation of this study was 32.62%.

Table 12. 1997 Demand Forecasting Study with MAED

Years	Forecasting (GWh)	Actual (GWh)	Deviations for Actual (%)
1997	105.250	105.517	-0,25
1998	113.750	114.023	-0,24
1999	123.650	118.485	4,36
2000	134.307	128.280	4,70
2001	146.195	126.871	15,23

2002	158.023	132.553	19,21
2003	170.807	141.151	21,01
2004	184.624	149.239	23,71
2005	199.560	160.794	24,11
2006	215.159	174.637	23,20
2007	231.794	190.000	22,00
2008	249.714	198.085	26,06
2009	269.021	194.079	38,61
2010	289.820	210.434	37,72
2011	308.807	230.306	34,09
2012	329.062	242.370	35,77
2013	350.653	246.357	42,34
2014	373.659	257.220	45,27
2015	398.168	265.724	49,84
2016	424.286	279.286	51,92
2017	452.123	296.702	52,38
2018	481.780	304.167	58,39
2019	513.386	303.320	69,26
2020	547.060	304.836*	79,46

Source: TEIAS and WEC-Turkish National Committee 1997

Another demand forecasting study was carried out by MENR in 2003, although the institutions and organizations are different, the excess demand forecast continued in this study. The estimates made in this study show an average of 35.73% deviation.

Table 13. 2003 Demand Forecasting Study of MENR

Years	Forecasting (GWh)	Actual (GWh)	Deviations for Actual (%)
2003	140.861	141.151	-0,21
2004	151.098	149.239	1,25
2005	168.262	160.794	4,64
2006	185.600	174.637	6,28
2007	204.150	190.000	7,45
2008	224.300	198.085	13,23
2009	246.150	194.079	26,83
2010	269.842	210.434	28,23
2011	295.800	230.306	28,44
2012	323.200	242.370	33,35
2013	351.300	246.357	42,60
2014	380.000	257.220	47,73
2015	409.531	265.724	54,12
2016	439.100	279.286	57,22
2017	470.175	296.702	58,47

2018	501.950	304.167	65,02
2019	535.425	303.320	76,52
2020	570.521	304.836*	87,15

Source: MENR and TEIAS. *Temporary

In 2004, within the scope of the electricity sector reform and privatization studies, medium and long-term planning studies were carried out by MENR and TEIAS under the Electricity Market Law, and demand forecasting's were realized in this scope. But, the high deviations still continued in this study, which showed two separate results as high and low scenarios.

The deviations occurred differently in the two scenarios with the same GDP growth rates, but other variables were calculated as high and low. While the deviation of Scenario 1 was 23.47% on average, of Scenario 2 was 8.15%. Thus, it can be said that the deviations in Scenario-2 in the 2004 study are reasonable. However, in the last five years, estimation deviations up to 36% are observed again.

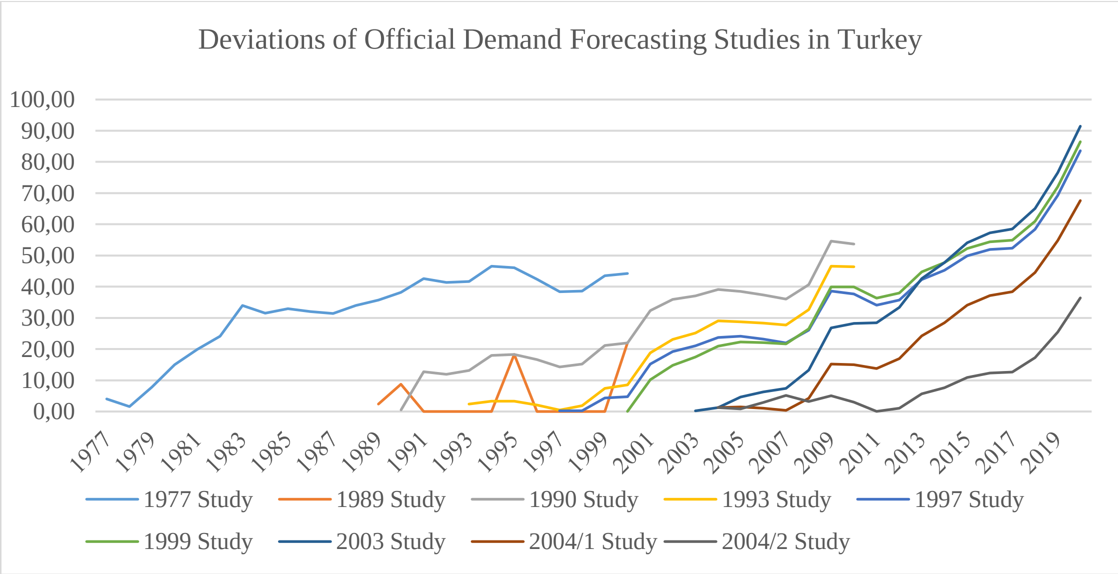
Table 14. 2004 Demand Forecasting Study of MENR

Years	Scenario 1	Scenario 2	Actual	Deviations Scenario 1 (%)	Deviations Scenario 2 (%)
2004	151.098	151.098	149.239	1,25	1,25
2005	163.191	159.399	160.794	1,49	-0,87
2006	176.400	169.520	174.637	1,01	-2,93
2007	190.700	180.250	190.000	0,37	-5,13
2008	206.400	191.680	198.085	4,20	-3,23
2009	223.500	203.830	194.079	15,16	5,02
2010	242.021	216.750	210.434	15,01	-3,00
2011	262.000	230.400	230.306	13,76	0,04
2012	283.500	244.950	242.370	16,97	1,06
2013	306.100	260.400	246.357	24,25	5,70
2014	330.300	276.800	257.220	28,41	7,61
2015	356.202	294.563	265.724	34,05	10,85
2016	383.000	313.600	279.286	37,14	12,29
2017	410.700	334.300	296.702	38,42	12,67
2018	439.600	356.500	304.167	44,53	17,21
2019	469.500	380.500	303.320	54,79	25,45
2020	499.489	406.530	304.836*	63,85	33,36

Source: MENR and TEIAS

Thus, it is seen that the demand forecasting, which started in 1977 and was mostly carried on from the end of the 80s until 2000, did not deviate much in the following one or two years. Still, as the forecast interval broadened in the following years, deviation rates have been increasing rapidly. Although the best initial forecastings were made with the low scenario in 2004, the estimates showed very low deviations in the first years. Still, since 2010 these forecastings also showed rapid increasing deviations.

Figure 11. Deviations of Official Forecasting Studies 1977-2004



2.4.1.3 Generation Capacity Projection Reports of TEIAS

After 2001, TEIAS has been assigned to preparing 10-year Generation Capacity Projection and submitting it to the EMRA for approval. These reports will be guide market participants based on the demand forecastings prepared by distribution companies (at that time TEDAS Distribution Companies) within the framework of the Old Electricity Market Law No. 4628 and the Grid Regulation. However, TEIAS is assigned in the law and regulation, in the Generation Capacity Projection Report prepared in 2005 and later, the results of the demand forecasting studies conducted by MENR. MENR has previously prepared energy demand series using the MAED Model. Later, the use of the MAED model was abandoned.

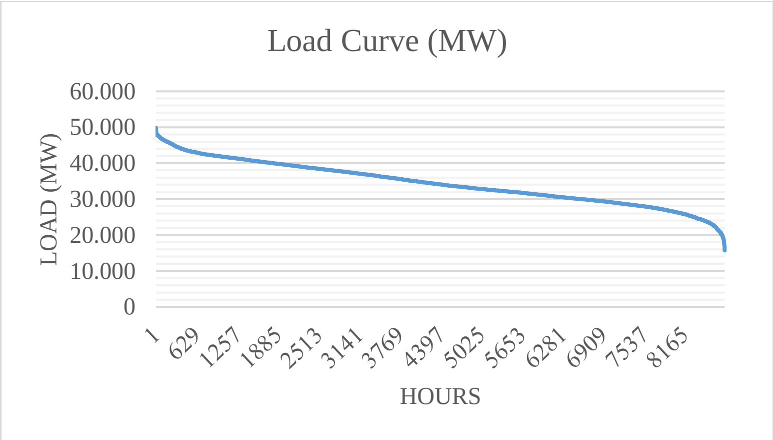
Although the MENR carries out the demand forecastings, the Generation Capacity Projection Reports are prepared by TEIAS. Covering 10-year demand forecastings information are used by MENR and EMRA. However, according to the demand plans made by MENR, TEIAS prepares these capacity reports in practice. This issue is expressed in the capacity reports as a reference (base) demand forecasting series from the demand series obtained by MENR following macroeconomic targets in the Generation Capacity Projection study. Moreover, in the 2019 report; there is an expression as "*The reference (base) determined by MENR, the 10-year average increase in high and low demand forecasts is 4.2% in the reference demand series, 4.8% in the high demand series and 3.6% in the low demand series*". Despite this statement, how these rates are determined and data systematics are not published by the MENR. According to these explanations, the demand forecastings are determined by the MENR and MENR is responsible for forecasting deviations.

About the Generation Capacity Projection Reports of TEIAS, electricity demand forecastings are made for Turkey's electrical system's current "gross demand." Net demand is not forecasted. Losses and leakages in transmission and distribution lines and internal needs of power plants are included in this forecastings.

According to the first capacity report of TEIAS, 2005 Generation Capacity Projection Report, electricity demand forecastings were prepared in 2 scenarios: the high scenario with 8.4% growth and the low scenario with 6.3% growth. It is stated that in order to meet the demand, which is expected to increase at an average rate of 8.4% (high scenario) annually by 2014, it is necessary to add 21.200 MW of new capacity, 6.900 MW of which is wind and hydraulic, 14.300 MW of which is thermal. For example, it is forecasted that electricity demand will increase by 8.4% on average between 2005 and 2014, and it has been predicted that the demand that will occur in 2012 will not be provided (TEIAS, 2005). However, although it was forecasted to reach 242 TWh in 2010 and 330.3 TWh in 2014, the actual consumption was 210,43 TWh and 257,22 TWh, respectively. Briefly, in almost all demand projections, it is emphasized that electricity demand cannot be provided with supply in the last years of the forecast range. Therefore, generation investments urgently should be increased.

Also, it is accepted that the load curve characteristic will not change for this period. Therefore, it is obvious that all demand forecast figures are dictated or approved by MENR, regardless of which institution they publish, and also deviations in the forecasts made in the last 15 years stem from the models and data prepared by MENR. On the other hand, the Load Curve characteristic has not changed much in the last decade. The significance of the load curve is that it represents the hourly amounts of the electrical loads in a year, assuming 8760 hours in a year. As can be seen from the Figure 12, approximately 6000 hours of the annual load is between 20.000 MW and 40.000 MW in 2020. This load shape has been showing this trend for about ten years.

Figure 12. Load Curve of 2020 (8760 Hours)



Source: TEIAS, National Load Dispatch Center

The importance of the load curve is the necessity to meet especially natural gas power plants between 40.000 and 50.000 MW and thermal power plants between 15.000 and 30.000 MW. It is necessary to provide the required electrical energy with the penetration of renewable resources. The better the renewable adaptations to the load curve, the lower the total electricity generation costs will be realized. The one of the striking feature of these capacity reports is that they show very few deviations in the first few years but increasingly high deviations in the following years. However, except for a few years, it is observed that very high growth forecastings are generally included in the calculations. Although, until 2012, two scenarios of low and high, and three scenarios as low, high, and base scenarios since 2013, high deviations observed again.

Table 15. Average Deviations of Forecasting in Generation Capacity Projection Reports

Generation Capacity Projection Report	Scenarios	Deviations %	Projected Growth Rate %
2005	Scenario 1	11,99	8,50
	Scenario 2	3,45	6,30
2006	Scenario 1	13,97	8,40
	Scenario 2	4,85	6,30
2007	Scenario 1	17,65	8,20
	Scenario 2	7,03	6,30
2008	Scenario 1	18,17	7,50
	Scenario 2	13,41	6,60
2009	Scenario 1	6,87	7,00
	Scenario 2	4,56	6,50
2010	Scenario 1	10,19	7,40
	Scenario 2	7,28	6,60
2011	Scenario 1	16,92	7,60
	Scenario 2	11,81	6,60
2012	Scenario 1	18,67	7,40
	Scenario 2	11,69	6,30
2013	Scenario 1	17,39	6,50
	Scenario 2	5,57	4,60
	Scenario 3	11,02	5,60
2014	Scenario 1	15,20	6,40
	Scenario 2	3,57	4,40
	Scenario 3	6,28	5,40
2015	Scenario 1	13,01	6,30
	Scenario 2	3,85	4,50
	Scenario 3	6,61	5,40
2016	Scenario 1	6,57	6,20
	Scenario 2	3,67	3,10
	Scenario 3	4,45	4,60
2017	Scenario 1	4,26	4,00
	Scenario 2	4,19	2,30
	Scenario 3	3,44	3,10
2018	Scenario 1	7,64	5,60
	Scenario 2	5,06	3,80
	Scenario 3	5,94	4,50
2019	Scenario 1	7,89	4,80
	Scenario 2	6,65	3,60
	Scenario 3	7,26	4,20
2020	Scenario 1	8,12	4,50
	Scenario 2	8,94	5,00
	Scenario 3	7,37	4,00

Source:TEIAS Generation Capacity Reports between 2005-2020 and TEIAS Electricity Statistics

In addition, the deviation rates in the capacity reports stated in the table above, calculated according to annual demand as of 2010 are below.

Table 16. Yearly Forecasting Deviations of Generation Capacity Projection Reports by Years

YEARS	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
2010	-0,7	-	-	-	-	-	-	-	_	-	-
2011	-4,7	-1,4	-	-	-	-	-	-	-	-	-
2012	-2,7	0,4	0,7	-	-	-	-	-	-	-	-
2013	2,9	6,3	6,3	3,7	-	-	-	-	-	-	-
2014	6,0	9,6	9,6	5,4	-0,2	-	-	-	-	-	-
2015	10,3	14,1	14,1	8,1	2,2	1,2	-	-	-	-	-
2016	12,7	16,7	16,7	8,4	2,9	1,9	-2,1	-	-	-	-
2017	13,9	18,1	18,1	7,4	2,1	1,5	-3,8	-4,1	-	-	-
2018	19,4	23,7	23,7	10,8	5,2	4,7	-1,6	-3,1	0,1	-	-
2019	28,34	33,1	33,1	17,5	11,4	10,9	3,6	0,5	5,2	3,8	-
2020	-	42,47	42,47	34,1	28,57	26,04	15,7	7,7	12,6	8,12	8,94

Source: 2010 -2020 Generation Capacity Projection Reports of TEIAS

On the other hand, MENR also makes 20-year demand forecasts. According to the Electricity Market Law No. 6446, it is mandatorily published every two years. The last forecasting report was published in 2018. The forecasting results, which were stated to be made using some econometric and statistical methods in the announcement, were estimated until 2039. According to the annual results, the average annual electricity demand increase rate for the next 20 years is calculated as 2.90% for Scenario 1, 3.36% for Scenario 2, and 3.84% for Scenario 3.[6] (MENR, 2019)

Table 17. MENR- Electricity Demand Forecasting Projections, 2019

Years	Scenario 1 (TWh)	Scenario 2 (TWh)	Scenario 3 (TWh)	Scenario 1 Growth (%)	Scenario 2 Growth (%)	Scenario 3 Growth (%)
2019	313,8	315,2	316,5	-	-	-
2020	327,3	329,6	332,1	4,3	4,6	4,9
2021	340,5	344,4	348,7	4,0	4,5	5,0
2022	353,2	359,6	366,4	3,7	4,4	5,1
2023	366,8	375,8	385,2	3,8	4,5	5,1
2024	380,4	392,1	404,3	3,7	4,3	5,0
2025	392,6	406,9	422,3	3,2	3,8	4,5
2026	404,6	421,8	440,7	3,1	3,6	4,3

[6]. Although it has been announced to use of (1) Econometric Model, (2) ARIMA Model, (3) Comparison Model, (4) Regression Model and (5) Flexibility Model, there is no information parameters and variables of the models. It is stated that the content of the forecasting methods and the share and values of variables and the details of the results are not published and not given for “confidentiality reasons”.

2027	416,6	436,6	458,9	3,0	3,5	4,1
2028	428,8	451,7	477,6	2,9	3,5	4,1
2029	441,0	466,8	496,6	2,9	3,3	4,0
2030	453,0	481,7	515,4	2,7	3,2	3,8
2031	464,6	496,7	534,0	2,6	3,1	3,6
2032	476,3	511,6	552,9	2,5	3,0	3,5
2033	487,8	526,4	571,6	2,4	2,9	3,4
2034	499,3	541,0	590,2	2,3	2,8	3,3
2035	510,8	555,7	608,5	2,3	2,7	3,1
2036	522,7	570,8	627,0	2,3	2,7	3,1
2037	534,0	585,3	644,9	2,2	2,5	2,9
2038	545,1	599,4	662,5	2,1	2,4	2,7
2039	556,3	613,4	679,9	2,1	2,3	2,6

Source: Ministry of Energy and Natural Resources- General Directorate of Energy Affairs

As stated above, these forecasting results also show very unrealistic results. Because even the 2019 consumption values in the first year have deviated; 3.5% for the lowest scenario; 4% for the base scenario; 4.3% for the high scenario. Moreover, despite the demand deficit in the past years, while consumption has increased by 29.32% in the last ten years, it is very difficult to reach even the consumption values of the lowest scenario in the projection due to relatively saturated demand.

Table 18. Forecasting of TEIAS Generation Capacity Projection June 2020[7]

Years	Low (GWh)	Base (GWh)	High (GWh)
2021	340.500	344.400	348.700
2022	353.200	359.600	366.400
2023	366.800	375.800	385.200
2024	380.400	392.100	404.300
2025	392.600	406.900	422.300
2026	404.600	421.800	440.700
2027	416.600	436.600	458.900
2028	428.800	451.700	477.600
2029	441.000	466.800	496.600
2030	453.000	481.700	515.400

Source: TEIAS 2020 Generation Capacity Projection Report (2020)

[7] The projected amounts in this report of TEIAS are the same as in the 2019-2039 forecast projection of MENR. Although there is two year between these two reports, the fact that TEIAS quotes the amounts in the estimation report of the Ministry without any updates raises doubts about the data reliability.

In summary, regardless of which institutions and organizations prepared by electricity demand forecast, studies performed in Turkey have always deviated at higher rates in the last 50 years. When these forecasting projections were prepared, despite the better conditions and developing technologies even today, it draws attention to the same high rate of deviation parallel with the previous years.

2.4.2. Reasons for Forecasting Deviations

Essentially, all future forecasting studies contain a certain amount of error terms. Naturally, it is a very difficult task to predict the future situation based on past situations accurately. In these matters, what needs to be done is to carry out forecastings with the awareness that the forecasting is not a static process and that corrective actions should be taken continuously (Hong and Shahidehpour, 2015).

Expressed in the previous sub-section models and techniques commonly used in Turkey, it is noteworthy that high rate deviations are noteworthy. For example, official forecastings of 12 power supply entities deviated as 1,62% in 2014 in the US (Least - 0,6; highest 3,6). Again, between 2005-2014, the total average deviation was 8,33% at the end of 2014 due to economic crises after 2008. Besides, the average peak-load forecasting deviations were 0.74 in 2014 in the US (Carvallo et. al., 2016). In the same year, peak-load deviation in Turkey was realized as 23.41%.

Even going back; forecastings made by Lawrence Berkeley Laboratory on behalf of U.S. Energy Department in 1992, electricity demand forecastings for 2010, 2015, and 2020 were respectively 3.652 TWh, 3.884 TWh, and 4.073 TWh, and they realized 3.894, 3.895 and 3.674 TWh. Thus, a maximum deviation of 9.6% has been observed in the forecastings made 30 years ago (Ross and Hwang, 1992 and EIA, 2021). Even the deviation in 2020 has been due to a decreasing demand due to the COVID 19 Pandemic.

In addition, as in the USA example, while the 89-page report clearly expresses the methods, models, variables, and their coefficients and expectations for the future, it was published and shared with the public. But, MENR announced the 20-year demand forecasting amounts with three scenarios and the only names of the methods used with only a “two-page” for Turkey. It is not understandable that the methods, variables, and approaches used in demand forecasts are not disclosed in detail because the planned investments and profitability-efficiency ratios will be shaped according to the forecast details.

When the reasons for the deviation of all these forecasts are examined, it is assumed that both electricity consumption and economic growth rates will always grow at the *same high rate* in certain periods. Then, it is not to be meticulous in compiling realistic consumption and sectoral data. However, there were a few small private generating companies and three privileged distribution companies until 1994, Turkish Electricity Authority (TEK) monopoly of the existence of the first reason for the deviation. Because in this institution, which was organized vertically integrated all stages of production, transmission and distribution (and retail sales) were gathered under a single structure. In 1994, TEK was divided into TEAS (production, transmission and trade) and TEDAS (distribution and retail). Although some institutional and legal regulations were made for the free-market transition after 2001, the monopoly effect continued until 2009. Production, transmission, trade, and distribution expenses, which are covered by cross-subsidies at every stage in the monopolistic structure of the state, ignored the deviations in demand estimates.

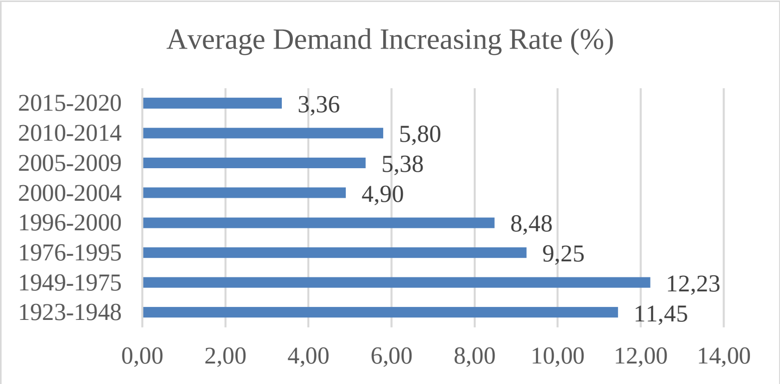
The second reason is that there has been *no accountability* for these high rate deviations in demand estimates neither past nor today. The forecasts making institutions and persons do not have any responsibilities due to these high deviations, neither in the past nor today.

Thirdly, the estimated demand amount is *not revised* according to the amount realized in the first year of the forecast, the deviations gradually increase in the successive years. This situation continued until 2005. Although the generation supply planning reports made every year since 2005 covered a 10 years’ period from the next year, the overly optimistic growth values still caused the deviations to be high. For example, institutions that carried out forecastings due to the recession that began in 2008 in the USA immediately revised their demand growth forecastings (Carvallo et. al., 2016).

Another reason for such high deviations is the *lack of transparency*. Because there is no administrative or financial liability for excessively high or low deviations in forecastings. Due to the lack of transparency, it is unknown how the data are collected and calculated. Although it was announced in the announcement published by the Ministry that estimates were made using five different methods, the data, inputs, coefficients, weights of the model, and the original model of the methods are not published. Thus, it is implicit which input and model are weighted.

Besides, while taking into account the past electricity consumption growth rates, the periodical increase in demand caused by the, for example, electrification efforts accelerated in the second half of the 1980s. The electrification rate, rather common in city centers in the 1960s, was only around 0.7% in villages (only 250 villages in all of Turkey) in the same years. This proportion reached 20% in 1975, then 50% in 1980, and finally 99% in 1990. For this reason, the electricity demand or consumption growth rate varies in some sub-periods.

Figure 13. Average Growth Rates of Electricity Demand



Source: TEIAS Statistics

The electricity demand growth is highest between 1923-1975. This increasing growth rate has decreased after the 1990s. The last five years corresponds to an average of 3.36%. The saturated demand is not taken into account in official forecasting studies.

In other words, the demand growth rates are now realized at lower amounts. Since the considering the high average growth rates in the period between 1980-2000 are included in today's forecasting analysis, high rates of deviations have been observed inevitably.

Improvements in energy efficiency have been ignored in demand forecasts. Energy intensity is tending to decrease, and there is no indication that these are taken into account in forecasting studies. If the general energy intensity decreases in Turkey and has a certain share in electricity, this trend ensures to lessen demand amounts in the future.

Although the loss and leakage rates are high by international standards, it is observed that they are in a decreasing trend. The loss and leakage rates, which were high in the past, had a high share in the gross demand. This decreasing rate causes a decreasing consumption effect in gross demand. However, past trends are handled as they are, *without taking this downward trend* into account in the gross demand forecast. This situation also leads to high forecasting of demand.

Finally, although TEIAS is assigned to make forecasting, *a multi-headed structure* is formed due to the supervision and control of the Ministry of Energy and Natural Resources. While TEIAS announces 10-year demand forecasting, MENR also announces 20-year demand forecasting. In a structure where TEIAS, MENR, and EMRA are located, duties, authorities, and responsibilities often interfere with each other. Such a market structure is also a serious handicap in terms of responsibility and accountability mentioned above.

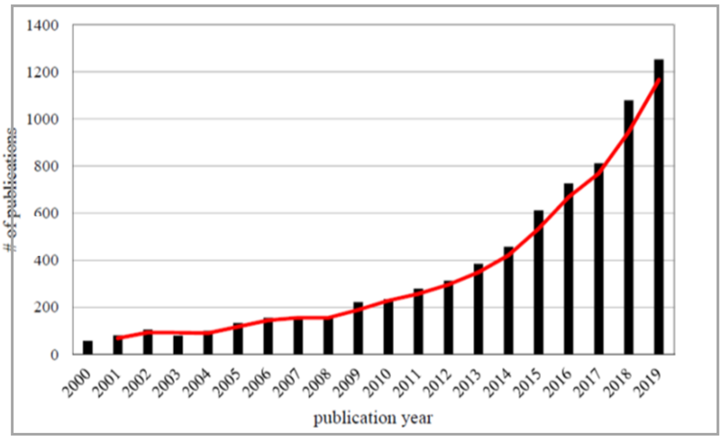
CHAPTER 3

LITERATURE REVIEW

Load and demand forecasting has become very important due to reasons such as a transition from conventional sources to renewable sources, demand saturation, increase in energy efficiency, changes in consumption patterns such as electric vehicles and technological developments. In addition to these forecastings, the importance of Turkey as well, it becomes the dominancy of the private sector. In addition, developments in software in computer technologies have caused an increase in prediction studies. Thus, especially after 2013, the number of academic publications increased very rapidly.

Other reasons for the increase in demand and load estimation studies can be considered as the widespread use of renewable resources, smart meters, and electric vehicles (Mir et. al, 2020)

Figure 14. Load and Demand Forecasting Publications by Years.



Source: Mir et. al. (2020)

As mentioned in Chapter II, electricity demand forecastings are carried out by time horizon. Time horizon forecastings are generally made for very short term, short term or less than a one-year period in the world because the generation companies pay attention more for system balance and short-term fuel price fluctuations. Sudden weather changes such as temperature, humidity and precipitation cause changes in electricity demand throughout the day. As a result, planning is required to avoid instantaneous supply shortages. This situation causes the emphasis on very short-term forecasts. In addition, there are very few long-term electricity demand forecasting studies in the literature. Long-term electrical power forecastings are generally made for power system expansion planning and resource utilization planning of power generation plants (Ardakani and Ardehali, 2014).

It is known, very short-term, namely daily and hourly, consumption forecastings do not deviate seriously in Turkey. This deviation rate has been observed around 1.5 - 2% on average. For this reason, the analysis has been made a long term in this dissertation. As also explained in Section II, long-term official forecastings show serious deviations up to 85%.

Again as stated in Chapter II, many models and methods that have been used in the electricity or energy demand forecastings are explained in general. The reason for using ARIMA and ANN methods, which are also used in the dissertation, is that these methods are common and highly accurate methods for Turkey.

Studies on electricity demand forecasts have been searched through SCOPUS. In the searching made over the keywords used as TITLE-ABS-KEY (“electricity demand forecasting(s),” “electricity demand prediction(s),” “electricity load forecasting(s)” and “electricity load prediction(s),” “electrical energy demand forecasting(s)”

It is clear from the Table 37 88% of the publications are short and medium-term forecasting studies. These terms are mostly in the interest of electrical system operators that ensure system balance, distribution, retail sales and generation companies, and generally are more related to engineering.

Table 19. "Electricity Demand Forecastings & Predictions" SCOPUS Search

		Language			Term		Methods		TURKEY		
Type	Number	English	Turkish	Others	Long Term	Short &Medium	ARIMA	ANN	ARIMA	ANN	Long Term
Article	421	804	5	35	93	751	33	148	3	17	4
Conference Paper	383										
Conf. Review	17										
Book	1										
Book Chapter	11										
Review	9										
Editorial	2										
Total	844										

Source: SCOPUS results; TITLE-ABS-KEY("electricity demand forecasting(s)", "electricity demand prediction(s)", "electricity load forecasting(s)" and "electricity load prediction(s)) on 12.01.2021

Since a study is categorized for more than one area, it is naturally associated with more fields than the number of studies. A total of 82 studies were associated in the fields of Economics-Econometrics-Finance, Social Sciences and Business Management-Account within 1549 fields.

Table 20. Related Fields of studies

Fields	Studies	Engineering	Energy	Computer Sci. Mathematics	Env. Sciences	Social Sciences	Bus. Man. &Account	Economics & Econometrics & Finance	Others
Electrcity Demand Forecasting(s)	344	191	120	165	54	17	15	7	42
Electricity Demand Prediction(s)	72	37	22	53	9	2	4		18
Electrcity Load Forecasting(s)	362	192	98	267	27	9	19	4	108
Electrcity Load Prediction(s)	35	15	3	34	2	1	2		12
Electrical Energy Demand Forecasting(s)	9	7	4	5	1	1	1		
Total	822	442	247	524	93	30	41	11	181

Source: SCOPUS

Also 844 scientific resources have been found and 804 of them are in English and 5 of them are published with Turkish. Also, there are 20 academic publications, 3 of them with ARIMA -and SARIMA- 17 of them with ANN and similar methods, and only four publications comprise for long-term forecastings for Turkey.

Table 21 shows some of the academic studies using ARIMA and ANN for Turkey's long term electricity and energy demand forecasts.

Table 21. Examples of Electiricty and Energy Demand Studies for Turkey

Authors	Method	Objective	Ind. Variables	Forecasting peridod	Data Range
Erdoğdu (2006)	ARIMA-Cointegration	Net Electricity Consumption	-	2005-2014	2000-2004
Ediger and Akar (2007)	ARIMA - SARIMA	Primary Energy Demand	-	2005- 2020	1950-2003
Kaytez (2020)	ARIMA - SVLM	Net Electricity Consumption	-	2019-2022	2007-2017
Kaytez et. al. (2015)	ANN-LLSVM	Net Electricity Consumption	Population- Number of Subscribber- Installed Pow.	-	1972-2008
Hotunoğlu and Karakaya (2011)	ANN	Total Energy Demand (Mtoe)	GDP - Population- Export- Import- Energy Intensity	2010 - 2030	1970-2008
Sözen and Arcaklıoğlu (2007)	ANN	Net Electricity Consumption	Installed power - Import- Export - Net Consumption -Population	2004 - 2020	-
Sözen et. al. (2006)	ANN	Net Energy Consumption	Gross Generation - Population - Installed capacity	1957 - 2000	1953 - 2020
Kavaklıoğlu et. al. (2009)	ANN	Net Electricity Consumption	GNP - Population- Import-Export	2007 - 2017	1975-2005
Es et. al. (2014)	ANN	Net Energy Consumption	GNP - Import- Export- Population- Building Area- Number of Vehicles	2011 -2025	
Kavaklıoğlu (2011)	SVRM	Electricity Consumption	Population - GNP-Import- Export	2007 - 2017	
Yumurtacı and Asmaz (2004)	Linear Regresyon Model	Electricity Demand		2000 - 2050	1970-2000

For long-term forecastings on Turkey with ARIMA; Erdoğdu (2006) used ARIMA and co-integration analysis for net electricity demand 2005-2014 period. Ediger and Akar (2007) used ARIMA for primary energy demand (not electricity) period of 2005 -2020. Kaytez (2020) used ARIMA and least square SVM for net electricity consumption only four years for 2019–2022 period.

One of the best and first studies on the ARIMA model, Erdoğdu (2007) analyzed "net electricity consumption" with ARIMA model for 2005-2014, and validation of this model 2000-2004. ARIMA result for validation ensure average 2,2% deviation, and it was given very successful results for the five-year validation period. However, there was a high deviation between the actual net electricity consumption announced for the 2005-2014 period. Kaytez (2020) estimated “net electricity demand” using a hybrid model and compared net electricity consumption with official gross estimates. However, a high MAPE rate of 1002% was calculated in the proposed ARIMA-LSSVM hybrid model.

Using long-term forecastings on Turkey with ANN; Kaytez et. al. (2015) used a comparison of regression analysis ANN and least squares support vector machines for past electricity demand of 1972-2008 period. Hotunoğlu and Karakaya (2011) used ANN with scenario method for energy demand 2010–2030. Sözen and Arcaklıoğlu (2007) used ANN for net electricity consumption 2004–2020, with independent variables of installed power, gross generation, import, export, net consumption, and population. Sözen et. al. (2006) used ANN for the 1953–2000 period with independent variables gross generation, population, and installed capacity. Kavaklıoğlu et. al. (2009) used ANN for electricity consumption for 2007–2017 with independent variables GNP, population, import, export variables. Es et. al. (2014) used ANN for net energy consumption 2011-2025 period with independent variables GNP, import, export population, building area (m^2), and number of vehicles.

In addition, other models included studies; Kavaklıoğlu (2011) used support vector regression for electricity consumption 2007–2016 period with independent variables population, GNP, import, and export. Yumurtacı and Asmaz (2004) used linear regression model for electricity demand by 2050. Ediger and Tatlıdil (2002) used MAED primary energy demand, Tutun et. al. (2015) used SARIMA Method (Seasonal Auto-Regressive Iterative Moving Average), and NARANN (Non-linear Auto-Regressive ANN) model for net electricity consumptions with independent variables Gross Generation, import, export and trasmitted energy.

Furthermore, using several mathematical, statistical, and computer-based models (ant colony, swarm, etc.), many short-term forecasting studies have been made for hourly, daily, and weekly electricity consumption and demand. SCOPUS is searching for electricity investments with TITLE-ABS-KEY ("electricity investment") with regard to electricity investments. There are 16.500 academic publications and 12 of their publications for Turkey. But only 2 studies of these 12 publications include investments in the whole country. Others have been shown minimal facilities for conversion or for certain buildings, plants, and specific sectors like agriculture, residential or industry sectors.

On the other hand, there is an article proposing an alternative exchange for build-operate-transfer plants by Yumurtacı and Erdem (2007). But, this article only takes place as a cost-benefit analysis for BOT power plants—another academic study examining the relationship between electricity demand forecasting studies and investments. Investments and electrical energy consumption are written by Tunç et. al. (2006) and this study is remarkable, including investments and forecastings. But, this study focused on the price of energy source and fuels for electricity generation. It is concerned with the cheap generation of electricity that will be needed in the future. Thus, to examine the relationship between electricity demand forecasting and electricity investments, there have not been hardly ever publications in Turkey.

Many of studies of electricity demand forecasting based on net electricity demand. On the other hand, official demand forecasts are prepared as *gross demand* amounts (GWh). For this reason, in this thesis, ANN and ARIMA models, which are widely used, are carried out for "gross electricity demand" forecasting. In almost all of the studies mentioned above, net electricity demand was used for electricity forecasting. In order to convert the gross demand data into net data, it is necessary to calculate the internal demand electricity consumption of the generation plants and the distribution loss-theft amounts by determining exactly. The most affecting factor for net demand is the amount of loss and leakage in distribution. In recent years, the amount of loss and leakage is not disclosed by EMRA, only rates are given. It is not possible to understand how much electricity loss all distribution companies have through these rates. For this reason, in this thesis, gross demand forecastings have been taken into account as announced in the official demand forecast amounts.

CHAPTER 4

ELECTRICITY INVESTMENTS

4.1. ELECTRICITY INVESTMENTS

Generally, energy investments take a long time to become operational after they are projected. Also, energy facilities are primarily capital-intensive facilities and require a huge investment volume, and it is very difficult to use them for generation purposes other than their own sector. The life of capital goods and their operating life is very long (Aydın, 2018). Power generation plants have an average operating life of 40–50 years, while transmission lines and equipment have an operating life of more than 50 years (Conejo et. al., 2016). The main factors affecting electricity investments are the lifespan of a power plant, discount rate, generation capacity, carbon price, exchange rates, transmission network connection and costs, decommissioning residuals (IEA and NEA, 2015).

Table 22. Life Span (Retirement) of the Power Plants

Plant Type	Activity Duration (Years)
Coal Fired	50-60
Natural-Gas steam	40-50
Combustion Turbine- CCTT	40-50
Nuclear*	30-40*
Hydralouic	50-100
Wind	20-25
Solar	25-30

Source: Lawrence Berkeley National Laboratory and National Renewable Energy Laboratory (NREL). * The lifespan of nuclear power plants can be increased to 80-100 years with some renovations and improvements.

Whether it is intermittent or dispatchable[8], the entire economy of generation technologies can be evaluated according to the expected market value of the generating electricity, their life-span costs, and the expected profitability. Such an analysis will reflect the expected electricity generation technologies, the price of electricity supplied

[8] Intermittent technologies are wind, solar and other renewable sources. These plants are traditionally defined not dispatchable generation. They are affected some weather conditions wind speed, cloud cover and fog. Dispatchable sources are power plants used nuclear, coal, and natural gas.

at different times, and other variable costs associated with their reliable integration into the grid. These considerations are the way investors evaluate whether to invest in power generation plants or not (Joskow, 2011).

Since electricity or energy investments should be comprehensive and integrated, good planning is required. An energy planning that determines the need for investments should have basic goals and broad perspectives. These goals and perspectives are shaped according to the situation and needs of that country. Planning studies can also be carried out by a completely private organization or completely state-owned companies. In most countries, planning is realized with a combination of objectives of public-privately owned companies. The basic goals are those that apply to every country in any situation (IAEA, 1984).

Generally accepted electrical system planning has to include the following aims: To provide low-priced energy supply to the consumer; to ensure optimum electrical system reliability; to reduce import dependency by resource diversification; to maximize the use of internal energy sources; to maximize the using of renewables; to provide electricity of affordable quality and price for industrial growth and to minimize the lessen environmental and pollution effects (IAEA, 1984). Although every country theoretically wishes to fulfill these basic aims, but political preferences, economic crises, natural disasters, and the specific conditions of the country may prevent reaching these goals. For example, the radioactive leakage that occurred at the Fukushima Nuclear Power Plant in Japan after an earthquake causes cutting nuclear energy planning and decommissioning of nuclear power plants worldwide.

As a result of these explanations of the aforementioned IAEA investment book asserts that investment projections to be made after good energy planning should include as follows:

- The situation of the global markets in countries where the country is a net energy exporter or importer,
- The levels of substitution and transitivity between energy sources in the country as a whole, region and local.

- The level of detailed information that provides flexibility to decision-makers in their decisions
- Covering a 20-30 years' time span for resource allocation and energy supply security and demand elasticity.

In many countries, investment decisions are made by many agents, whether in markets dominated by liberal or vertically integrated public structures. Nevertheless, without climate policies affecting the entire long-term economy, government regulations are often expected to be regulated to guide some standards and especially emission-reducing standards for decentralized renewable energy sources. There is uncertainty because of carbon-reducing technologies, which are currently very expensive technologies (Morris et. al., 2018). Since the construction and commissioning times of electricity investments are long, correct and detailed planning is essential.

Although methodologically, the same budgeting and calculation tools for other investments are used in calculations, there are also some unique difficulties. The long planning period, construction process and operation, and discounting of expected cash flows are slightly different. Economically, fuel costs and emission limitations, technically thermal stress and fuel losses during startup and shutdown must be well calculated (Zweifel et. al., 2017). Generation investments generally vary according to the annual fluctuations in demand, changes in the geographical distribution of demand, annual changes in operating costs, and countries' perspectives on the source of generation (Conejo et. al., 2016).

To generate electricity from resources such as oil, natural gas, and coal, the energy used in the extraction, processing, and transportation processes of the relevant resource must be calculated individually at each stage. In this thesis, an evaluation is made on the total amount of electric power plants and other related investments.

Electricity investments are planned for various purposes by many institutions and organizations in many countries around the world, and various models and calculation methods are used for these plans: Simple Profitability Ratio, Payback Period Method, Net Present Value Method, Net Present Value Ratio Method, Internal Profitability Ratio Method (Aydın, 2018).

While some comparison and calculation tools such as EROI are used extensively for investments to be made in primary resources such as oil, natural gas, and coal, there are not many investment decision tools other than general financial calculation tools for electricity investments specifically. EROI (Energy Returned on Energy Invested) can be defined briefly as the energy benefit obtained from a unit energy investment (Hall, 2017).

$$EROI = \frac{Energy\ Gathering\ Activity\ (ER)}{Energy\ Investment\ to\ get\ Energy\ (EI)}$$

The most used investment planning approach after WWII was Cost-Benefit Analysis. This concept, which was introduced by economists such as Hicks, Pigou, and Samuelson in the 1930s and 1940s in terms of welfare economics, was widely used in electricity investments, especially in France. This analysis was first started with demand analysis and planning and was made according to thermal and hydraulic power possibilities. Concentration of this method is the annual generation amount and peak-load, and the total investment amount that can be reached. In France, a tool that avoids personal prejudice and interference has been developed for the use of this model in the electricity sector. (Tehrani et. al., 2013)

These methods mentioned above, which are generally used by the private sector in planning many generation facilities, give general clear results except for crisis periods. Capital and profitability calculations need to be made to evaluate the feasibility of energy investments. However, these profitability methods are generally ignored by the public sector due to various factors such as political preferences, economic uncertainty and security concerns that have various limitations in energy investments.

Besides, to reduce greenhouse gas emissions, various general equilibrium models and resource-based investment calculations are made compatible with the targets.

The main source used by the Turkish Electricity Authority (TEK) for investment planning was the “Expansion Planning for Electrical Generating Systems: A Guide Book” prepared by the IAEA. According to this book, Turkey's electricity investments have been inspired since 1985. Naturally, for the complete lack of demand saturation, bringing electricity to the entire population perspectives and advice in this book have made many contributions to Turkey’s electricity system. As stated above, Turkey’s electrical energy planning must be based on its specific objectives and main objectives.

According to the investment planning stages in the IAEA Book, in the targets determined within this scope, the electricity plannings in Turkey have been realized with WASP and MAED in the TEK era (also TEAS). However, again, as stated in the previous section, it can be said that it has moved away from these planning targets, especially since the MAED application has been abandoned. Although the importance of resource diversification and the use of renewable resources are evident, it is also seen unnecessary investments not matching the needs.

On the other hand, regardless of the type of generation, facilities with installed capacity over 1 MW in Turkey must obtain a license from EMRA. However, if the power plant to be built is below the 1 MW, it is operated without a license. But, they must obtain approval from TEDAS on behalf of MENR whether it meets the necessary technical conditions. In practice, separate approvals are generally taken for more than one unit in order not to be caught in the licensing bureaucracy, each with an installed capacity such as 0.90 to 0.99 MW. For this reason, there is no integrated planning process for unlicensed power plants and licensing processes for licenced power plants subject to license are carried out by different organizations and whether these investment decisions comply with the system requirements.

However, Turkey Electricity Generation Capacity Projection Report is prepared by TEIAS, is the only official justification and resource that can be achieved for the electricity sector investments in Turkey. This report is published annually, and it includes 5-year projections such as the demand development and actual production quantities by years, the status of the electricity system, and the assumptions regarding the generation capacity projection are included in this report. The realistic situation of the forecastings and determinations in these reports were discussed in the previous section and indicated these reports do not serve as a guide for the efficiency and need of investments.

4.2. RESTRICTIONS OF INVESTMENT DECISION

4.2.1 Environmental Restrictions

Before making investment decisions, it is necessary to consider the necessary feasibility studies, access to energy resources, resource diversification, and bindings, and mandatory international agreements on climate and environment. It is useful briefly to explain these agreements because carbon emissions and environmental impacts are a global problem, and intentions have been declared on international platforms to take measures against these. This is directly related to investments.

Although electrical energy is a clean source of energy, electricity generation itself has an impressive impact on nature. The effects of hydraulic power plants on the natural life and people living on the riverside, the effect of nuclear power plant wastes, and the carbon emission effects of thermal power plants are the most important environmental impacts (Berrie,1992).

Under de carbon restirictions, the optimum investment amount in the electricity sector is determined according to the current consumption (demand) and the expected consumption. Accordingly, this relationship is formulated as follows (Morris et. al., 2018):

$$\max_{x_1} C_1(x_1) + E_0 \{\max_{x_2} [C_2(x_2, S_2, \theta)]\} \tag{4.1}$$

Where C_t is the consumption of period t and $t \in \{1,2\}$; x_t decision variables vector; θ is carbon cap (it is uncertain period 1 and known at period 2); S_2 is a system state previous period decision function.

This function (3.1) are calculated by dynamic programming with Bellman Equation. This process aims to choose applications to maximize total expected discounted social welfare in the economy over the planning horizon.

$$V = \max[C_t (S_t , x_t) + \gamma E\{V_{t+1} (S_{t+1} (S_t , x_t, \theta_t))\}] \qquad (4.2)$$

At the *t* period, *V* is the total amount, γ is discount factor, *S* is a state variable of emissions of installed power capacity at the current technology, *C* is welfare (consumption), *x* is non-emission facilities, θ is carbon cap (uncertain at Stage, but predictable at Stage 2).

Thus, electricity generation and power plant planning can be made under carbon limitation with Bellmann Equation. However, neither in Turkey nor in many countries can political decision-makers have not made such formulated plans yet.

Nevertheless, the carbon emission reduction committed by the countries is essentially a guide to which electricity generation source investments should be directed. The first step in the world regarding carbon emissions was The United Nations Framework Convention on Climate Change (UNFCC). It was adopted in 1992 to organize efforts for combatting the climate change problem on a global scale. This agreement was signed 21 March 1994 by 194 members of the UN. Thus, it was aimed to regulate the measures to reduce and prevent the human-induced greenhouse gas effect in the atmosphere on the basis of climate. Turkey took place in this agreement because it was an OECD member country, but it has become a party on May 24, 2004, for the whole of this contract.

The second step is Kyoto Protocol. It was contracted with holding UNFCC in Kyoto on 11 December 1997. The Protocol imposes bindings greenhouse gas emission limitation and reduction obligations to industrialized countries. With the Grand National Assembly of Turkey (TBMM) adoption on 26 August 2009, Turkey became a party to the Kyoto Protocol. For the First Commitment Period of the Protocol (2008-2012), Turkey was not a party when the protocol was first adopted in the UNFCC;

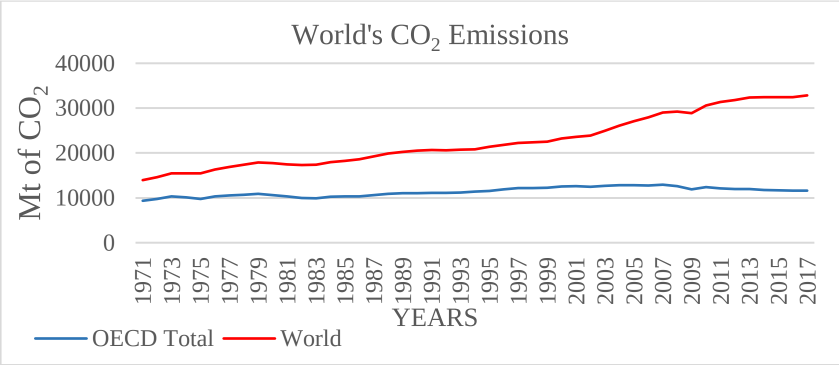
Turkey does not have any quantified emissions limitation or reduction commitments as a unit.

Finally, since the Kyoto Protocol had expired in 2020, the Paris Agreement has been adopted at the 21st Conference of the Parties held in Paris in 2015. This Agreement was designed on 4 November 2016 as a contribution of at least 55 countries that realized 55% of global greenhouse gas emissions. The agreement aims to keep the global average temperature rise in the long term at 2 °C below the pre-industrialization period for sustainable development and poverty eradication. Turkey signed the Paris Agreement in New York with representatives of 175 countries, but it is not yet a party to the Agreement. Although not party to the Paris Agreement, Turkey has declared it's national contributions. Thus, it is foreseen that reducing greenhouse gas emissions by up to 21% compared to the reference scenario in 2030. Turkey awaits the resolution of the two issues under the Paris Agreement. The first subject to access to finance and technology support to Turkey with countries in similar positions is treated equally. The second issue is considering the criteria, such as economic growth and population growth, Turkey's impossible to make absolute emissions reduction.

Upon this process, the growth rate of all carbon dioxide emissions in the world declined, while a net reduction in OECD countries increased more than two-fold increase in Turkey in the last two decades. Accordingly, it had declared that Turkey's commitment to reducing greenhouse gas emissions is 21% by 2030. Thus, in addition to planning the resources with high greenhouse gas effect in investments, it includes taking measures such as filter technologies of existing production facilities (power plants or industrial facilities). Therefore, these agreements are one of the important factors to be taken into consideration when making investment decisions.

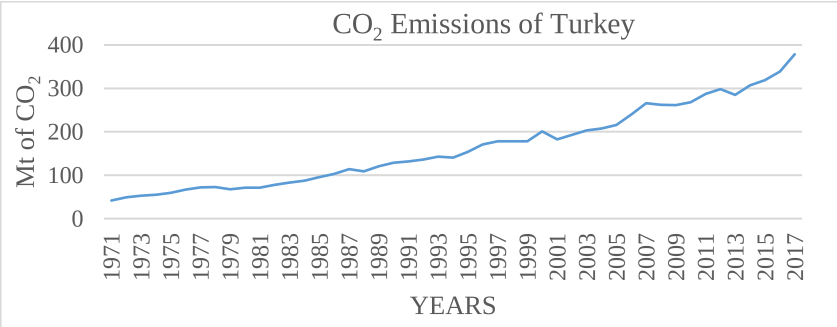
On the other hand, Turkey's carbon emissions have increased nearly 10 times during the period 1971 - 2017. The total World carbon emissions increased approximately 2.5 times, remained almost constant in OECD countries, and it increased only around 20% in the same period.

Figure 15. CO_2 Emissions of OECD and World



Source: IEA

Figure 16. CO_2 Emissions Development of Turkey



Source: IEA, MENR

Turkey's carbon emission growth rate is 4 times higher than the World's, while 50 times that of OECD countries. While thermal power installed capacity was 23.786 MW in 2013, it has reached 47.794 MW in Turkey in March 2021. That is, it has realized an increase of two-fold in the power of thermal power plants. Although the share of renewable resources has also increased at a high rate, it is obvious that there is a high rate of addition to the already high installed power of thermal. Due to the coal power plants added to the interconnected electricity system in recent years and the subsidies given to domestic coal (lower calories lignite) plants by the Treasury, Turkey's commitment of reducing by 21% of carbon emissions by 2030 is difficult to fulfill. Because the increasing role of coal power plants for carbon emissions is quite high. As can be seen from Table 19, coal plants produce an average of 971 tons of carbon dioxide per GWh. This figure is almost 40 times the amount of nuclear, hydraulic, and solar power plants.

Table 23. Carbon Emissions Produced by Power Plants

Source of Electricity Generation	ton CO_2 e/GWH		
	Mean	Low	High
Lignite	1054	790	1372
Coal	888	756	1310
Oil	733	547	935
Natural Gas	499	362	891
Solar PV	85	13	731
Biomass	45	10	101
Nuclear	29	2	130
Hydraulic	26	2	237
Wind	26	6	124

Source: World Nuclear Association, 2011

Thus, neither investment and subsidy decisions of MENR nor license decisions of EMRA, it is clear that they are not taken into account the carbon emissions for electricity generation investments in Turkey. Because carbon emission, which was 319 Mtoe in 2015, increased by 20% in just 2 years and reached 379 Mtoe in 2017.

4.2.2 Technical Restrictions

One of the factors to be considered in electricity investments is peak-power demand in the electricity system. This concept refers to the electrical power needed instantaneously in milliseconds. In other words, peak-load demand is the power that will be added to the minimum required electrical energy power, called base load, as a necessity of calendar events, seasons, economic activity and daily life.

While the peak demand amount was around 29.000 MW in 2009, it has been 49.000 MW in 2020. With the algorithms developed by the system used, the peak demand has been estimated to be the lowest 66.147 MW, the highest 73.669 MW, and the base 69.686 MW by TEIAS until 2028.

Table 24. Peak-Load Demand Actual and Forecastings

Date	Base Forecasting	High Scenario Forecasting	Low Scenario Forecasting	Actual	Deviation % (High)	Deviation % (Low)
2009	-	29.900	29.900	28.013	6,74	6,74
2010	-	33.276	31.246	29.719	11,97	5,14
2011	-	35.772	32.964	32.147	11,28	2,54
2012	-	38.455	35.173	35.752	7,56	-1,62
2013	-	41.339	37.529	35.951	14,99	4,39
2014	-	44.440	40.044	36.009	23,41	11,21
2015	-	47.728	42.727	43.300	10,23	-1,32
2016	-	51.260	45.546	44.734	14,59	1,82
2017	-	55.063	48.553	48.832	12,76	-0,57
2018	-	55886	53.038	49.516	12,86	7,11
2019	48.261	60.022	56.539	47.010	27,68	20,27

Source: TEIAS 2009, 2010, and 2019 Capacity Projection Reports.

The installed power, which is currently about 97.000 MW, is planned to increase to over 120.000 MW in the next decade. Accordingly, this planned investment is higher than 2.5 times for low and 2 times for base, and 1.7 times for high scenarios. In addition, the minimum load requirement of the electricity system called baseload is provided by thermal power plants or nuclear power plants that provide stable generation. Since these power plants operate without being affected by environmental and climatic conditions such as renewable resources, they are called baseload plants. For this reason, the share of these power plants in the total installed power must be kept at a certain level.

Table 25: Start-Up Time for Power Plants

Plant Type	Start Up Time	Load Change in 30 Seconds (%)	Max. Ramp Rate (%/Min)
Open Cycle Gas Turbine	10- 20 Minutes	20-30	20
Combined Cycle Gas Turbine	30-60 Minutes	10-20	5-10
Coal Plant	1-10 Hours	5-10	1-5
Nuclear Power Plant	2 hours-2 days	Up to 5	1-5

Source: IEA and NEA (2015)

Since the commissioning times of the plants vary, baseload plants are generally operational. Gas cycle power plants are the fastest commissioned power plants. On the other hand, coal and nuclear power plants are put into operation longer according to their technologies. In addition, thermal stress significantly affects commissioning times, and thermal stress has the most serious impact on equipment. Accordingly, very serious calculations should be made in the commissioning of the power plants.

On the other hand, power plants can malfunction at any time and therefore it is possible that they are unable to generation or under-generation. The under-generation of the power plants in the electrical system directly affects the amount of electricity that can be obtained from these power plants. After removing the capacity that cannot produce, the capacity that is ready to generate electricity at any time is called “available capacity”.

Except for malfunctions and maintenance operations, as the reasons for power plants not to produce or underproduction; fuel constraints or low fuel quality for thermal power plants, insufficient precipitation for hydraulic power plants and lack of wind or insufficient wind for wind power plants, can be listed. For the security of electricity supply, a certain power backup should be reserved in case of malfunction and maintenance. This is called “power reserve.” According to the 2019-2023 Generation Capacity Projection prepared by TEIAS, the reserve capacity calculation is made as follows:

$$APR = \left(\frac{AAC - PLD}{PLD}\right) \text{ x } 100$$

APR : Available Power Reserve

AAC : Annual Average Available Capacity

PLD : Peak Load Demand

TEIAS calculated available power reserve rate as 81.9% for 2019. (TEIAS, 2019) For this reason, sudden changes in the electrical system are balanced with ancillary services called primary and secondary frequency control. Primary frequency control refers to bringing the system frequency to a new equilibrium point by automatically increasing or decreasing the active output power of the ancillary service unit in response to a decrease or increase in the system frequency. Secondary frequency control aims to bring the active power output of the service units to the nominal value of the system frequency and the programmed value of the total electrical energy exchange with neighboring electricity networks with the signals sent automatically from the system operator.

4.2.3 Financial Restrictions

One of the most important elements of an investment project is financing. Investment financing decisions will be affected by decision-makers based on their own equity or loan resources. If the own resources are insufficient, naturally, loans and other financing tools will be used. According to the financing source, the investment decision will be made according to the profitability expectation of the investments to be made.

The initial investment cost is defined as the cost that must be paid to obtain one unit of power. Fixed operating cost is the cost that must be paid to obtain unit power from the plant in a year. Variable operating cost is defined as the cost to be paid to obtain one unit of energy. The initial investment cost is calculated as machinery equipment, building, land, etc. in order to make the power plant ready for energy production before it starts to operate. Most of the power plant costs consist of the initial investment costs (Kaya and Koç, 2015).

Operation-maintenance costs are the expenses that must be made to generate energy from the power plant after the installation of the plant. Operating costs are divided into two as fixed operating cost and variable operating cost. Fixed operating costs are costs such as wages of employees, general and administrative expenses of the power plant, power plant support equipment, and planned maintenance. Variable operating costs are the costs caused by the fuels used in the power plant, energy, water, chemicals, catalysts, gases, consumables and resources, and waste.

Table 26. Power Plants Construction and Operational Costs

Power Plant Type	Initial Costs ($/kW)	Fixed Operation Cost ($/kW - Yearly)	Variable Operation Cost ($/MWh)
Biomass	4114	105,63	5,26
Coal Fired	3246	37,80	4,47
Geothemal	4362	100,00	0
Hyraulic	2936	14,13	0
Natural Gas	917	13,17	3,6
Nuclear	5530	93,28	2,14
Solar	3873	24,69	0
Wind (Offshore)	6230	74,00	0
Wind (Onshore)	2213	39,55	0

Source: Kaya and Koç (2015)

Thus, off-shore wind, nuclear, and geothermal power plants have the most expensive initial investment cost. In contrast, the variable cost of hydraulics, solar, wind, and geothermal is almost zero. The lowest fixed operating cost is seen in natural gas and hydraulics.

Accordingly, investors make investment decisions by carrying out feasibility studies, except for the state sector. Naturally, incentives and purchase guarantees can be effective in decision-making. The biggest problem here emerges as financing. Financing can be provided either from own resources, external loans or through public-private cooperation. In recent years, it is seen that the public sector has only invested in renewal and efficiency in the energy generation sector.

Thus, investments are generally provided by credit facilities from the private sectors. In the last decade, the share of the public in the installed capacity has decreased from 54% to 22% as a result of privatizations and an increase in private sector investments.

In the February 2021 announcements of the Banking Regulation and Supervision Agency (BRSA); the total loan amounts of the electricity sector and sectors of providing raw materials for electricity have reached the level of 416.069.639.000-TL at the end of February 2021[9]. It is about 51 Billion USD in terms of exchange rates at that time. Therefore, the high foreign currency cost of investments and the slowdown in capital accumulation due to payments to external sources prove that over-investment in this sector is unreasonable because financing the investments needed in many sectors is prevented because the sectors with excessive investment use these resources.

Table 27. Number of Electricity Generation Corporations

Years	Closed Power Generation Co.	Newly Established Power Generation Co.
2013	56	649
2014	63	1004
2015	81	1943
2016	152	729
2017	268	292
2018	364	262
2019	358	226
2020	354	345
Total	1696	5450

Source: UCCET (TOBB), Statistics

Also, about of statistics of The Union of Chambers and Commodity Exchanges of Turkey (TOBB), After 2010, Turkey has started to accelerate their establishment of new electricity generation company. The number of company establishments, which increased very rapidly until 2015, started to decrease rapidly since 2016. The number of company establishments, which increased very rapidly until 2015, started to decrease rapidly since 2016. Similarly, the number of companies that have been closed since 2016 has started to increase.

In addition, only power plants and project costs should not be considered as electrical energy investments. The generated electricity must be transmitted and reduced to a certain low voltage and delivered to the distribution network and the end consumer. In other words, each additional power plant construction increasingly requires investment

[9] The share of energy sector debt about the the BRSA Loan Table of February 2021 in whose Line 7: Energy Generating Mine Sector 7%; Line 8: Non-Energy Generating Mine Sector 6% Line 15: Nuclear Fuel Refinery Sector 12% and Line 26: Electricity Water and Natural Gas Generating and Distrbution Sector 75% .

in transmission and distribution facilities. Each additional power plant construction requires connecting the electricity generated from these plants to the interconnected system. Otherwise, there will be congestion in the system since the load flow will be excessive in the existing transmission lines, which will cause imbalances in the system. For this reason, both the locations and regions of the power plants are closely related to the distances of the transmission lines.

The prices of conductors and capital goods used in the transmission lines, of course, distrubition lines, increase in parallel with the increase in exchange rates because of imported metals of which prices are determined on the commodity exchange such as aluminum and copper, and insulation oils used in transformers. Furthermore, the renewal of transmission equipment such as power-transformer, current-transformer, voltage-transformer, disconnector, breaker, capacitor and reactor, new substations built to connect the increased power supply to the interconnected system, installation of overhead lines and underground-submarine cables are also very costly. Most of the costs, most of which are dependent on imports, are added to the final electricity prices primarily through the system usage charges in the transmission and distribution tariffs. In other words, most of the expensive connection facilities of some substations are waiting inactive.

Its own revenues compensate investments of TEIAS, and if its own revenues are not enough, compensated by the transfers from the Treasury. In addition, the investments of the privatized distribution companies are compensated in the same way as the Treasury owns them. These costs are reflected to users, namely citizens, through distribution and transmission tariffs. It is widely accepted that the electricity grid (transmission and distribution lines and equipment) is public property. Therefore, considering the investments in the electricity sector, it would not be correct to consider only the investment costs of generation plants. Each additional surplus power plant investments require other sub-sector investments and gradually causes operating costs.

Meanwhile, payments are paid by TEIAS to keep available capacity ready under the name of “capacity utilization mechanism” based on demand forecasting for system balancing. As a requirement of the system, this mechanism is generally used by thermal power plants, namely natural gas and coal power plants. This mechanism, which was first implemented with a regulation in 2018 for Turkish electricity markets, and it was also implemented in EU after approving by European Parliament’s Committee on Industry, Research and Energy (ITRE) in the same year to be valid in six countries; Germany, Belgium, France, Italy, Poland, and Greece. However, at this point, capacity utilization mechanisms are one of the incentives given to fossil fuels, and it is claimed that countries postpone the necessary transformation in their energy systems by risking their carbon emission reduction targets through existing and planned mechanisms. In some countries in the EU (Belgium and Germany), this mechanism was adopted to be implemented temporarily to gradually remove nuclear power plants from the system. It has been found beneficial to keep a certain capacity in order to ensure the security of electricity supply during the phasing out of nuclear power plants from the system. In some countries (France and Greece), when production drops, it is applied to consumers in the form of payment for not consuming. In Turkey, in accordance with the instructions of the system operator as practiced in Italy and Poland, payments of production plants are scheduled to be available for power generation. This system is a permanent state in Turkey since there is no provision for the regulation period.

Table 28. Capacity Utilization Mechanism Payments of April 2020

Power Plant Type	Payment (TL)	Rate (%)
Domestic Coal	129.338.676,55	49,66
Domestic Coal/Imported Coal	9.808.836,35	3,77
Natural Gas	101.903.652,31	39,12
Hydraulic	19.415.618,30	7,45
Total	**260.466.783,51**	**100,00**

Source: TEIAS Capacity Utilization Mechanism Announcements

In Turkey, 10 hydraulic power plants, 22 coal power plants, and 14 natural gas power plants are included in the capacity mechanism system for the year 2021. Moreover, public power plants cannot benefit from this mechanism. As shown in Table 24, 92.55% of the capacity mechanism is implemented for thermal power plants and mainly for domestic coal plants. Especially in a situation when the demand has dropped by around 18% due to the COVID-19 pandemics in April 2020, the capacity utilization cost paid for unused electricity is remarkable. In addition, this mechanism, which will not have a positive result in terms of the commitment to reduce carbon emissions stated above, does not provide competitive advantage to price formations in the market.

4.2.4 Bureaucratic Restrictions

Although bureaucratic restrictions can be made for technical, environmental and financial purposes, they are also determined by the political and administrative structure of the country. Facilities established to generate electricity in many countries have to operate with permission from central or local units. It can be said that these permits have become difficult at various levels due to environmental, economic, security, and technical concerns. For example, Turkey has an obligation to obtain licenses from the Energy Market Regulatory Authority to be established on 1 MW of power plants. Although generation plants below 1 MW are unlicensed, there are bureaucratic procedures such as project and facility approvals to MENR.

While the production license was obtained very easily in the first years of the EPDK, license permission procedures have become more difficult today. This is because access to the source of electricity generation and electricity generation and the transmission and distribution of this electricity depend on the adequacy of the physical electricity lines. In addition, support mechanisms concern which resources to what extent will be supported and their economy. bureaucratic procedures can be very restrictive as this will put a burden on the public.

4.3. ELECTRICITY INVESTMENTS IN TURKEY

4.3.1. Total Electricity Investment

It has been stated in the previous chapters that the share of electricity in final consumption is gradually increasing. Therefore, this increasing trend causes an increment in the electricity sector investments. Between 2005- 2015, while the value of investments in petroleum in the world energy investments was higher than the electricity sector investments on an annual basis, the electricity sector investments have reached higher amounts since 2016.

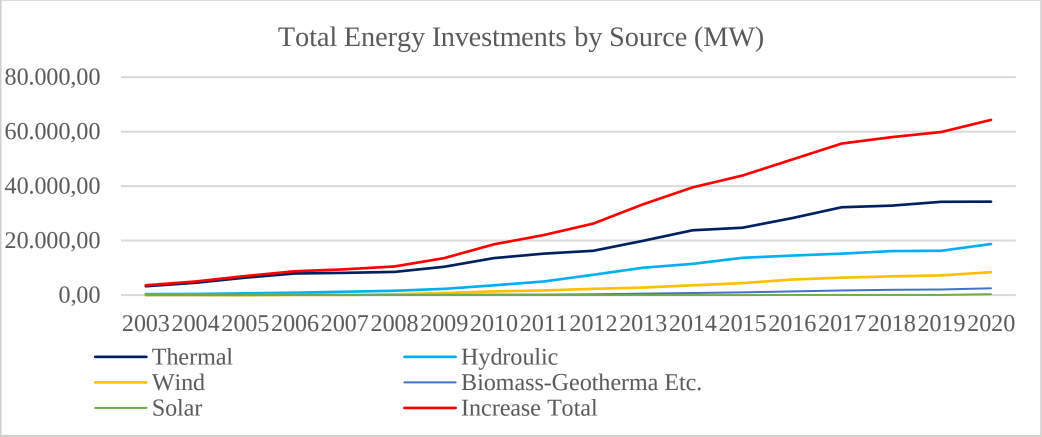
If the electricity market is to be operated in the stock exchange or a free market, and if all citizens are to access electricity without discrimination, the electricity supply and demand infrastructure should include all parties. However, market liberalization has also created new challenges and uncertainties in OECD countries. As markets adapted to new conditions, new concerns have arisen about the adequacy of investments. In liberalized markets, investors are more exposed to risk than in regulated markets.

IAEA (c) 2004 stated that some market and regulatory failures could lead to inadequate electricity market investments. For example, prices may deteriorate due to government policies to protect small consumers. It is uncertain whether competitive markets will adequately meet peak load capacity investments. Policymakers in most OECD countries believe that current market designs do not guarantee an adequate level of security of supply, and planning how to intervene to address this problem is explored.

In addition, more stringent environmental regulations are come into force to reduce the emissions of power plants and other industrial facilities. Uncertainties regarding future environmental constraints create obscurity for the private sector. Legal regulations on current emissions will have regional and local effects. Since the emission rates will be high in countries where coal is used extensively in electricity generation, the restrictions will affect these countries the most. In most OECD countries, it is clear that strict measures will be taken against emissions, so investment requirements will increase significantly. (IAEA (c), 2004)

It will have discussed in this thesis installed power-ups in terms of MW that have been announced because private sector companies and public institutions of power plant construction costs are not officially announced in Turkey. In the following sections, determinations will be made based on average costs in some countries and reports.

Figure 17. Turkey's Electricity Power-Plants Investments by Source (2003-2020)



Source: MENR, General Directorate of Energy Affairs, Energy Investments

Accordingly, the growth rate of installed capacity in Turkey has increased approximately 3-fold in the last 20 years. The Electricity Market Law enacted in 2001 and the increasing privatization activities after 2009 had a major impact on this increase. However, although there are power plants that have been commissioned with good feasibility studies, it is observed that investments have been made without the necessary feasibility studies. Because the generation licenses issued by EMRA in order to benefit from the renewable energy incentives are either transferred or closed because they cannot be operated economically towards the end of the incentive.

Table 29. Total Installed Capacity March, 2021

Sorce-Fuel	Licenced (MW)	Non-Licenced (MW)	Total (MW)
River	8.090,50	8,65	8.076,65
Dam	23.234,60	-	23.234,60
Asphaltite	405,00	-	405,00
Waste Heat	156,12	210,10	366,20
Biomass	1.064,20	83,70	1.147,90
Natural Gas	20.519,10	185,40	25.697,80
Fuel-Oil	251,90	-	251,90
Solar	515,40	6.448,60	6.964,00
Import Coal	8.986,90	-	8.986,90
Geothermal	1.623,90	-	1.623,90
Lignite	10.119,90	-	10.119,90
LNG	2,00	-	2,00
Diesel	1,04	-	1,04
Nafta	4,73	-	4,73
Wind	9.289,80	70,83	9.360,83

Hard Coal	810,76	-	810,76
Total	**90.060,40**	**7.007,30**	**97.067,70**

Source: TEIAS

Table 30. Development of Generation Capacity by Source (2009 – 2021 (March))

						Unit: MW
	Thermal	**Hydraulic**	**Geothermal**	**Wind**	**Solar**	**Total**
2009	**29.339,10**	**14.553,30**	**77,2**	**791,6**	**-**	**44.761,20**
Share %	65,55	32,51	0,17	1,77	-	100
2021 March	**47.794,10**	**31.325,10**	**1.623,90**	**9.360,60**	**6.964,00**	**97.067,70**
Share %	49,24	32,27	1,67	9,64	7,17	100

Source: TEIAS, Electricity Statistics 2021

According to investments planned until 2025 as of February 2021, planned licenced investments can be seen Table 28.

Table 31. Planned Licenced Generation Plants

Licenced Plant Investment	Installed Power (MW)	Unit
Hydraulic	3.361,88	44
Natural Gas	2.817,00	4
Biomass	746,41	98
Solar	1.035,50	3
Import Coal	5.425,50	6
Geothermal	504,77	28
Lignite	2.515,00	5
Wind	3.729,85	106
Hardcoal	1.149,50	2
Nuclear	4.800,00	1
Total	**26.085,41**	**297**

Source: TEIAS and EMRA

Besides, since 2016, the installed power of unlicensed power generation plants has reached approximately 7.000 MW and, considering the potential in Turkey, it is almost certain that these power plants will also increase. Thus, in 2025, Turkey's installed capacity will reach 121.975 MW, now 97.067 MW. With this installation capacity, it is calculated as at least 570.000 GWh electricity will be generated.

Installed Power Reserve is an important indicator that should affect investments.

$$\frac{Installed\ Power - Peak\ Load\ Demand}{Peak\ Load\ Demand}\ x\ 100$$

Supply capacity projections prepared by TEIAS are calculated to keep this ratio higher than the demand projection. In fact, in the latest supply capacity projection report, it is calculated that if the electricity demand reaches 329.000 GWh in 2020 and 406.900 GWh in 2024, the energy demand can be met with sufficient reserve until the end of this 5-year working period. In other words, it has been stated that in 2020, together with high forecastings, even if no new power plants are put into operation under current conditions, the high demand amount will be easily met in 2024.

In addition, according to “5 and 10-Year Connected Regional Production Facility Capacities Report,” the installed power development for the years 2025 and 2030 has been calculated by TEIAS as 119.538 MW and 133.702 MW, respectively. (TEIAS, 2021 (b)) Thus it can be easily said that the size of the idle capacity that will emerge will gradually increase. As can be clearly seen from Table 27, the current licensed and unlicensed power plant plans in 2020 will cause an increase of 21.304 MW by the end of 2024. Since it is not clear whether the power plant will be licensed or approved for this amount of installed power in the coming years, it is obvious that these amounts will increase.

Table 32. Planning Power-Plants Investments and Types

Commissioning Power Plants by 2024						(MW)
Licenced - Pre-Licenced Private Sector Power Plants						
Fuel-Resource	**2020**	**2021**	**2022**	**2023**	**2024**	**Total**
Biomass	38,60	456,57	144,10	141,70	96,30	877,30
Natural Gas	37,50	175,21	0,00	0,00	0,00	212,70
Fuel-Oil	0,00	9,20	0,00	0,00	0,00	9,20
Solar	293,00	0,00	0,00	0,00	0,00	293,00
Hydraulic	1.273,80	905,29	63,20	84,90	631,80	2.959,00
Imported Coal	0,00	0,00	1.320,00	0,00	0,00	1.320,00
Geo-Thermal	90,50	76,60	158,70	117,20	28,40	471,40
Wind	1.011,00	1.069,00	941,00	930,00	667,00	4.618,00
Uranium	0,00	0,00	0,00	1.200,00	1.200,00	2.400,00
Domestic Asphaltith	0,00	0,00	0,00	0,00	135,00	135,00
Hardcoal	30,00	0,00	0,00	0,00	0,00	30,00

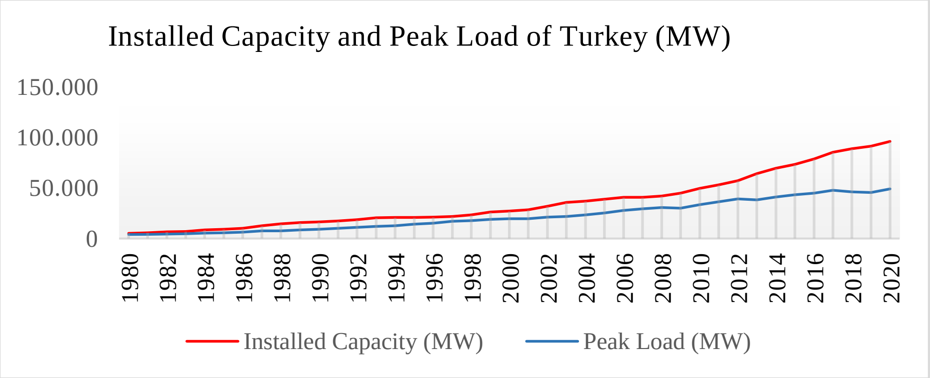
Lignite (Domestic)	0,00	59,83	36,00	0,00	0,00	95,83
Total	2.774,40	2.751,69	2.663,00	2.473,80	2.758,50	**13.421,43**
Public Power Plants Under Construction						
Fuel-Resource	**2020**	**2021**	**2022**	**2023**	**2024**	**Total**
Hydraulic	1.204,20	548,10	0,00	0,00	0,00	1.752,30
Total	1.204,20	548,10	0,00	0,00	0,00	**1.752,30**
Specific Renewable Reources Projects Plants (YEKA Project)						
Fuel-Resource	**2020**	**2021**	**2022**	**2023**	**2024**	**Total**
Solar	500,00	500,00	500,00	500,00	0,00	2.000,00
Wind	0,00	0,00	0,00	0,00	700,00	700,00
Total	500,00	500,00	500,00	500,00	700,00	**2.700,00**
Unlicenced Power Plants						
Fuel-Resource	**2020**	**2021**	**2022**	**2023**	**2024**	**Total**
Biomass	14,00	15,00	15,00	15,00	15,00	74,00
Solar	574,00	557,00	550,00	550,00	800,00	3.031,00
Wind	15,00	15,00	15,00	15,00	15,00	75,00
Co-generation	46,00	54,00	50,00	50,00	50,00	250,00
Total	649,00	641,00	630,00	630,00	880,00	**3.430,00**
General TOTAL						
Fuel-Resource	**2020**	**2021**	**2022**	**2023**	**2024**	**Total**
Thermal	113,50	298,20	1.406,00	50,00	185,00	2.052,70
Uranium	0,00	0,00	0,00	1.200,00	1.200,00	2.400,00
Hydraulic	2.478,00	1.453,40	63,20	84,90	631,80	4.711,30
Solar	1.367,00	1.057,00	1.050,00	1.050,00	800,00	5.324,00
Wind	1.026,00	1.084,00	956,00	945,00	1.382,00	5.393,00
Geo-Thermal	90,50	76,60	158,70	117,20	28,40	471,40
Biomass	52,60	471,60	159,10	156,70	111,30	951,30
Total	**5.127,60**	**4.440,80**	**3.793,00**	**3.603,80**	**4.338,50**	**21.303,70**

Source: TEIAS Electrical Energy Supply Capacity Reports (2020-2024)

Stating in this capacity report, the electrical energy generated reliably has been calculated over the years. Although the gross electricity consumption was realized as 304.835 GWh in 2020, the generation capacity was calculated as 492.803 GWh in the same year. There was 55% overcapacity in the first year, and the 2020 surplus was 62%. Moreover, the installed capacity growth is faster than demand until 2024 due to new licenses and approvals after 2021.

On the other hand, it started the construction of the nuclear power plant to be built in Akkuyu with the “Build-Own-Operate” model, which will be applied for the first time in our country. The power plant is planned to be operational in 2025. It was decided that the power plant, which has a total power of 4800 MW with four-1200 MW reactor units, will be left to the Russian company at the end of the operation period. Thus installed capacity of power plants will gradually increase although not needed.

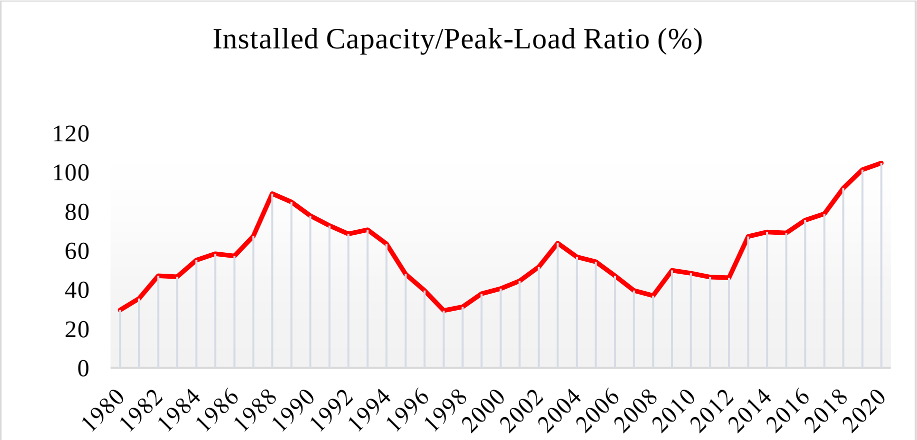
Figure 18. Turkey's Electricity Installed Capacity and Peak Load by Years



Source: TEIAS, Electricity Statistics.

As can be seen from Figure 19, the installed capacity/peak-load rate has increased with the commissioning of large thermal and hydraulic power plants in the second half of the 1980s. But it started to decline in the 1990s with the cessation of investments. This rate, which followed a fluctuating trend in line with the increasing demand until 2010, boomed with the increment in private sector investments. Finally, the installed capacity reached more than 2 times the peak load in 2020. In other words, even the peak load target of a highest scenario for 2031 is less than about 30% of the current installed capacity.

Figure 19. Installed Capacity to Peak-Load Ratio



Source: TEIAS, Electricity Statistics

Although there are countries such as France with high installed power and relatively lower demand, their electricity exports are quite high. According to 2018 Electricity Annual Report of RTE,[10] the electricity generation of France was 548.600 GWh in 2018, and its export was 51.700 GWh. In other words, France exports approximately 10% of the electricity generation and is Europe's largest electricity exporting country. Therefore, the increase in installed power compared to demand does not create a severe problem for this country. Moreover, considering that it has been one of the leading countries in electricity technology for many years and has produced its own technology, France is advantageous. However, the designing of the electrical system in Turkey has modeled France's EDF company, and during the same period, exports of electricity were 0,5% of the total generation of Turkey. So, it is seen that Turkey's installed electricity capacity is much higher than it needs and will continue to increase.

Table 33. Generation Capacity of Turkey by Years (GWh)

YEARS	Gross Demand	Average	Firm
1980	24.617	24.019	20.934
1981	26.289	26.044	23.041
1982	28.325	31.100	28.615
1983	29.568	32.211	29.543
1984	33.267	39.112	35.116
1985	36.361	42.927	38.931
1986	40.471	48.803	44.811
1987	44.925	63.588	59.416
1988	48.430	68.806	64.028
1989	52.602	74.998	69.801
1990	56.812	81.628	76.301
1991	60.499	86.156	80.424
1992	67.217	93.470	86.956
1993	73.432	100.363	92.966
1994	77.783	103.360	95.516
1995	85.552	105.257	97.414
1996	94.789	106.519	98.395
1997	105.517	110.868	102.150
1998	114.023	120.147	108.566
1999	118.485	140.346	123.575
2000	128.276	147.933	137.555
2001	126.871	154.176	143.251
2002	132.553	180.022	168.238
2003	141.151	206.697	194.875
2004	150.018	216.429	204.411
2005	160.794	229.697	217.434

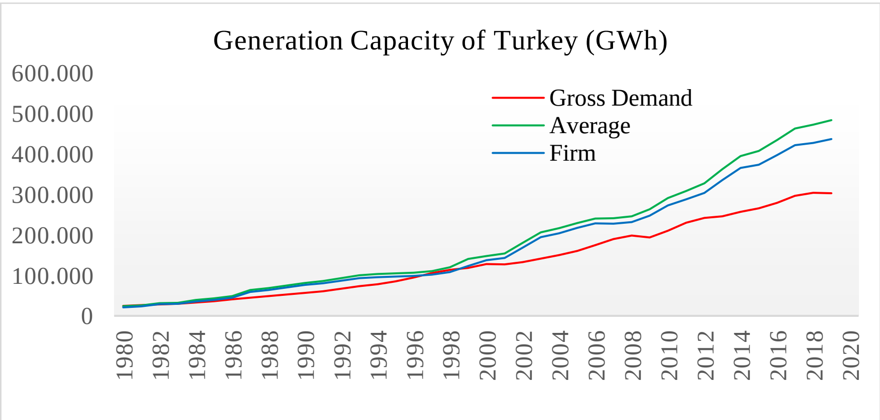
[10] RTE: Réseau de Transport d'Électricité (Electricity Transmission System Operator of France)

2006	174.637	240.805	228.247
2007	190.000	240.916	227.689
2008	198.085	245.845	231.862
2009	194.079	263.308	247.848
2010	210.434	291.099	273.164
2011	230.306	308.472	288.302
2012	242.370	327.439	303.593
2013	246.357	362.604	335.747
2014	257.220	394.660	365.297
2015	265.724	407.226	373.901
2016	279.286	434.471	397.370
2017	296.702	462.858	421.565
2018	304.167	472.345	427.741
2019	303.320	483.718	436.986
2020	304.836*	492.803	445.193

Source: TEIAS Capacity Reports *Temporarily

This overcapacity development can also be seen from the firm's capacity. Firm capacity, expressed as reliable capacity, indicates the amount of electrical energy a power plant can produce under average operating conditions. According to the last forty years since 1980 in Turkey, only beginning of the 80s, and the middle of the 90, this amount is equal to or slightly below demand for a few times. Since the beginning of 2000, the firm capacity started to increase in parallel with previously expressed overcapacity starting at the beginning of 2010. Firm capacity is 437.000 GWh against the demand of 303.000 GWh 2019.

Figure 20. Development of Generation Capacity of Turkey



Although it is stated in the Law and Regulation that Supply Capacity Projections are prepared by TEIAS and then sent to EMRA, it is not possible to cite any modeling and methodology for power plant investments. Thus, if calculations are made in the next

10 or 20 years according to demand forecasts, it is evident that the idle capacity will be very high.

4.3.2 New Investment Trends

In recent years, especially renewable energy investments have made great progress thanks to developing technologies in the world. The cost of electricity from renewable sources has dropped significantly in the last decade. The main reasons for this decline are new technologies, economies of scale, improved supply opportunities and increased experience (IRENA (b), 2020).

Table 34. Generation Cost of Renewables 2010-2019 (USD/kWh) of IRENA

	Biomass	Geothermal	Hydraulic	Solar Photovoltaic	Concentrating Solar	Off-Shore Wind	Onshore Wind
2010	0,076	0,049	0,037	0,378	0,346	0,161	0,086
2019	0,066	0,073	0,047	0,068	0,182	0,115	0,053

There will be shown very remarkable changes in the energy mix in 2050 by IRENA forecasting. According to estimates, the share of fossil fuels in final consumption will decrease to one-third of today’s, and the share of renewable resources will increase four times. As a result of this transformation, the share of technologies that provide low carbon emissions within the total investment will increase very quickly (IRENA (a), 2017).

In such a future depicted, although the increase in the share of renewable energy sources is a positive development in Turkey, there is a huge contradiction with a rapid increase in the thermal and nuclear power plant investments too. Regarding energy efficiency, although some legal regulations have been made, these are seen as showpiece measures. Energy efficiency investments have started to take an important place in the investments realized in the energy and electricity sector in the world.

According to the IEA World Energy Investments Report 2019, it is emphasized that the share of energy efficiency investments in all electricity investments is increasing. Energy efficiency investments manifest themselves in the decrease in energy density. Energy density; it is used as an energy efficiency indicator when any technical or physical indicator (specific energy consumption, total energy consumption, etc.) cannot explain the efficiency level of any activity. Accordingly, Turkey's primary energy density index decreased by 1.3% annually and the final energy density index decreased by 1.4% from 2000 to 2017 (MENR-EEED, 2021). A decrease in energy density or a low level indicates that more GNP is obtained from one unit of energy.

In addition, it is stated that electric and hybrid cars, which are becoming widespread in the world, will decrease the primary demand for fossil fuels in the future and increase the electricity demand. Turkey Electric and Hybrid Vehicle Association (TEHAD), according to data from 2015 to the end of March 2021, a total of 1573 electric, 43.887 hybrid vehicles have been sold in Turkey. (TEHAD, 2021) Considering the trend in the world, it is clear that this number will increase faster. According to IEA's Global EV Outlook 2020 data, there is currently a stock of 7.2 million electric vehicles in the world. In addition, there are a total of 7.3 million charging stations, 6.5 million of which are private and 800 thousand of which are public. (IEA, EV Outlook 2020)

The increasing number of electric and hybrid vehicles in Turkey will naturally increase the share of final electricity consumption. Since the number of charging stations will increase with the increasing number of vehicles, the effect of this situation on the distribution system will also increase. In this context, the distribution network will need to be improved and developed. Therefore, the investment amount is expected to be increased, especially in distribution networks. In the IEA Report, it is estimated that electric vehicles will consume 4% of the world's electricity demand in 2030.

Yet, developments have been taking place in the field of globally distributed energy generation in recent years. Distributed systems are of great importance in meeting the needs of those regions with small-scale power plants by reducing losses in transmission and distribution.

The most important distributed systems are roof-type solar panels. The use of roof-type solar panels is widespread in places with large roof areas such as homes, schools, hospitals and shopping malls. It is calculated that these panels, which are gradually decreasing in cost, meet 25% of the electrical energy of the households with the current technology. In 2018, the average initial installation cost of photovoltaic power plants was calculated as 1.200 USD / kW. The investment costs of these systems decrease between 10% and 15% each year (IRENA, 2019). Therefore, by providing various incentives and support mechanisms, increasing these production opportunities will reduce energy imports and carbon emissions.

4.4 CALCULATIONS OF GENERATION POSSIBILITIES OF TURKEY

By means of developing renewable energy sources in the installed capacity, capacity factors of power plants have increased in Turkey. Although hydraulic power plants have a fluctuating rate depending on the precipitation regime, not much change has been observed in thermal power plants. The table below shows the average annual production projections and firm capacities of the power plant types.

Table 35: Projected Capacity of Power Plants by Type

Power Plants Capacity (By 8760 Hours)		
Power Plant Type	**Projected Capacity**	**Firm Generation Capacity**
Coal	7000	7000
Naural Gas	7000	7000
Wind	3200	1100
Hydraulic	3400	3200
Nuclear	8000	-
Geothermal	8000	8000
Biomass	7000	7000
Solar	2500	0

However, these capacities and projections can be realized lower due to reasons such as lack of maintenance and repair and failure demand. At this point, the average capacity factor activates for the calculations. The capacity factor is a very important element in electricity generation calculations. Accordingly, the projections and capacity utilization of the power plants are determined, and the generation possibilities of the power plants are also planned in the future by capacity factor.

Electricity Generation = 8760 x Nameplate Capacity x Capacity Factor

$$Capacity\ Factor: \frac{Actual\ Electricity\ Generation\ (MWh)}{Nameplate\ Capacity(MW)\ x\ Yearly\ Time(Hours)}$$

This formula shows that a power plant can generate electrical energy amount by annually. Amount of hours per year indicate as 365 Day x 24 Hour = 8760 Hours. However, considering the conditions such as maintenance repair and breakdowns, the operating capacity of each plant is lower in hours.

Capacity factors compared to year according to the following table illustrates the type of power plants in Turkey. They have been calculated on the basis of installed capacity and their actual generations. (APPENDIX C)

Table 36. Installed Power and Average Capacity Factors (%) of Power Plants in Turkey

	Renewables				Thermal			
Years	Wind	Solar	Hydraluic	Geothermal	Nat. Gas	Lignite	Hard Coal / Import/Asph.	Fuel Oil / Diesel
2013	31,26	-	30,43	50,08	69,88	42,01	87,32	32,21
2014	26,80	4,94	19,62	66,65	73,51	50,47	69,28	19,74
2015	29,54	8,90	29,63	62,66	61,55	42,57	58,92	55,84
2016	30,80	14,30	28,76	67,01	51,26	48,21	74,78	67,97
2017	31,37	9,64	24,37	65,76	56,33	50,74	67,97	59,12
2018	32,51	17,59	24,19	66,14	48,21	54,39	81,40	29,57
2019	32,75	18,24	35,60	67,30	29,10	53,72	78,71	44,27

Source: TEIAS

Thus, between 2013 - 2019 average capacity factors have been realized as follows; wind 30,72%, solar 10,50%, hydraulic 27,51%, geothermal 63,65%, biomass 24,11% and thermal 49,51%. The average capacity factor of all of the installed capacity has been 34.34%.

Accordingly, the capacity factors of the last five years were calculated, and the amount of electrical energy generation between 2020 and 2024 could be calculated according to this average capacity factor.

Table 37. Additional Installed Capacity and Generation Capacity Calculations

Years	2020	2021	2022	2023	2024
Additional Capacity (MW)	4.441	3.793	3.604	3.604	4.339
Total Firm Generation Capacity (GWh)*	492.803	505.847	526.090	545.162	560.701

Source: TEIAS

***** Total Firm Generation Current Generation capacity plus added power plant's capacity.

Table 38. Detailed Electricity Generation Capacity Calculation (GWh)

Ownership	Source/Plant Type	2020	2021	2022	2023	2024
EUAS (State)	Diesel	7	7	7	7	7
	Lignite	13.741	15.756	15.756	15.756	15.756
	Natural Gas	34.558	34.558	34.558	34.558	34.558
	Wind	39	39	55	55	55
	Hydraulic	37.295	40.232	41.088	41.115	41.115
	Total	**85.640**	**90.592**	**91.464**	**91.491**	**91.491**
Transfer of Operating Rights	Lignite	10.823	8.808	8.808	8.808	8.808
	Geothermal	105	105	105	105	105
	Hydraulic	5.350	5.350	5.350	5.350	5.350
	Total	**16.278**	**14.263**	**14.263**	**14.263**	**14.263**
Build Operate Transfer	Hydraulic	559	516	507	458	458
	Wind	16	0	0	0	0
	Total	**575**	**516**	**507**	**458**	**458**
Private Power Plants	Fuel Oil	2.238	2.238	2.238	2.238	2.238
	Lignite	+41.428	41.563	41.563	41.563	41.563
	Hard Coal- Aspha.	8.425	8.425	8.425	9.397	9.397
	Import Coal	60.228	60.228	70.128	70.128	70.128
	Uranium	0	0	0	8.698	17.395
	NAFTA	33	33	33	33	33
	Natural Gas-LNG	150.375	151.076	151.076	151.076	151.076
	Geothermal	13.004	14.274	15.211	15.433	15.433
	Hydraulic	54.521	54.874	55.142	57.335	57.335
	Biomass	9.432	10.305	11.462	12.136	12.136
	Wind	28.580	31.978	35.737	38.698	40.688
	Solar	1.010	1.010	1.010	1.010	1.010
	Total	**369.274**	**376.004**	**392.025**	**407.745**	**418.432**
	Solar	1.250	2.500	3.750	5.000	5.000

Renewable YEKA Project	Wind	0	0	0	0	2.100
	Total	**1.250**	**2.500**	**3.750**	**5.000**	**7.100**
Unlicenced	Biomass	2.068	2.173	2.278	2.383	2.488
	Hydraulic	30	30	30	30	30
	Solar	16.249	17.891	19.516	21.141	23.391
	Wind	257	302	347	392	437
	Cogeneration	1.183	1.561	1.911	2.261	2.611
	Total	**19.787**	**21.957**	**24.082**	**26.207**	**28.957**
General Total (GWh)		**492.804**	**505.832**	**526.091**	**545.164**	**560.701**

Source: TEIAS Generation Capacity Projection Report (2020 - 2024)

Table 39. Generation Calculations (GWh) of Power Plants (2020-2024)

Sources	**2020**	**2021**	**2022**	**2023**	**2024**
Lignite	65.991,00	66.126,00	66.126,00	66.126,00	66.126,00
HardCoal and Asphaltithe	8.425,00	8.425,00	8.425,00	9.397,00	9.397,00
Import Coal	60.228,00	60.228,00	70.128,00	70.128,00	70.128,00
Natural Gas	184.933,00	185.634,00	185.634,00	185.634,00	185.634,00
Fuel Oil	2.238,00	2.238,00	2.238,00	2.238,00	2.238,00
Diesel	7,00	7,00	7,00	7,00	7,00
Uranium	0,00	0,00	0,00	8.698,00	17.395,00
Others	1.216,00	1.594,00	1.944,00	2.294,00	2.644,00
Total Thermal	**323.039,00**	**324.252,00**	**334.502,00**	**344.522,00**	**353.569,00**
Biomass	11.500,00	12.478,00	13.740,00	14.518,00	14.623,00
Hidraulic	97.755,00	101.002,00	102.117,00	104.288,00	104.288,00
Wind	28.893,00	32.335,00	36.139,00	39.145,00	43.281,00
Geothermal	13.109,00	14.379,00	15.316,00	15.538,00	15.538,00
Solar	18.509,00	21.401,00	24.276,00	27.151,00	29.401,00
Total Renewables	**169.766,00**	**181.595,00**	**191.588,00**	**200.640,00**	**207.131,00**
Gross Total	**492.805,00**	**505.847,00**	**526.090,00**	**545.162,00**	**560.700,00**

Source: TEIAS Generation Capacity Projection Report

According to these calculations, the amount of electrical energy that can be generated with current and planned investments at the end of 2024 will be 560.701 GWh. With the addition of installed power for the years 2025 and 2030, since power plant types are not informed, the electricity generation capacity corresponding to the installed power could not be calculated. Nevertheless, by interpolation, there will be an electricity generation capacity of around 580.000 GWh for 2025, corresponding installed power of 119.538 and 630.000 GWh for 2030, corresponding installed power of 123.702 MW. In parallel with the development of installed capacity in renewable energy sources, it has increased the capacity factor of such power plants in Turkey

Considering the dates when licensed or unlicensed power plants will come into operation in the five-year period covering the period of 2020 -2024, the calculations of the installed capacity on the basis of resources were explained above by years. In the calculations made with the capacity factors of the resources, the electrical energy resources that can be produced for each year are included in Table 35. The thermal generation capacity, which increased steadily until 2022, increased rapidly with the commissioning of the first unit of the nuclear power plant by 2023 and the second unit the following year. Nevertheless, natural gas power plants have the largest share in thermal generation capacity. The share of natural gas power plants in production will be 35% on average. In this 5-year period, thermal generation capacity will increase by 10%, while its renewable capacity will increase by around 22%.

However, although hydraulic power plants have a fluctuating rate depending on the precipitation regime, not much change has been observed in thermal power plants. In these calculations, the most striking feature is that by the end of 2024, unlicensed production will have 50% more production capacity than today. Thus, thanks to the diversification of energy generation resources to be provided, the dependency on thermal power plants will also decrease, apart from base load and sudden energy demands.

As stated in the latest Supply Capacity Projection Report prepared by TEIAS: "*When the public and private sector power plants with license / pre-license are examined together with the generation plants within the scope of the YEKA project and the unlicensed generation plants, the ratio of peak demand to available power is 94.8% in 2020. It is clearly stated that it reached 93.2% in 2021, 94.1% in 2022, 95.4% in 2023 and 95.0% in 2024*." (TEIAS 2020 Capacity Report) Therefore, there are 1.95 MW units of available capacity for each 1 MW for peak demand in 2020.

CHAPTER 5

FORECASTING MODEL

5.1 FORECASTING METHODOLOGY

5.1.1 ARIMA Model

Box and Jenkins lead a new advanced forecasting method of their book *Time Series Analysis: Forecasting and Control*. This process, also known as the Box-Jenkins Model, is technically called the ARIMA Model (Box et. al, 1994).

Unlike regression models in which the dependent variable (Y_t) is explained by k regressors X_1, X_2, X_3, *and* X_k , the dependent variable (Y_t) is explained by the past or lagged values Y itself and error terms in the ARIMA Model. Therefore, differently from the economic theory derived from simultaneous equations, the ARIMA model is also called the “atheoretic model” (Gujarati, 2003).

A time series is an aggregate display of measurements made for a variable in sequence over time. Understanding the direction of measurements with time series and accurately predicting future values of variables in the time series. That is, in the ARIMA Model, the values in the time series are modeled over the past period values, and forecastings are made. Time series usually include AR and MA processes. Also, I (integrated) defines the trend included by the series. ARIMA(p,d,q) Model shows as p refers to the degree of autoregression, d to the difference operation, q to the degree of the moving average model.

5.1.1.1 Autoregresivve Process (AR)

The dependent variable is a function of its past value in an AR model. It may be written an AR process

$$Y_t = \beta_0 + \beta_1 Y_{t-1} + \beta_2 Y_{t-2} + \ldots\ldots\ldots + \beta_\rho Y_{t-\rho} + \varepsilon \qquad (5.1)$$

and used β_0 , β_1 , β_2 and β_p for a finite set of weight parameters. This process defined by equation 4.1 referred Autoregresivve Process. β_0 represents the constant term while coefficients such as β_1 , β_2, and β_p show the relationship of the lagged values to the present value of Y. Also, ε is an error term and defines random shocks. It is commonly expressed as AR(p).

More descriptive by Gujarati (2003);

$$(Y_t - \delta) = \beta_1(Y_{t-1} - \delta) + u_t \qquad (5.2)$$

δ = Mean of Y
u_t = Uncorrelated Random Error with Zero Mean and Constant Variance (σ^2)

Y_t maintains AR(1) the first-order autoregressive process. That is, the value of Y in AR(1) depends on its value at time t and its value in the previous period and the random shock term. The Y value includes the deviation from its mean value. Thus, in the AR process, part of the predicted value of Y at time t is calculated by the ratio of its value at time t-1 to β_1 and the white noise (u_t) in t period.

According this second-order autoregressive process AR(2) is

$$(Y_t - \delta) = \beta_1 (Y_{t-1} - \delta) + \beta_2 (Y_{t-2} - \delta) + u_t \qquad (5.3)$$

Finally *p*th-order autoregressive**,** or AR(*p*), of Y_t is

$$(Yt - \delta) = \beta_1 (Y_{t-1} - \delta) + \beta_2 (Y_{t-2} - \delta) + \cdots \cdot + \beta_p (Y_{t-p} - \delta) + u \qquad (5.4)$$

5.1.1.2 Moving Area Process (MA)

Only AR process does not generate Y. If the lagged white noise error term of the series affects the current white noise error term, the moving average process (MA) is defined. The predictive value of the variable in a moving average process is related to the predictive value of the error terms.

Y at time t equals the moving average of constant (μ) plus current and past white noise error terms. If defining about the present time value of Y, MA(1);

***μ** = constant*
***u** = stochestic error term*

$$Y_t = \mu + \alpha_0 u_t + \alpha_1 u_{t-1} \qquad (5.5)$$

Then, MA(2) is

$$Y_t = \mu + \alpha_0 u_t + \alpha_1 u_{t-1} + \alpha_2 u_{t-2} \qquad (5.6)$$

Finally, MA(q) is

$$Y_t = \mu + \alpha_0 u_t + \alpha_1 u_{t-1} + \alpha_2 u_{t-2} + \cdots\cdots + \alpha_q u_{t-q} \qquad (5.7)$$

Thus a MA is a linear combination of error terms. As a result of an ARMA process, described as ARMA(1,1)

$$Y_t = \theta + \beta_1 Y_{t-1} + \alpha_0 u_t + \alpha_1 u_{t-1} \qquad (5.8)$$

where θ is a constant term.

But an **ARMA(p,q)** process generally it is showed *p* autoregressive, *q* moving average terms.

5.1.1.3 Integrated Process (I)

Gujarati (2003) states that the time series are integrated from order 1 (I(1)); thus, their first difference is I(0), and they are stationary. So, if a time series is I(2), the second difference is I(0). As a result, if a time series is I(d), we get an I(0) series after differentiating.

If the values in a time series are not stationary around the average value of this series, the stationarity is achieved by taking the differences of the series. The degree of differentiation is denoted by *d* and usually takes the value 1 and 2.

According to these explanations, ARIMA is one of the major economic forecasting methods. Many time series includes both the AR and the MA process. In addition, I (integrated) refers to the trend included by the series. This whole process, which is explained as ARIMA(*p,d,q*) autoregressive integrated moving average time series, involves the AR(*p*) process, which expresses the relationship of the time series with its lag of pth order; it explains the MA(*q*) process with q, which expresses the relationship of error terms with their past values and is one of the methods of smoothing error terms. In addition, if there is usually a non-stationary in time series, it is expressed with d, and at what level the time series is I- integrated. I is defined as I*(d*).

In the ARIMA(*p,d,q*) model, time series with autoregressive and moving averages are examined. The stationarity of the time series is determined with a correlogram, and again, what kind of process the time series contains is analyzed with correlation functions. In case of not being stationary in time series, it is stabilized by taking the difference; But, if there is no stability again, the data is returned. However, if the stability is achieved, then the model is estimated with ARMA, and the prediction process is performed. (Gujarati, 2003)

For example, if the model is described as ARIMA(2,1,2), and if the model is desired to be 1^{st} degree stationary or only stationary, that is, ARMA (2,2), it must be differenced one (d=1). There are two AR and two MA terms in ARMA(2,2). If d = 0, the model is stationary from the beginning, and it takes the form of ARIMA (p,d=0,q). This expression is also equal to ARMA(p, q).

In an ARIMA Model, p or q can be zero in the model. In this case, the model either AR(d,p) or MA (d,q) model is continued. In addition, if the model is completely stationary, described as;

- ARIMA(p,0,0) = AR(p)
- ARIMA(0,0,q) = MA(q)

5.1.2. Stages of ARIMA

An ARIMA process consists of the following stages: Identification, Estimation, Control-Checking, and Forecasting (Gujarati, 2016).

5.1.2.1 Identify

At this stage, it is examined whether the series is stationary or not. If the series is not stationary, the difference is taken, and the ACF and PACF graph is examined, and the difference is taken until the series is stationary.

The Box-Jenkins method checks whether the series is stationary or not by starting from the *d* parameter. For this purpose, the “correlogram” is analyzed, or formal unit root tests are performed. If the series is not stationary, the difference is taken and the stationarity is tested again. This process is repeated until the stationarity of the series. After the series is stabilized by taking the difference in d times, it is time to find the values of p and q. For this, the correlogram of the series is examined. It is necessary to consider AC values in the correlogram in the context of testing “stationarity.”

The second element in the correlogram that has an important place in the Box-Jenkins method is the “PACF” (Partial Autocorrelation Function). PACF is denoted as ρ_{kk} and measures the correlation between observations of lag length *k* from each other, similar to ACF. On the other hand, unlike *p*, it controls the intermediate delays up to *k*. In other words, it keeps it constant. Correlogram helps find the lag length p in an autoregressive process by giving the PACF corresponding to increasing k values. (Yalta, 2011)

It is known that AR (p), MA (q) and ARMA(p, q) processes give their specific ACF and PAC patterns.

Model	ACF	PACF
AR(p)	Exponential decreasing, decreasing sine curve, or both	Significant spike to lag p
MA(q)	Significant spike to lag q	Exponential decreasing
ARMA(p,q)	Exponential decrease	Exponential decreasing

Source: Gujarati (2016)

5.1.2.2 Estimation

In the previous step, the p, d, and q parameters are estimated. After determining the p, d, and q values, the second step in the Box-Jenkins method is the estimation of the model. In practice, estimation methods such as Maximum Likelihood can be preferred.

5.1.2.3 Control-Checking

After a specific ARIMA model has been estimated, the next step is to examine how accurately the data fits the model. A simple check tool is to look at the ACF and PACF shapes and decide if the residuals are white noise. At this point, eligibility criteria such as AIC, BIC, and HQC can also be used. The importance of diagnostic control is that by using different p, d, q's, close compatibility can be obtained. It should be noted that ARIMA modeling is an iterative process. (Yalta, 2011)

5.1.2.4 Forecasting or Diagnostic

The final stage of the ARIMA process, forecasting, looks at the actual value and the performance of the estimates of this model. If a good fit is observed and it is considered that there is no need to look for another model, the current model can finally be used for predictive purposes (Gujarati, 2016). If the difference of the data is taken at the beginning, this process is reversed first. In other words, “integral” is applied to the series. Then, a one-step-ahead forecast is obtained by replacing the historical values of the data in the formula. The multiperiod forecast values and their errors for the second and subsequent future periods can also be found by repeating this process.

5.1.3 Artificial Neural Networks (ANN)

Artificial neural networks are a method that can be used based on the cause-effect relationship as well as in estimation methods based on time series. While ANN inputs for a prediction based on cause and effect relationship express independent variables, inputs (x_1 , x_2 , ... x_n), output (Y) is the dependent variable. Nonlinear equation determined by ANN can be written as,

$$Y = f (x_1 , x_2 , \ldots\ldots x_n) \qquad (5.9)$$

The inputs of ANN used for estimation based on time series consist of the past observation values of the data series, and the output shows the predicted future value. Nonlinear relationship determined by ANN is written as (Es et. al, 2014)

$$Y_{t+1} = f (Y_t , Y_{t-1}, Y_{t-2} , \ldots\ldots Y_{t-n}) \qquad (5.10)$$

Ardakani and Ardehali (2014) indicate in ANN using multivariate regression, the estimate at time t is determined as n + 1 independent variable:

$$GD(t) = ao + \sum_{i=1}^{n} ai\ ti + r(t) \qquad (5.11)$$

where GD is gross demand, $\mathbf{a_0}$ and $\mathbf{a_i}$ are coefficients, **r(t)** is residual of GD at t year.

In this thesis, the models found the values of a_0 and a_i 1^{st} and 2^{nd} order, that is i = 1 and i = 2, linear and quadratic forms are used. For this r(t) vector must be minimized.

Mean Absolute Percentage Error (MAPE), that is, Min GD_{MAPE} is

$$Min\ GDMAPE = \frac{1}{p} \sum_{i=1}^{p} \left(\frac{Ti - Oi}{Ti} \right) x\ 100 \qquad (5.12)$$

where T_i targeted GD values, O_i forecasted values of GD at period i.

p number of input data for all variables are used to get better for forecasting accuracy. So,

$$\bar{x}_i = \frac{Xi - min(Xi)}{max(Xi) - min(Xi)} \qquad i = 1,2, \ldots, p \qquad (5.13)$$

where $\bar{x}_i$ data are normalized values; x_i data are actual values.

In the guidance of the above explanations, The dependent variable is GD (Gross Electricity Demand) whereas independent variables are GDP, POP, EXP and IMP.

$$GD_{t+1} = f(GD_t , GD_{t-1}, GD_{t-2} , \ldots GD_{t-n}) \qquad (5.14)$$

$$GD_t = \alpha_0 + \alpha_1 GD_{t-1} + \alpha_2 GD_{t-2} + \ldots + \alpha_n GD_{t-n} \qquad (5.15)$$

$$GD_t = f(GDP_t , POP_t , EXP_t , IMP_t) \qquad (5.16)$$

$$GD_t = \alpha_0 + \alpha_1 GDP_t + \alpha_2 POP_t + \alpha_3 EXP_t + \alpha_4 IMP_t \qquad (5.17)$$

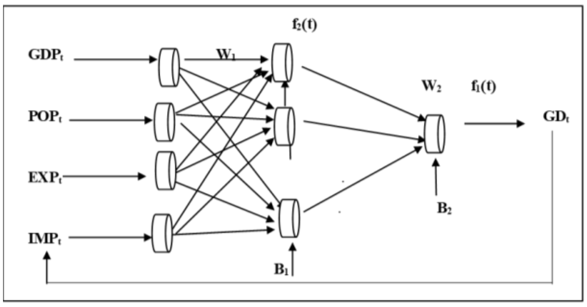
where GDP_t , POP_t , EXP_t , IMP_t are input data;.

W_1 and W_2 are weight vectors; X is input Vectors and B_1 and B_2 are bias values of hidden and output layers.

$$f_1(t) = W_1 X + B_1 \qquad \text{(Linear Function)} \qquad (5.18)$$

$$f_2(t) = \frac{1}{1+exp(-\lambda\, x\, (W2\, x\, (f1(t)+B2))} \qquad \text{(Sigmoid Function)} \qquad (5.19)$$

Figure 21: ANN Model with Single Layer Four Inputs



Source: Ardakani and Ardehali (2014)

Besides, NARX (Nonlinear Autoregressive Network with Exogenous) networks are a feedback artificial neural network model that gives successful results in nonlinear system modeling and time series prediction applications. Compared to traditional feedback network structures, NARX networks converge faster and show more effective learning. NARX networks are similar in training aspect to static MLP (Multilayer Layer Perception) network structure, but network output is implemented as feedback. They can give successful results in NARX nonlinear model simulations

That is, the feedback and input layers contain time-delayed and historical data. The feedback layer can consist of predicted or real data and, according to its structure, it is called parallel and series-parallel, respectively. In a model developed using the parallel structure, the prediction output is applied to the input as feedback, while in the serial-parallel model, this real data is applied to the input as feedback with the real data obtained.

5.2 DATA

5.2.1 ARIMA Data

Electricity demand data for 98 years between 1923-2020 were used statistics of TEIAS. While considering electricity consumption (demand) data, “Net Consumption” has been calculated in most studies. Addressing “gross consumption” was required as stated in previous sections in Turkey. Also, Gross Demand quantities are taken into account in the official demand forecast in Turkey. Therefore, gross demand amounts have been used and calculated in all official demand forecasts.

In addition, due to the peculiar characteristics of the electricity demand increase rates between 1923-1948, 1949-1975, and 1975-1990, it is thought that the relatively saturated demand rates of the 2000s, especially the increase rates between 2013-2020, are more significant. For this reason, as Gross Demand data between 1923-2020 can be accessed, these demand amounts (GWh) are used for model setup, and the amounts between 2013-2020 are taken into account for ARIMA estimation. (APPENDIX A-1)

In order to obtain the most precise results, the study ranges have been estimated from 2000, 2005, 2010, 2012 and 2015 to 2020. However, the MAPE values of the aforementioned years until 2020 are quite high. Especially the demand forecasts of the Model for the years 2000-2020, 2005-2020 and 2010-2020 yielded very low demand amount results compared to the actual amounts. Therefore, the MAPE values (%) of these periods are quite high. The MAPE values have been calculated as 13.11, 18.38 and 10.41 in these preiods, respectively. Relatively lower MAPE values have been found in 2012-2020 and 2015-2020: 2.37 and 1.67 (APPENDIX A).

However, all of these values are higher than the calculated value of 1.38 for the period 2013 - 2020, which we consider as the most appropriate forecasting range. As it is known, the high accuracy of the forecasting models is evaluated according to the MAPE value (%) of <10. Thus, in the forecasting study referenced in this thesis, since the lowest MAPE ratio has been calculated for the 2013-2020 period, the results obtained in the forecasting interval of this period has been used for future estimations.

When calculating the Gross Demand amount, imports are added to the domestic gross consumption and exports are subtracted. (Gross Demand = Domestic Elec. Demand – Elec. Export + Elec. Import)

5.2.2 ANN Data

While using data for ANN, growth rates of GNP, population, import and export have been the variables used in modeling in many studies. These data were used Turkish Statistical Institute. Although the reference studies were conducted for general energy demand, these variables were used in the model due to the widespread use of electricity described in the previous sections. (APPENDIX A-2)

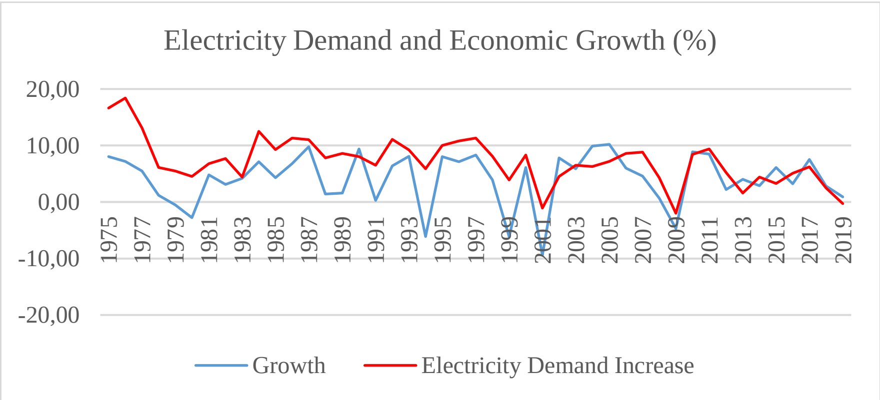
Also, in this model, it is assumed that the energy density is constant. Because the energy density fell slightly between 1970 and 2020 and remained stable for the last 15 years, although energy efficiency efforts are thought to decrease energy intensity, there is no public data on how much this ratio will decrease. For this reason, this data, which has a demand-reducing effect, could not be used in the model.

Likewise, the demand reduction effect of the decrease in loss and leakage rates stated in the previous sections is also tried to be addressed in the model. However, since the amount of leakage losses in the distribution was not disclosed, these data could not be used because there was doubt about the reliability of these data.

5.2.2.1 Economic Growth Rate

There is a positive relationship between electricity demand and economic growth. Except for high electrification efforts at the end of the 70s and mid-80s, it can generally be seen that the linear trends between these two variables in Turkey. While the average growth rate of electricity demand has been 9.61% since 1923, the increase in economic growth has been 5.07. When we compare these two values, it can be said that 1 unit of economic growth causes an increase of 1.90 units in electricity demand. However, it is seen that this rate has dropped significantly in the last 10 years. It is seen that this ratio has decreased to 0.78 in the last 10 years. In other words, 1 unit of economic growth increase increases the electricity demand by only 0.78 units in the last 10 years.

Figure 22. Relationship Electricity Demand and Economic Growth (%)



Source: TEIAS and Turkish Statistical Institute

5.2.2.2 Population Growth Rate

One of the important facts that increase electricity consumption is the population growth rate. Population growth increases urbanization and the consumption of goods and services in general. Thus, there is a positive relationship between increasing population and electricity consumption. Population growth rates between 1923 and 2020 are used in the model. The average population growth rate in the last 98 years is around 2%.

5.2.2.3 Export Growth Rate

The increase in exports is a factor that increases general energy consumption and electricity consumption in particular, as it increases domestic production activities. Since it is possible to reach export values since 1924, these increase rates (of course, decrease rates) are examined in the series.

5.2.2.4 Import Growth Rate

Known the fact that the great majority is composed of imports of interim goods and capital goods in Turkey. Among these, energy imports also hold an important item. In other words, as production increases or exports increase, imports also increase. It can be said that these increases also increase the energy and electricity demand.

5.3 RESULTS

5.3.1 ARIMA Model Results

The 3 correlograms with 50 lags shown in Appendix are calculated by taking level, first difference, and second difference, respectively. Functions of AC (autocorrelation) and PAC (partial autocorrelation) 50 lags values can be seen in the APPENDIX B.

The Correlogram of Level the bars on the left shows the 95% confidence interval and the 0 axes. At the 1st lag, the AC value has a very high value of 0.958 and regularly decreases to 29th lag. It takes negative values from 30th lag. At the same time, the PAC values in the 1st lag show a very rapid decrease from the 2nd lag and take negative values. Nonstationary can be seen Q statistics, it is different from zero at all values. At the 50th lag, Q Statistics is 867,32. Therefore, this time series is nonstationary.

Since this time series is nonstationary, it will be necessary to evaluate by taking the 1st and 2nd differences of the series. In the correlogram of the first difference of this series, it is seen that the same PAC values rapidly decrease. This can be seen in the Augmented Dickey-Fuller Test of this series.

The second difference of the series will also need to be taken as the end. In this case, it can reach some significant values. For example, 1, 2 and 9 in AC; Lags 2, 3, 5, and 9 may be significant in PAC. Accordingly, this is the AR (2) model. Thus, if the values up to the 9th lag are considered, the values in the 2, 3, 5 and 9 lags are remarkable.

That is,

$$\rho \sim N(0, \frac{1}{n}) \text{ , and } \sigma^2 = \frac{1}{n} \text{ ,}$$

then, $\sigma^2 = \frac{1}{98} = 0{,}010204082$ and $\sigma = \sqrt{0{,}010204082}$

$$\sigma = 0{,}10101$$

for 98 observation values.

Confidence interval at 0,05 is [0 ± 1.98(0,10101)] or [-0,199 , +0,199]. As a result only four PAC values at 2nd Differenced Correlogram at 2, 3, 5, and 9 are upper than ± 0,199. Thus, the values of lags are **2** = -0,423 , **3** = -0,268 , **5** = -0,217 and **9** = -0,220 respectively.

In addition, the Augmented Dickey-Fuller Test for D(GROSS_DEMAND) show to indicate unit root. Because calculated ADF statistic values -6,506 less than -4,057 (1%), -3,457 (5%) and -3,155 (10%). Again for ADF Test Result Time Series of Gross Demand is nonstationary.

Our time series model is the AR(9,2,0). As a result, the model determination stage, which is the first stage, ends.

The second step is the estimation of the model. Since lag 2, 3, 5 and 9 will be used in the model, the equation is:

$$\boldsymbol{GD_t^* = \beta_0 + \beta_2 GD_{t-2} + \beta_3 GD_{t-3} + \beta_5 GD_{t-5} + \beta_9 GD_{t-9} + u_t} \qquad (5.20)$$

As the coefficients of this Equation 5.20 are calculated by the Eviews 11, the equation becomes:

$$\boldsymbol{GD^* = 3110{,}76 + 0{,}045 GD_{t-2} + 0{,}274 GD_{t-3} + 0{,}532 GD_{t-5} - 0{,}085 GD_{t-9}} \qquad (4.21)$$

Figure 23: ARIMA Model Output by EViews

Dependent Variable: D(GROSS DEMAND)
Method: ARMA Maximum Likelihood (OPG - BHHH)
Date: 03/20/21 Time: 15:19
Sample: 1924 2020
Included observations: 97
Convergence achieved after 58 iterations
Coefficient covariance computed using outer product of gradients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3110.761	3093.029	1.005733	0.3172
AR(2)	0.044571	0.078951	0.564538	0.5738
AR(3)	0.274329	0.083668	3.278799	0.0015
AR(5)	0.531747	0.076797	6.924062	0.0000
AR(9)	-0.085204	0.093766	-0.908693	0.3659
SIGMASQ	11909268	1304729.	9.127772	0.0000

R-squared	0.457473	Mean dependent var	3142.177
Adjusted R-squared	0.427664	S.D. dependent var	4709.579
S.E. of regression	3562.933	Akaike info criterion	19.28016
Sum squared resid	1.16E+09	Schwarz criterion	19.43942
Log likelihood	-929.0875	Hannan-Quinn criter.	19.34455
F-statistic	15.34671	Durbin-Watson stat	1.416422
Prob(F-statistic)	0.000000		

Inverted AR Roots	.93	.63	.29+.76i	.29-.76i
	-.05+.65i	-.05-.65i	-.59	-.72-.60i
	-.72+.60i			

Third step is control and checking: For this, the residuals up to 50th of the above equation must be checked. The correlogram of the residuals of this equation is shown APPENDIX B. None of the AC and PAC values of residuals are statistically significant and randomly distributed. Thus the basic equation for the ARIMA model has been established.

Starting from the basic equation established at the last stage, the future prediction stage (forecasting) will be started. According to Equation 4.21, the forecasted electricity demand amounts have been calculated by EViews 11. As a result, electricity gross demand forecasting values have been forecasted as GWh for the period 2013 – 2020.

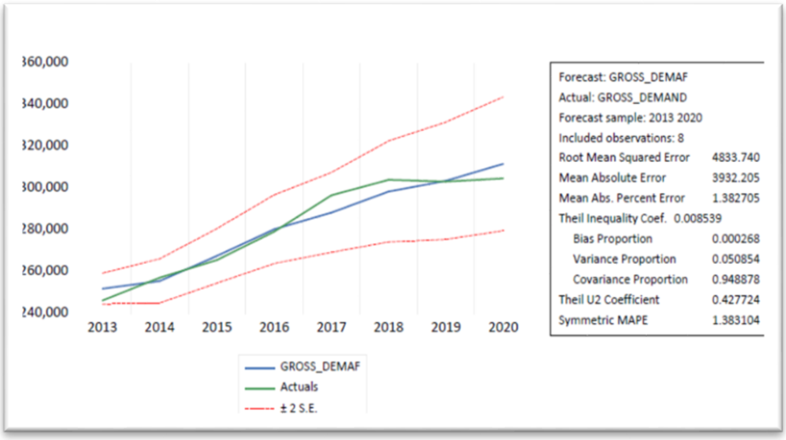
It should be stated here that there is a special purpose in selecting 2013 as a reference. Gross electricity demand in Turkey has dropped only 3 times since 1923: in 2001 (-1,09%), 2009 (-2,02%) and 2019 (-0,28%). Accordingly, if 2010 were taken into consideration in ARIMA model estimation, the rapid growth rates after 2009 would give the model a false growth signal. For this reason, the forecast range has been taken from 2013 to the present. Due to the economic recession in 2009 and the decline in electricity demand, the rapid increase in demand that started the next year continued in the 2010-2012 period. Likewise, the rate of increase is quite moderate in these 8 years' period of 2013 - 2020.

Table 40. Electricity Gross Demand Forecasting of ARIMA 2013 – 2020.

Years	Actual Demand (GWh)	Forecasting (GWh)	Deviations (%)
2013	246.357	252.016	2,25
2014	257.220	255.686	-0,60
2015	265.724	267.672	0,73
2016	279.286	280.470	0,42
2017	296.702	288.466	-2,86
2018	304.167	298.525	-1,89
2019	303.320	303.680	0,12
2020	304.836	311.732	2,21

The average deviation rate between the actual electricity demand and the forecasted demand calculated by the model is 0.05% for the 2013 - 2020 Period. MAPE is 1.383 in this forecasting.

Figure 24. EViews Output for Actual and Forecasted Demand 2013-2020 Period



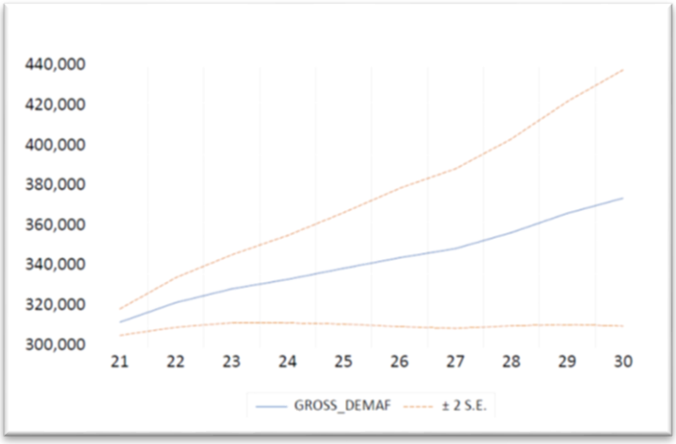
Electricity demand amounts have been calculated with the guidance of these forecast data up to 2030. As a result, electricity demand forecasting is calculated between 2021 and 2030 by Eviews 11 as in Table 39.

Table 41. Electricity Gross Demand Forecasting of ARIMA (2021 – 2030)

Year	**Gross Demand Forecasting (GWh)**	**Increase Rate (%)**	**Index 2020=100 (304.836 GWh)**
2021	321.228	2,96	102,96
2022	327.161	1,81	104,82
2023	335.559	2,50	107,44
2024	340.878	1,56	109,12
2025	346.800	1,71	110,99
2026	354.439	2,16	113,38
2027	359.190	1,32	114,88
2028	365.911	1,84	116,99
2029	371.090	1,40	118,63
2030	375.763	1,24	120,10

Using these assumptions of the model, the demand amounts for the 2021-2030 period were also calculated, and thus, an average annual growth rate is 1.85%, and finally, it is estimated that the electricity demand will reach 375.763 GWh by 2030 with a total increase of 20,10% compared to 2020.

Figure 25. EViews Output for 2021-2030 Forecasting



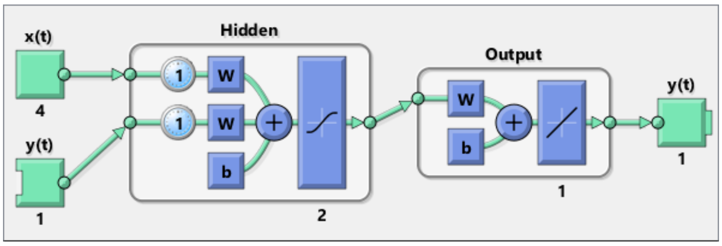
5.3.2 ANN Model Results

To carry out electricity demand forecasting with an artificial neural network model, Deep Learning Tool Box Module has been used in MATLAB R2020 a's Neural Network Time Series Tab.

The dependent variable is used as the Gross Electricity Demand (Y(t)) growth rate in this tab. Growth rates of economic growth, population, export, and import are independent variables (X(t)s).

The pattern of consumption demand was established between 1923 and 2020 through the Non-linear Auto-Regressive External Model (NARX). The period of 2013-2030 was estimated via Non-linear Auto-Regressive (NAR). 70% of the data were used for training, 15% for validation, and the remaining 15% for testing.

Thus, the estimation results were calculated as a result of the operations performed with 1000 iterations. The model has been trained for 1000 iterations, and the best training performance has been realized at 39. epoch.



In this model has been established, variables indicate that; Economic Growth Rate: x1, Population Growth Rate: x2, Export Growth Rate: x3, Import Growth Rate: x4, and Electricity demand: y

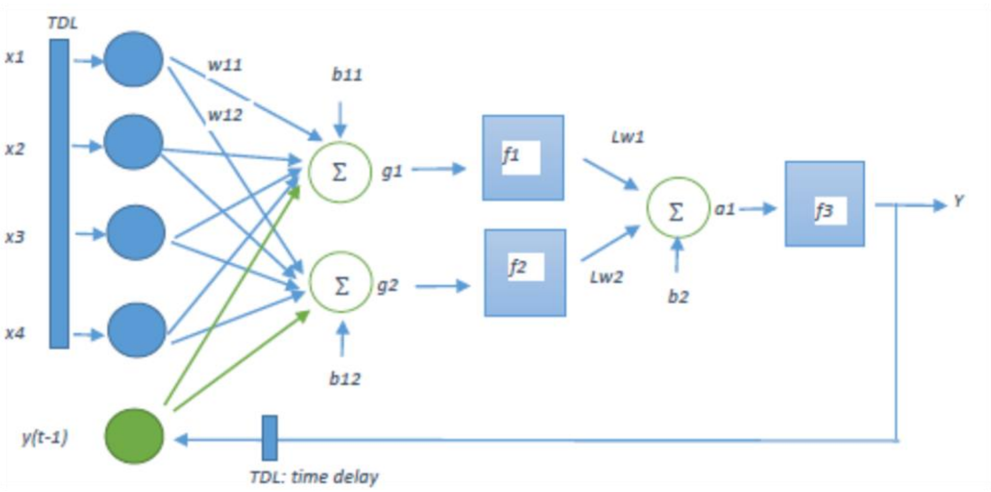
Layer 1:

Weigts of Inputs and Y					b (bias)
x1	x2	x3	x4	Y	
w11= -0.001475	w21= -0.003447	w31= 0.000129	w41= -0.000569	w51= - 0.432093	b11= 0.712258
w12= 0.000234	w22= -0.000547	w32= 2.092696e-5	w42= -9.0944098e-5	w52= 0.290863	b12= 0.566773

Layer 2:

Weights of f1 ve f2 (LW)	Bias
LW1= -1.326214	b2
LW2= 3.000351	-0.725403

Figure 26 : ANN Schema with Weights and Bias



$$[x1(t-1) \quad x2(t-1) \quad x3(t-1) \quad x4(t-1) \quad y(t-1)] * \begin{bmatrix} w11 & w12 \\ w21 & w22 \\ w31 & w32 \\ w41 & w42 \\ w51 & w52 \end{bmatrix} + [b11 \quad b12] = [g1 \quad g2]$$

f1 = tansig (g1) = $\frac{2}{1+e^{-2g1}} - 1$

f2 = tansig (g2) = $\frac{2}{1+e^{-2g2}} - 1$

a1= f1*Lw1+f2*Lw2+b2

f3 = linear (a1) = minmax (-1<a1<1)

Y = f3

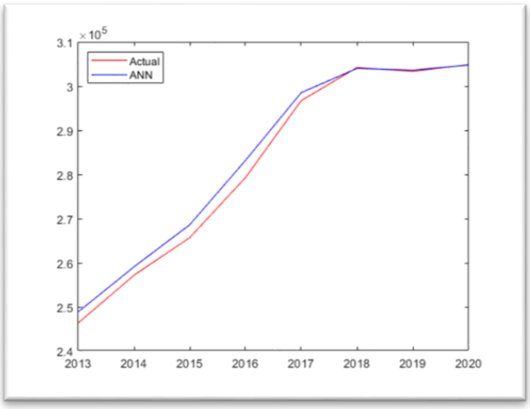
In the network created with the codes prepared in this way, both past and future consumption amounts were estimated as a result of the calculations of MATLAB ANN Tools.

For the 2013-2020 Period, since taking 2013 as a reference, the estimation results made with the NARX model for the 2013-2020 period are estimated as shown in Table 42.

Table 42. ANN Forecasting Results Using MATLAB (2013 -2020)

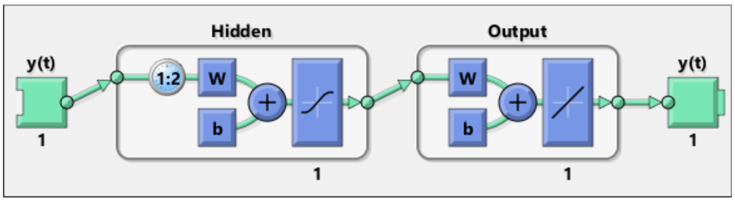
Years	Actual Demand (GWh)	Forecasting Demand (GWh)	Deviations (%)
2013	246.360	248.890	1,02
2014	257.220	259.130	0,74
2015	265.720	268.630	1,08
2016	279.290	283.170	1,37
2017	296.700	298.500	0,60
2018	304.170	303.980	-0,06
2019	303.320	303.580	0,09
2020	304.836	304.760	-0,03

Figure 27: MATLAB Output for Actual and Forecasting Demands (2013-2020)



The calculated avarage deviation of this ANN Model is about 0,60 for the 2013 – 2020 period. Also, MAPE is calculated at 0.328 in this model.

For 2020-2030 period;



Y = Electricity Demand

Layer 1 w2 = -0.120700

Layer 2

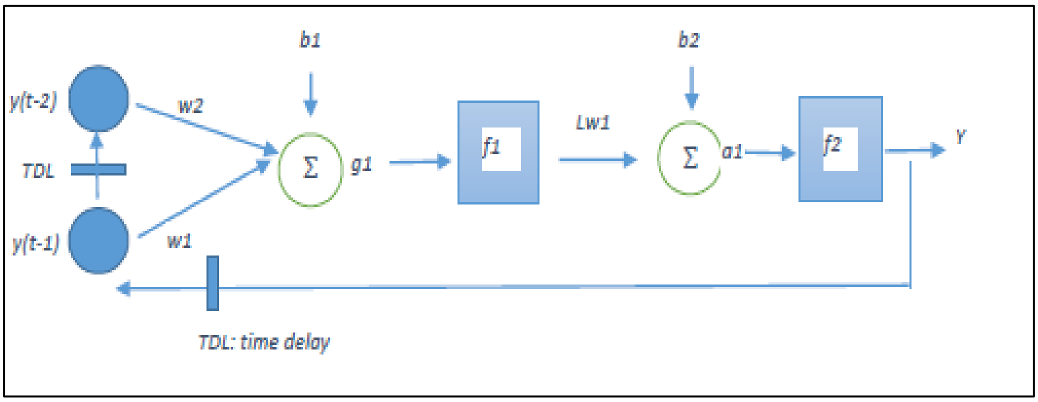
	Weight of f1	bias
	Lw1 = 4.246566	b2 =-0.617180

$$[\, y(t-1) \quad y(t-2)] * \begin{bmatrix} w1 \\ w2 \end{bmatrix} + [b1] = [g1]$$

$$f1 = \text{tansig}\ (g1) = \frac{2}{1+e^{-2g1}} - 1$$

a1 = f1*Lw1+b2 f2 = liner(a1) = minmax (-1<a1<1) Y= f2

Figure 28: ANN Schema

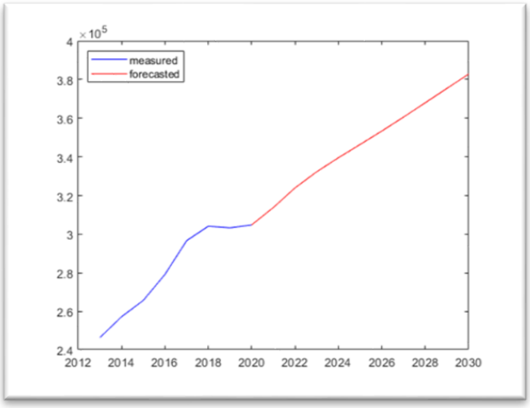


Based on the 2013-2020 period, the estimates for the 2021-2030 period have also been calculated as the values in the table below. The average growth rate is calculated as 2,25% for the 2021-2030 period with MATLAB.

Table 43. ANN Results for 2021-2030 Using MATLAB

Year	Gross Demand Forecasting (GWh)	Increase Rate (%)	Index 2020=100
2021	313.810	2,86	102,86
2022	323.970	3,14	106,09
2023	332.280	2,50	108,74
2024	339.540	2,14	111,07
2025	346.390	1,98	113,27
2026	353.340	1,97	115,50
2027	360.570	2,01	117,82
2028	367.980	2,01	120,19
2029	375.430	1,98	122,57
2030	382.840	1,94	124,95

Figure 29. MATLAB Output for 2021-2030 Forecasting



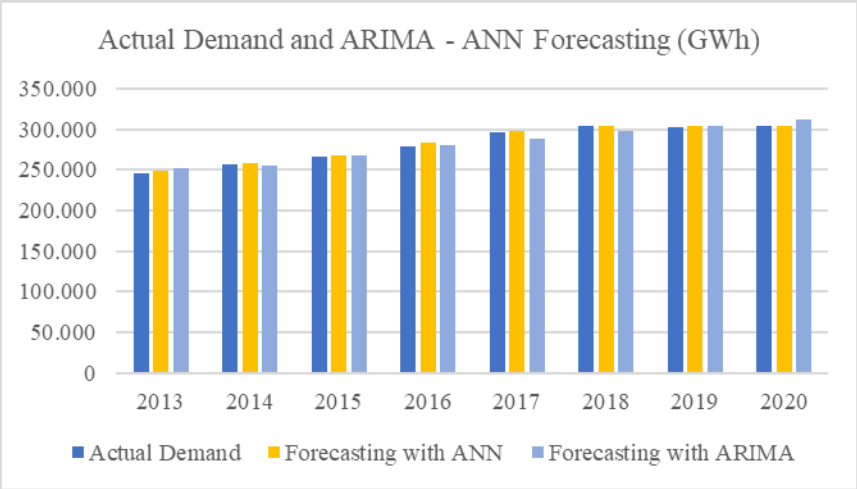
5.3.3 Comparison of Model Results

As a result, in comparing the actual gross electricity demand values with the forecasts made with ARIMA and ANN, the most approximate forecasting is made with the model established with ANN from 2013 to 2020. In addition, the forecast made with ARIMA provides very approximate results to the actual gross electricity demand.

Table 44. Actual Demand and ARIMA-ANN Difference (GWh)

Years	Actual Demand	Forecasting with ANN	Forecasting with ARIMA	Difference Actual - ANN	Difference Actual - ARIMA
2013	246.357	248.890	252.016	-2.533	-5.659
2014	257.220	259.130	255.686	-1.910	1.534
2015	265.724	268.630	267.672	-2.906	-1.948
2016	279.286	283.170	280.470	-3.884	-1.183
2017	296.702	298.500	288.466	-1.798	8.236
2018	304.167	303.980	298.525	187	5.642
2019	303.320	303.580	303.680	-260	-359
2020	304.836	304.760	311.732	76	-6.896

Figure 30: Actual Demand and Forecastings of ARIMA and ANN



Although ARIMA seems to be more successful, since the average deviation for the 2013-2020 period has been calculated as 0.5% for the ARIMA model and 0.60% for the ANN Model, the MAPE values are more significant. The MAPE value is the lowest estimation of the ANN model. While MAPE of these models are compared, ARIMA's rate is 1.382, whereas ANN's MAPE is 0.328. The 0,328% MAPE value obtained in the test set shows that the model successfully makes almost definite forecastings. Thus, it is clear that ANN is more successful each year.

CHAPTER 6

DISCUSSION AND RECOMMENDATIONS

In the previous section, using ARIMA and ANN methods, actual data of Turkey between 1923 and 2020 have been analyzed and the gross electricity demand forecastings for the 2013-2020 period have been calculated. And according to these findings, future gross demand forecastings have been realized for the 2021-2030 period.

The relation to the actual gross demand average deviations of forecasting of ARIMA and ANN is calculated as 0.05% and 0.60%. However, the average deviation rate of official forecastings for the same period was 9.34%. But for 2020, the deviation between actual demand and the official forecasting value has been 19.25%. Moreover, these deviation amounts had occurred despite the corrected data over a period of only seven years. The wider the forecast range, the higher the deviation rate tends to be seen. On the contrary, the average deviations calculated by us with ARIMA and ANN are 2.21% and -0.03%, respectively, for the year 2020.

Table 45. Deviations of Official Forecastings between 2013 - 2020

Years	Official Forecastings (Base)	Actual	Deviations Official (%)	Deviations of ARIMA (%)	Deviations of ANN (%)
2013	255.100	246.357	3,43	2,25	1,02
2014	271.010	257.220	5,09	-0,60	0,74
2015	287.310	265.724	7,51	0,73	1,08
2016	302.700	279.286	7,74	0,42	1,37
2017	318.710	296.702	6,91	-2,86	0,60
2018	337.130	304.167	9,78	-1,89	-0,06
2019	356.830	303.320	15,00	0,12	0,09
2020	377.490	304.836	19,25	2,21	-0,03

As shown in Table 43, the rate of deviation increases over the years between the actual demand and the forecasted demand. Also, based on 2013 as the beginning of the period, the deviation in the official estimates for 2020 is 19,25%. When considered on a long-term basis, it is seen that these deviation rates are increasing. Thus, while the demand values calculated with ANN and ARIMA deviate less than 1% on average, it official forecastings deviate by high average rates.

After the comparison of the past amounts and the actual consumption amounts, the forecastings for the next 10 years have also been calculated by MATLAB and EViews. The forecastings for the 2021-2030 period have been compared with the official forecasts of the MENR and TEIAS.

Table 46. Comparison of ARIMA, ANN and Official Forecastings (2021-2030)

Years	ARIMA Forecastings	Increase Rate (%)	ANN Forecastings	Increase Rate (%)	Official Forecastings (Base)	Increase Rate (%)
2021	321.228	2,96	313.810	2,86	344.400	4,50
2022	327.161	1,81	323.970	3,14	359.600	4,40
2023	335.559	2,50	332.280	2,50	375.800	4,50
2024	340.878	1,56	339.540	2,14	392.100	4,30
2025	346.800	1,71	346.390	1,98	406.900	3,80
2026	354.439	2,16	353.340	1,97	421.800	3,60
2027	359.190	1,32	360.570	2,01	436.600	3,50
2028	365.911	1,84	367.980	2,01	451.700	3,50
2029	371.090	1,40	375.430	1,98	466.800	3,30
2030	375.763	1,24	382.840	1,94	481.700	3,20
	Av. Growth ARIMA	**1,85**	**Av. Growth ANN**	**2,25**	**Av. Growth Official Projections**	**3,86**

Unfortunately, over-demand forecastings are still applied despite huge deviations from past forecastings. The average increase rate is calculated on models established with ARIMA and ANN as 1,85% and 2,25%, respectively, while the average growth rate in official forecastings is calculated as 3,86%.

MENR does not explain or publish that they have used which variables, models, coefficients, justifications and it is still calculating high demand forecasting. Without explaining any scientific methodology, only the demand quantities forecasted by them are disclosed. But, huge deviating demand forecastings have no positive effects on investment decisions or on public investment financing. Because the investment plans of the private sector and the transmission and distribution facilities, which are public services, also put a burden on the public. Each investment to be made based on these demand forecasts requires additional investment in the electricity transmission system. If the consumption is not as expected, both power plant investments and transmission-distribution investments will remain idle.

It is seen that Table. 47, in the demand forecasting studies carried out in the past (net demand estimations), both successful estimations and low deviations from the estimations of MENR have been observed. For example, Kaytez (2020) made very successful predictions; however, the prediction interval has been very short. However, in this thesis, both ANN and ARIMA results are highly accurate predictions. Accordingly, as seen in the academic publications, despite the successful predictions in both this thesis and other academic publications, the high deviation of the estimates of the MENR should be considered.

Table 47. Some Forecasting Studies Performance

Years	Actual Net Demand (Consumption)	Erdoğdu (2006)		Kaytez (2020)		Hamzaçebi and Es (2014)		Kavaklıoğlu et.al (2009)	
		Forecasting	Deviation (%)	Forecasting	Deviation (%)	Forecasting	Deviation (%)	Forecasting	Deviation (%)
2000	98.296	98.788	0,5						
2001	97.070	101.167	4,05						
2002	102.948	105.143	2,09						
2003	111.766	111.053	-0,64						
2004	121.142	112.466	-7,71						
2005	130.263	129.311	-0,74						
2006	144.091	132.631	-8,64						
2007	155.135	138.134	-12,31					155.120	-0,01
2008	161.948	146.365	-10,65					165.940	2,21
2009	156.894	145.144	-8,1					175.040	10,37
2010	172.051	155.667	-10,52	170.380	-0,98			182.680	5,82
2011	186.100	156.010	-19,29	183.410	-1,47	174.201	-6,83	189.320	1,7
2012	194.923	158.150	-23,25			185.498	-5,08	195.370	0,23
2013	198.045	169.210	-17,04			191.225	-3,57	201.090	1,51
2014	207.375	160.090	-29,54			201.202	-3,07	206.670	-0,34
2015	217.312					208.916	-4,02	212.170	-2,42
2016	231.204					218.725	-5,71	217.670	-6,22
2017	249.023					227.751	-9,34	223.170	-11,58
2018	258.232					237.933	-8,53	223.170	-15,71
2019	257.273			259.820	0,98	248.005	-3,74	228.700	-12,49
2020	260.000			268.240	3,07	258.834	-0,45	234.250	-10,99

*Net Consumption Amount of 2020 is temporarily.

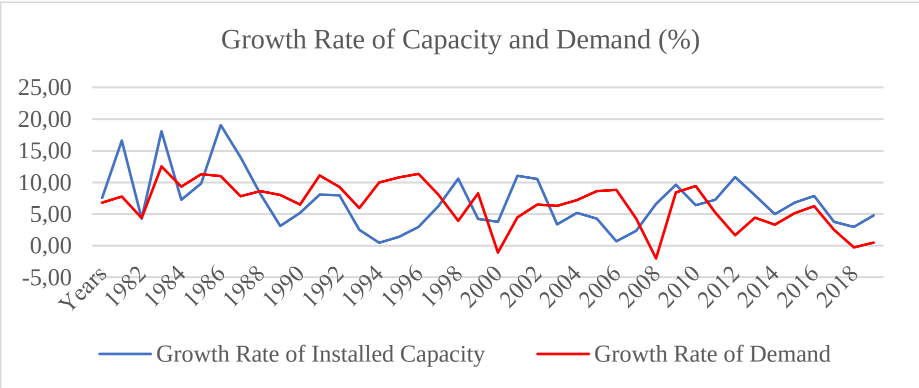
The electricity amount can be produced by Turkey's installed capacity of 2015 and 2020, and these amounts and corresponding power were calculated in 2007 by WEC-

TNC. In fact, the WEC- TNC 2007 report forecasted that Turkey electricity gross-demand would be approximately 500.000 GWh in 2020. Also, installed capacity would be 96.300 MW for meeting this demand:

"*…However, according to demand forecasting until 2020, in order to meet the demand of 356.200 GWh in 2015 and 499.490 GWh in 2020, therefore much more capacity will be required to be added to the system in addition to the facilities under construction and newly licensed. Thus, the installed power should be 96.300 MW to meet the demand in 2020*" (WEC-TNC, 2007).

In these evaluations made by the WEC Turkish National Committee, which consists of public and private sector representatives, installed power of 96.300 MW can be ensured 500.000 GWh in 2020. Accordingly, although today the installed power is more than 97.000 MW, gross consumption (demand) has remained around 304.000 GWh. Even this indicator alone, considering that the installed power has reached a very high level, even compared to the forecasting of 14 years ago and it will reach 121.000 MW within 5 years, it can be said that this capacity will increase faster than the demand in the longer term.

Figure 31. Installed Capacity and Gross Demand Growth Rate



In the calculations made by considering the past capacity factors of the investments planned until 2024 in Section III, it is seen that there is a firm generation capacity that increases faster than the demand (consumption) amount until 2024. It is clear that this process will continue until 2030. According to the estimations, as a result of the investments planned until 2025 with the current investment stock, there will be a power generation capacity of 560.000 GWh in 2024. Even today, there is about 60% excess generation capacity. The projected amount for 2024 means enough generation for 2039, even for the high forecastings of the MENR. In this extent, extreme-optimistic growth rates are taken into account in generation plant investment and planning.

Table 48. Available Generation Capacity and Surplus by 2025

Years	**2020**	**2021**	**2022**	**2023**	**2024**
Firm Generation Capacity (GWh)	492.803	505.847	526.090	545.162	560.701
ARIMA Forecastings (GWh)	Actual	321.228	327.161	335.559	340.878
ANN Forecastings (GWh)	Actual	313.810	323.970	332.280	339.540
Generation Capacity Excess to ARIMA (GWh)	188.968	184.619	198.929	209.603	219.823
Generation Capacity Excess to ANN (GWh)	188.968	192.037	202.120	212.882	221.161

Zweifel et. al. (2017) suggest technically, about 10% of maximum-load reserve margins have to be reserved for scheduled or unscheduled black-outs. This reserve policy is provided by the day ahead capacity market according to forecastings. In Turkey, as the system operator, TEIAS operates in this intra-day and day-ahead market in terms of supply security network. As stated before, TEIAS's daily forecastings deviate at a negligible low rate. In this respect, it is seen that there is a peak load of approximately 50.000 MW today in Turkey, although the allocation of around 5.000 MW of reserve capacity is considered sufficient in terms of system security, operation experience can ensure that this amount is lower.

Naturally, demand forecasting can be overestimated or underestimated. However, high deviations have major effects on the entire electrical system, such as financial, generation planning, transmission planning, and distribution planning (Conejo et. al., 2016).

Financially, overestimation causes to increase in infrastructure spending. It requires more labor hire. More credit or equity is used to commission more production units than needed. Therefore, the expected rate of profitability is calculated higher than it should be. This disrupts the financial balance of the business by affecting the cash flow in terms of expected future returns. Overestimation in terms of production planning; requires the planning of more or larger turbines or production facilities. More costs are incurred to offer more supply. In terms of transmission and distribution planning, Overestimations require the capacity of transmission lines and transformer substations to be increased. Each surplus generation capacity obliges the transmission capacity to be increased and then to adapt the distribution lines to it.

Underestimations lead to the opposite of over-estimates. For this reason, it is very important to make accurate electricity demand forecasts. Considering the installed capacity of the OECD countries and the production-consumption data in Table 46, Turkey is 10th in the ranking of installed power. It ranks 9th in gross production. Given these quantities, it is planned to reach 124.000 MW installed power in Turkey in 2025. Thus, similar countries in terms of installed capacity five years later, for example, France with 133.000 MW installed power and South Korea with 122.000 MW installed power, produces around 560.000 GWh. In Turkey in 2025, the installed power generation capacity will be at least as much as these countries' generation. Considering the accuracy of the forecastings made in the previous section, even though industrialized countries such as France and South Korea have as much power as their installed power, demand will remain very low in Turkey. These amounts are an indication that the installed power planning has been overestimated.

In addition, compared to Turkey in Mexico, although less than 10.000 MW of installed capacity, power generation was realized the same year more than 30.000 GWh in 2017. Moreover, despite the installed power reaching 97,000 MW at the end of 2020, the production remained around 304,000 GWh, which indicates how high the idle capacity is compared to the OECD.

Table 49. OECD Electricity Generation, Installed Capacity and Consumption

No	Countries	Installed Capacity (MW)	Gross Generation (GWh)	Gross Supply (GWh)	Net Consumption (GWh)
1	Australia	66.460	258.020	243.350	211.850
2	Austria	24.920	71.320	68.630	61.850
3	Belgium	22.260	86.610	87.480	81.730
4	Canada	147.630	658.400	575.880	488.260

5	Chile	26.310	79.420	76.990	72.920
6	Czech Republic	22.270	87.050	65.300	58.000
7	Denmark	14.360	31.040	33.920	31.150
8	Estonia	2.530	12.900	8.500	7.140
9	Finland	17.170	67.520	85.040	80.830
10	France	133.100	562.140	490.680	440.970
11	Germany	215.510	653.740	558.350	517.380
12	Greece	19.430	55.270	56.720	53.360
13	Hungary	8.860	32.870	43.550	37.540
14	Iceland	2.820	19.240	18.650	17.300
15	Ireland	10.490	30.870	29.010	26.100
16	Israel	17.830	67.670	59.830	56.130
17	Italy	114.240	295.830	320.550	286.030
18	Japan	334.430	1.068.320	1.025.830	957.750
19	Korea	122.950	566.880	540.320	504.020
20	Latvia	2.940	7.530	6.960	6.480
21	Lithuania	3.330	4.160	11.870	10.060
22	Luxembourg	1.700	2.240	6.550	6.370
23	Mexico	74.430	322.060	309.280	259.070
24	Netherlands	33.820	117.260	116.970	105.330
25	New Zealand	9.300	44.210	42.910	38.730
26	Norway	34.250	149.360	130.790	114.000
27	Poland	42.850	170.470	156.420	132.840
28	Portugal	20.930	59.430	52.760	46.350
29	Slovak Rep.	7.670	27.740	28.280	24.990
30	Slovenia	3.620	16.330	14.520	13.030
31	Spain	103.840	275.730	270.410	233.170
32	Sweden	39.800	164.250	139.040	127.500
33	Switzerland	21.610	63.090	63.030	58.230
34	**Turkey**	**85.200**	**297.280**	**283.680**	**228.400**
35	United Kingdom	103.470	338.340	334.340	303.900
36	USA	1.100.330	4.286.430	4.113.070	3.807.710
	OECD	**3.012.640**	**11.051.030**	**10.469.470**	**9.496.410**

Source: IEA Statistics, Electricity Information 2019

The generation capacity of Turkey has reached from 45.000 MW to 97.000 MW in the last 10 years. In this capacity, the share of thermal power plants has decreased from 65% to 49% today, while renewable energy has exceeded 50%. While the contribution of renewable energy is a positive factor, the price effect must also be better in terms of social welfare. Meanwhile, considering the characteristic of the load curve, the better the adaptation of renewable resources to the load curve, the lower the total electricity generation costs. In this way, a significant economic contribution will be made by reducing the import of energy resources.

While the installed power of renewable energy sources has increased and their production has been increasing, the construction of the 4800 MW nuclear power plant, which will come into operation after 2023, and it is noteworthy that the thermal capacity has increased high rate. For every four units of the nuclear power plant, a purchase guarantee is given at varying rates by units. In addition, due to the incentives and support mechanisms given to power plants using domestic lignite coal and imported coal, the installed power of these power plants continues to increase. Although there is a policy to make maximum use of domestic resources, the low calorie and high carbon emissions of domestic lignite coal are a problem. Since the lifespan of these power plants is quite long, it is seen that the coal power plants will remain idle due to the post-nuclear purchase guarantees.

Because, besides idle investment, it is clear that purchase guarantees will suppress the decrease in prices. Considering that the share of the private sector gradually increased due to privatization and incentives in the process that started in the post-2001 period on the grounds of providing cheap and high-quality electricity through free competition, it is seen that the increase and diversification of investments are not in favour of the final consumer. Because the increased electricity production and resource diversification did not provide a welfare effect for the final consumer.

At this point, as stated in the WEC Turkey Report, reason of increasing in installed power for all types of resources is based on long-term demand forecasts. Considering the principles of transparency and openness, accountability and responsibility that dominate the public administration, high calculation of electricity demand forecasts and no corrective action against high deviations and making new calculations based on high deviating demand amounts are worthy of criticism. Because, in the demand forecast report, which was announced to the public as only a two-page announcement by MENR, but the details were not disclosed. It is not known which methods and variables were used, how the calculations were made, the share and weights of the methods in the calculations. These are all matters of direct public interest.

For this reason, considering that the long-term demand forecasts prepared by universities, searching institutions and energy-related organizations by the Federal Energy Department and state departments in the USA, a comprehensive reports have been announced and deviated very little even in 30-year periods. The long-term demand forecasts, which are also cited as reasons for investments in Turkey, should be prepared with the participation of universities and representatives of relevant energy institutions, and announced to the public in the light of the principles underlying public administration and with full justifications. Thus, more realistic and accurate results will be possible thanks to the participation of all relevant institutions and academia.

Otherwise, the non-transparent demand forecasting methodology will lead to an increase in idle investment capacity in Turkey and high costs for final consumers and all sectors using electricity, as funds needed by other sectors will shift to this sector due to the financing gap.

CHAPTER 7

CONCLUSION

The power generation (supply) and consumption (demand) forecasting studies started with the planned periods in 1961 in Turkey. Hence, initially, negligible rates were observed; later, high rate deviation rates were realized in this studies. It is remarkable that long-term electricity demand forecastings deviate by up to 85% despite advanced technology and trained labor. Because parallel to information technologies and software developments, international experiences show low estimation deviations in many countries. While these technologies and methods, which are almost free goods internationally, are used in many academic studies in Turkey, give relatively consistent results, it cannot be explained why official forecastings deviate so much.

By many official reports it is stated that the license and establishment permits of power generation plants are released according to future demand forecasts. Accordingly, demand forecasts and energy supply security and resource diversification policy are among the most important reasons for establishing power generation plants. Therefore, demand forecasts have a guidance function for investments. The higher rate of the forecasting deviation causes the less effective investments.

These deviations, which were not taken into account under the conditions of unsaturated demand and vertically integrated state monopoly (TEK) in the early periods, nowadays create serious problems due to the dominance of the private sector in the market. Since high official demand forecastings have led to an acceleration in electricity generation investments recently, in this context, both renewable resource purchase guarantees and keeping spare capacity of base-load plants (especially thermal plants) cause social costs. The idle capacity of state-owned power plants does not pose serious problem for supply security. However, investments made by considering demand forecasts create inconveniences for both investors and consumers. Therefore, demand forecasts should be made meticulously in Turkey, where the private sector’s share is high.

Also it has been observed that investments made in the electricity generation sector without considering the factors such as profitability and efficiency, which are among the common investment models. Incomplete feasibility studies, as well as the fact that the amount of demand does not increase as much as in official calculations, is also an important factor. Because, especially after 2010, many investors moved from other sectors to the electricity generation sector. Their generation projections were far below the realized demand values, thus they could not make the profits as much as they expected and even some firms started to make losses. In particular, small and medium-sized power plants generate electricity lower than expected, and although there is a guarantee of purchase at high prices with various incentives, their projections are not realized due to their low generation. Thus, high calculated demand forecast amounts are one of the major factors that cause many power plants to stand idle or change their ownership. If private sector power plants with idle capacity do not operate profitably, they will be decommissioned.

In addition, imported natural gas and high-calorie import coal power plants are also commissioned to meet the high estimated electricity demands, as they provide base load. The power market payments in return for the capacity mechanism supports and standbys provided to these power plants not only put a burden on end-users with tariffs, but also cause a serious deficit in the balance of payments. As a result, the result of high demand forecasts is in a position to affect all economic activity in the country.

As it has been explained extensively in the previous chapters, the reasons for the high estimation could not be fully revealed, since the estimator MENR has not disclosed the details of forecasting. However, in this thesis, the previous period demand amounts have been estimated with very low deviation rates by ARIMA and ANN models. Low-rate deviations are also observed in some studies on the subject. But, it can be stated that the reasons for these high rate deviations are especially the lack of accountability and transparency and absence of institutional responsibilities. TEIAS, which is legally required to be autonomous and is in charge of forecasts, uses the demand forecasts of MENR exactly. These extremely high amount of forecastings made by the Ministry are maintained by another public institution. Generation licenses of EMRA and unlicensed power plant permits are given according to these forecastings. In such a structure that has lost its autonomy, basic governance principles do not work.

In the past, while some obligations were imposed with the five-year development plans, today, there is no obligation for plan objectives. Also, it is not clear what criteria the public decision-makers approved the investment decision and the generation license in this way. Although some technical and bureaucratic qualifications and responsibilities are defined, there is no general policy and roadmap for electricity investments. In addition, this lack of policy creates an imbalance in resource allocation and prevents investments that other sectors need.

Furthermore, Turkey's lack of a holistic energy plan while planning the investments also causes high deviated demand forecasts and idle investments. Although some partial projections are announced in terms of quantities for each energy source and electricity sector, these are "wishes" that cannot be called planning. It has not been an electrical planning process in Turkey in recent years, so there is no electricity plan put forward in Turkey. Because, while it is necessary to prepare a holistic energy plan that includes the following stages; (i) The objectives and broad targets of the plan are explained, (ii) the approaches are determined, (iii) the information needed in the planning process is defined, (iv) the analysis and processes of the data are staged, (v) the stages of the analysis are defined, (vi) the results are presented to all decision-makers. However, these processes are implemented by making investment decisions without being defined and planned. The lack of a holistic energy plan, combined with high demand forecasts, turns into an environment where over-investment and idle capacity are seen.

In addition, the preparation of a capital investment program for opportunities in electrical energy generation is the most important planning stage. Because, in order to make an inclusive analysis that will affect all sectors in terms of financial and labor resources, this stage must first be performed compulsorily. Government policies to improve energy systems, whether private or public, should be signaled to relevant institutions and industries in the future about the direction of investment policy. The fact that the obligatory feasibility studies could not be carried on investment decisions, many power plants have handed over or standed idly. Besides, even if they do not generate power plants kept in reserve for the capacity market and day-ahead system balance, they receive a price equal to the committed generation reserve.

Despite these negative aspects, high growth rates of renewable energy sources investments are appreciated in Turkey. Today, more than half of the installed power consists of renewable energy resources.

Besides, the right infrastructure investments for energy supply and demand are an important requirement to ensure the transition to a sustainable electricity system. Therefore, policy makers should support the necessary investments in order to minimize the effects of climate change. Energy infrastructure investments are a highly dynamic issue as climate policy is one of many different risk factors to consider. Therefore, it is important to research and implement investments that have the flexibility to adapt quickly to the impact of climate change. (Blyth, et. al.,2007)

For this reason, the demand forecasting work should be carried out in a more serious and organized manner by the official institutions which is responsible for electricity demand forecasting. The methods used in demand forecasting in many developed countries, the reasons for using the methods, model variables, and coefficients are explained in detail, and the demand forecasts are announced to the public. Unfortunately, although also TEIAS's task in Turkey, demand forecasting is determined by MENR. MENR, on the other hand, announces the 20-year estimation amounts, in which only names of five methods it uses, with a 2-page announcement. It is not known how and based on which variables these non-transparent demand amounts are found. It is seen that the demand forecasts determined and announced in this way are not a guide for investment decisions and cause inefficient investments.

Thus, demand forecasts should be carried out by a board consisting of representatives of the electricity sector and academics, or by organizations independent of political interference, as in many countries. In this way, independent committees should work according to pre-determined methods and procedures and explain the demand forecasting model and its results with all variables and coefficients. This is a requirement of transparency and accountability.

As a result, it is necessary to prepare official demand forecasting studies, which are carried out only with intent, without paying much attention in Turkey, must be carried-out seriously due to effects on whole economy. Unfortunately, the official forecastings do not reflect the real situation of the Turkey and the electricity sector, and do not take into account the security of energy supply and optimal investment opportunities. Demand forecasting studies not prepared in this way will not have long-term benefits in terms of either the efficiency of investments or resource allocation. Otherwise, due to the electricity demand, which is estimated at a very high rate compared to the real consumption, after 2023, when nuclear power plants will be activated, a large rate of idle capacity will emerge. Many conventional and renewable power plants will likely be shut down. Thus, electricity demand forecasts, which are pointed out as the most important reason for electricity generation investment decisions, will cause idle power plant piles in the future if no corrective action is reealized.

APPENDIX - A

1- ARIMA DATA

1923- 2020 Gross Electricity Consumption (Demand) by Yearly

Years	Gross Demand (GWh)	Years	Gross Demand (GWh)	Years	Gross Demand (GWh)
1923	44,50	1956	1.819,10	1989	52.601,70
1924	44,60	1957	2.056,70	1990	56.811,70
1925	45,30	1958	2.303,40	1991	60.499,30
1926	65,80	1959	2.587,30	1992	67.216,80
1927	70,10	1960	2.815,10	1993	73.431,70
1928	89,40	1961	3.011,10	1994	77.783,00
1929	97,80	1962	3.559,80	1995	85.551,50
1930	106,30	1963	3.983,40	1996	94.788,70
1931	117,90	1964	4.450,90	1997	105.517,10
1932	131,60	1965	4.952,70	1998	114.022,70
1933	151,90	1966	5.576,20	1999	118.484,90
1934	195,20	1967	6.216,80	2000	128.275,60
1935	212,90	1968	6.935,80	2001	126.871,30
1936	231,10	1969	7.838,00	2002	132.552,60
1937	289,80	1970	8.623,00	2003	141.150,90
1938	312,10	1971	9.781,10	2004	150.017,50
1939	353,30	1972	11.241,90	2005	160.794,00
1940	396,90	1973	12.425,20	2006	174.637,30
1941	415,20	1974	13.477,00	2007	190.000,21
1942	408,20	1975	15.719,00	2008	198.085,19
1943	457,40	1976	18.615,00	2009	194.079,07
1944	496,10	1977	21.056,80	2010	210.433,96
1945	527,80	1978	22.347,10	2011	230.306,26
1946	562,70	1979	23.566,20	2012	242.369,90
1947	625,00	1980	24.616,60	2013	246.356,64
1948	676,30	1981	26.288,90	2014	257.220,15
1949	736,60	1982	28.324,90	2015	265.724,35
1950	789,50	1983	29.567,60	2016	279.286,39
1951	887,90	1984	33.266,50	2017	296.702,12
1952	1.020,20	1985	36.361,30	2018	304.166,89
1953	1.200,80	1986	40.471,40	2019	303.320,36
1954	1.402,50	1987	44.925,00	2020	304.835,70*
1955	1.579,80	1988	48.430,00		

*Temporary

Source: TEIAS

2- ANN DATA

Data for ANN Model: 1923 – 2020 Growth Rates of Gross Electricity Demand, Economic Growth, Population, Export and Import

Years	Electricity Demand Growth Rate	Economic Growth Rate	Population Growth Rate	Export Growth Rate	Import Growth Rate
1923	-	-	-	-	-
1924	0,22	14,80	-	62,31	15,64
1925	1,57	12,90	-	24,58	28,36
1926	45,25	18,20	-	-6,10	-5,85
1927	6,53	-12,80	7,96	-16,27	-11,25
1928	27,53	11,00	2,09	9,32	5,53
1929	9,40	21,60	2,09	-15,24	8,66
1930	8,69	2,20	2,09	-4,61	-43,72
1931	10,91	8,70	2,09	-15,63	-13,81
1932	11,62	-10,70	2,08	-20,35	-32,06
1933	15,43	15,80	2,09	21,04	10,74
1934	28,51	6,00	2,09	25,73	52,49
1935	9,07	-3,00	2,09	4,42	2,73
1936	8,55	23,20	1,87	22,87	4,22
1937	25,40	1,50	1,71	16,61	22,98
1938	7,69	9,50	1,71	5,30	31,32
1939	13,20	6,90	2,56	-13,36	-22,20
1940	12,34	-4,90	1,94	-18,81	-45,91
1941	4,61	-10,30	1,33	12,55	10,62
1942	-1,69	5,60	1,05	38,50	103,94
1943	12,05	-9,80	1,06	56,00	37,62
1944	8,46	-5,10	1,05	-9,55	-18,74
1945	6,39	-15,30	1,05	-5,44	-23,18
1946	6,61	31,90	1,81	27,53	22,61
1947	11,07	4,20	2,15	4,06	105,78
1948	8,21	15,90	2,15	-11,87	12,43
1949	8,92	-5,00	2,15	25,93	5,51
1950	7,18	9,40	2,15	6,29	-1,57
1951	12,46	12,80	2,55	19,23	40,75
1952	14,90	11,90	2,73	15,55	38,26
1953	17,70	11,20	2,74	9,13	-4,21
1954	16,80	-3,00	2,74	-15,44	-10,17
1955	12,64	7,90	2,74	-6,44	4,03
1956	15,15	3,20	2,78	-2,67	-18,15
1957	13,06	7,80	2,81	13,19	-2,51
1958	11,99	4,50	2,81	-28,37	-20,66

1959	12,33	4,10	2,81	43,08	49,15
1960	8,80	3,40	2,81	-9,35	-0,38
1961	6,96	2,00	2,55	8,11	8,33
1962	18,22	6,20	2,43	9,94	22,13
1963	11,90	9,70	2,43	-3,44	11,00
1964	11,74	4,10	2,43	11,60	-21,87
1965	11,27	3,10	2,43	12,89	6,46
1966	12,59	12,00	2,46	5,77	25,58
1967	11,49	4,20	2,49	6,49	-4,68
1968	11,57	6,70	2,49	-4,96	11,54
1969	13,01	4,30	2,49	8,14	4,92
1970	10,02	4,40	2,49	9,62	18,27
1971	13,43	7,00	2,47	14,98	23,56
1972	14,93	9,20	2,47	30,80	33,46
1973	10,53	4,90	2,47	48,83	33,51
1974	8,47	3,30	2,47	16,33	81,07
1975	16,60	6,10	2,47	-8,56	25,44
1976	18,42	9,00	2,18	39,91	8,23
1977	13,12	3,00	2,04	-10,57	13,02
1978	6,13	1,20	2,05	30,53	-20,66
1979	5,46	-0,50	2,04	-1,18	10,23
1980	4,46	-2,80	2,04	28,70	56,02
1981	6,79	4,80	2,42	61,61	12,95
1982	7,74	3,10	2,46	22,18	-1,02
1983	4,39	4,20	2,46	-0,32	4,44
1984	12,51	7,10	2,46	24,54	16,48
1985	9,30	4,30	2,46	11,56	5,45
1986	11,30	6,80	2,19	-6,30	-2,10
1987	11,00	9,80	2,15	36,66	27,49
1988	7,80	1,50	2,15	14,45	1,25
1989	8,61	1,60	2,15	-0,32	10,16
1990	8,00	9,40	2,15	11,48	41,22
1991	6,49	0,30	1,69	4,89	-5,63
1992	11,10	6,40	1,50	8,25	8,67
1993	9,25	8,10	1,50	4,28	28,67
1994	5,93	-6,10	1,50	17,99	-20,93
1995	9,99	8,00	1,50	19,50	53,46
1996	10,80	7,10	1,50	7,34	22,17
1997	11,32	8,30	1,56	13,08	11,31
1998	8,06	3,90	1,48	2,71	-5,43
1999	3,91	-3,40	1,45	-1,43	-11,43
2000	8,26	6,60	0,53	4,47	34,01
2001	-1,09	-6,00	1,33	12,81	-24,04
2002	4,48	6,40	1,20	15,08	24,53

2003	6,49	5,60	1,17	31,04	34,50
2004	6,28	9,60	1,21	33,68	40,67
2005	7,18	9,00	1,23	16,32	19,72
2006	8,61	7,10	1,25	16,41	19,53
2007	8,80	5,00	1,21	25,41	21,84
2008	4,26	0,80	1,30	23,08	18,76
2009	-2,02	-4,70	1,44	-22,64	-30,22
2010	8,43	8,50	1,57	11,49	31,66
2011	9,44	11,10	1,34	18,46	29,80
2012	5,24	4,80	1,19	13,01	-1,78
2013	1,64	8,50	1,36	-0,43	6,39
2014	4,41	5,20	1,32	3,83	-3,77
2015	3,31	6,10	1,33	-8,74	-14,43
2016	5,10	3,20	1,35	-0,91	-4,16
2017	6,24	7,50	1,23	10,15	17,71
2018	2,52	2,80	1,46	6,96	-4,60
2019	-0,28	0,90	1,38	2,11	-9,12
2020	0,50	-	0,55	-	-

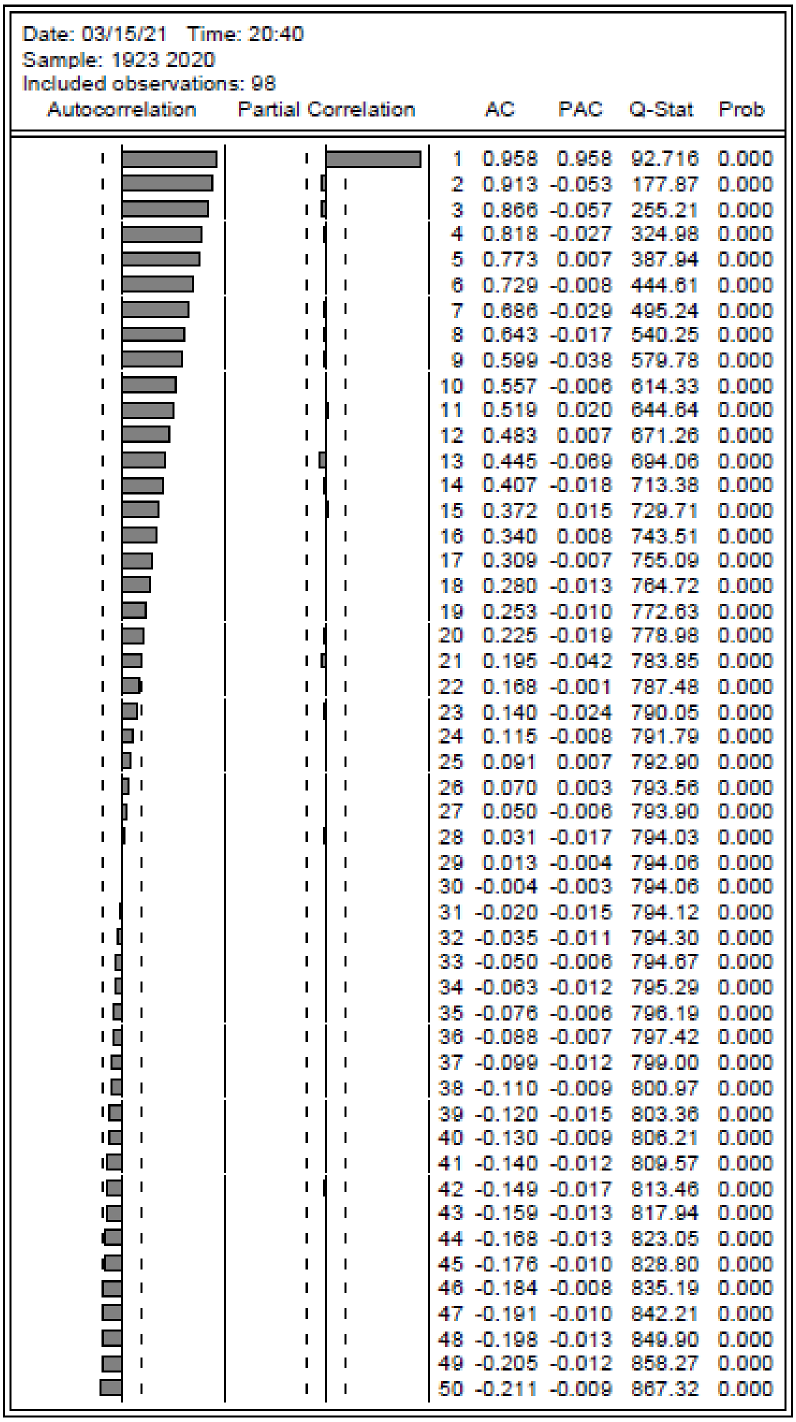
Source: SIO.

APPENDIX - B

1- ARIMA MODEL OUTPUT of EViews 11

Corellogram of Level Raw Gross Demand Data for 50 lags

Correlogram of GROSS_DEMAND



Date: 03/15/21 Time: 20:40
Sample: 1923 2020
Included observations: 98

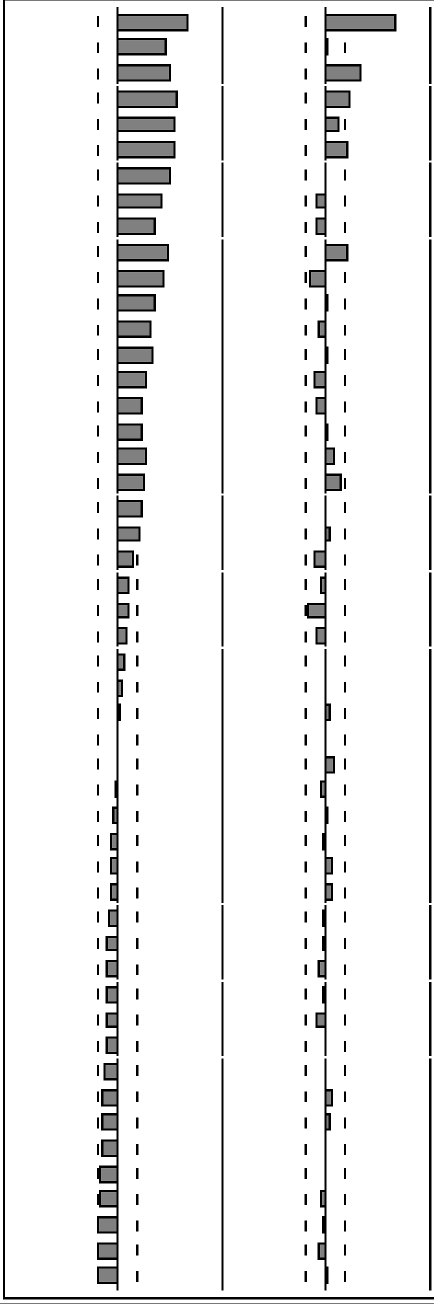
	AC	PAC	Q-Stat	Prob
1	0.958	0.958	92.716	0.000
2	0.913	-0.053	177.87	0.000
3	0.866	-0.057	255.21	0.000
4	0.818	-0.027	324.98	0.000
5	0.773	0.007	387.94	0.000
6	0.729	-0.008	444.61	0.000
7	0.686	-0.029	495.24	0.000
8	0.643	-0.017	540.25	0.000
9	0.599	-0.038	579.78	0.000
10	0.557	-0.006	614.33	0.000
11	0.519	0.020	644.64	0.000
12	0.483	0.007	671.26	0.000
13	0.445	-0.069	694.06	0.000
14	0.407	-0.018	713.38	0.000
15	0.372	0.015	729.71	0.000
16	0.340	0.008	743.51	0.000
17	0.309	-0.007	755.09	0.000
18	0.280	-0.013	764.72	0.000
19	0.253	-0.010	772.63	0.000
20	0.225	-0.019	778.98	0.000
21	0.195	-0.042	783.85	0.000
22	0.168	-0.001	787.48	0.000
23	0.140	-0.024	790.05	0.000
24	0.115	-0.008	791.79	0.000
25	0.091	0.007	792.90	0.000
26	0.070	0.003	793.56	0.000
27	0.050	-0.006	793.90	0.000
28	0.031	-0.017	794.03	0.000
29	0.013	-0.004	794.06	0.000
30	-0.004	-0.003	794.06	0.000
31	-0.020	-0.015	794.12	0.000
32	-0.035	-0.011	794.30	0.000
33	-0.050	-0.006	794.67	0.000
34	-0.063	-0.012	795.29	0.000
35	-0.076	-0.006	796.19	0.000
36	-0.088	-0.007	797.42	0.000
37	-0.099	-0.012	799.00	0.000
38	-0.110	-0.009	800.97	0.000
39	-0.120	-0.015	803.36	0.000
40	-0.130	-0.009	806.21	0.000
41	-0.140	-0.012	809.57	0.000
42	-0.149	-0.017	813.46	0.000
43	-0.159	-0.013	817.94	0.000
44	-0.168	-0.013	823.05	0.000
45	-0.176	-0.010	828.80	0.000
46	-0.184	-0.008	835.19	0.000
47	-0.191	-0.010	842.21	0.000
48	-0.198	-0.013	849.90	0.000
49	-0.205	-0.012	858.27	0.000
50	-0.211	-0.009	867.32	0.000

Correlogram of 1st Differenced Data for 50 Lags

Correlogram of D(GROSS_DEMAND)

Date: 03/15/21 Time: 20:40
Sample (adjusted): 1924 2020
Included observations: 97 after adjustments

Autocorrelation Partial Correlation

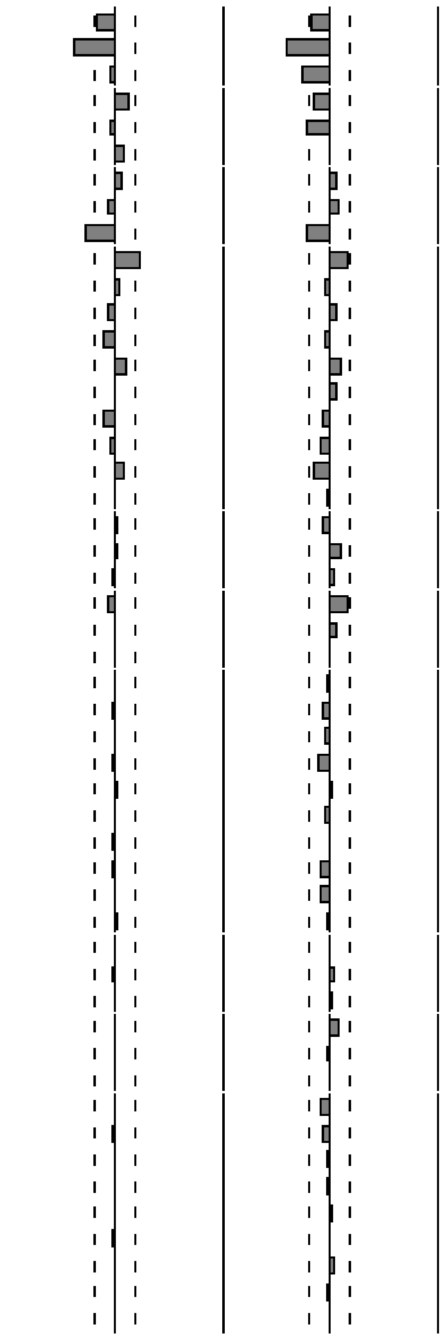


	AC	PAC	Q-Stat	Prob
1	0.689	0.689	47.494	0.000
2	0.484	0.017	71.163	0.000
3	0.519	0.341	98.655	0.000
4	0.589	0.235	134.49	0.000
5	0.574	0.135	168.83	0.000
6	0.576	0.211	203.80	0.000
7	0.532	0.006	233.95	0.000
8	0.439	-0.088	254.73	0.000
9	0.383	-0.094	270.73	0.000
10	0.501	0.210	298.48	0.000
11	0.462	-0.167	322.28	0.000
12	0.372	0.011	337.91	0.000
13	0.324	-0.076	349.92	0.000
14	0.343	0.012	363.56	0.000
15	0.288	-0.121	373.26	0.000
16	0.234	-0.101	379.74	0.000
17	0.247	0.019	387.08	0.000
18	0.283	0.085	396.85	0.000
19	0.267	0.142	405.60	0.000
20	0.244	-0.008	413.01	0.000
21	0.209	0.041	418.52	0.000
22	0.151	-0.112	421.44	0.000
23	0.110	-0.057	423.03	0.000
24	0.103	-0.179	424.42	0.000
25	0.084	-0.094	425.37	0.000
26	0.060	-0.014	425.85	0.000
27	0.035	-0.003	426.02	0.000
28	0.025	0.028	426.11	0.000
29	0.014	0.001	426.14	0.000
30	0.011	0.079	426.15	0.000
31	-0.012	-0.047	426.17	0.000
32	-0.041	0.020	426.42	0.000
33	-0.056	-0.022	426.90	0.000
34	-0.062	0.056	427.48	0.000
35	-0.063	0.061	428.09	0.000
36	-0.081	-0.018	429.11	0.000
37	-0.100	-0.033	430.72	0.000
38	-0.103	-0.070	432.44	0.000
39	-0.101	-0.041	434.14	0.000
40	-0.106	-0.103	436.03	0.000
41	-0.115	0.002	438.28	0.000
42	-0.132	-0.011	441.34	0.000
43	-0.150	0.060	445.33	0.000
44	-0.157	0.032	449.80	0.000
45	-0.160	-0.003	454.56	0.000
46	-0.170	-0.003	459.97	0.000
47	-0.179	-0.044	466.15	0.000
48	-0.182	-0.017	472.63	0.000
49	-0.187	-0.069	479.63	0.000
50	-0.194	0.014	487.32	0.000

Correlogram of 2^{nd} Differenced Data for 50 Lags

Correlogram of D(GROSS_DEMAND,2)

Date: 03/15/21 Time: 20:41
Sample (adjusted): 1925 2020
Included observations: 96 after adjustments



	AC	PAC	Q-Stat	Prob
1	-0.175	-0.175	3.0213	0.082
2	-0.379	-0.423	17.425	0.000
3	-0.046	-0.268	17.635	0.001
4	0.135	-0.155	19.487	0.001
5	-0.035	-0.217	19.614	0.001
6	0.078	-0.003	20.246	0.003
7	0.070	0.069	20.765	0.004
8	-0.049	0.084	21.027	0.007
9	-0.274	-0.220	29.133	0.001
10	0.252	0.158	36.090	0.000
11	0.056	-0.050	36.435	0.000
12	-0.053	0.065	36.747	0.000
13	-0.100	-0.048	37.887	0.000
14	0.119	0.097	39.522	0.000
15	-0.006	0.068	39.527	0.001
16	-0.112	-0.066	41.011	0.001
17	-0.037	-0.106	41.177	0.001
18	0.082	-0.172	41.994	0.001
19	0.002	-0.021	41.995	0.002
20	0.033	-0.069	42.127	0.003
21	0.031	0.094	42.245	0.004
22	-0.023	0.032	42.312	0.006
23	-0.051	0.158	42.644	0.008
24	0.015	0.054	42.675	0.011
25	0.008	-0.014	42.684	0.015
26	-0.004	-0.035	42.687	0.021
27	-0.021	-0.072	42.745	0.028
28	0.001	-0.041	42.745	0.037
29	-0.015	-0.116	42.776	0.048
30	0.031	0.023	42.914	0.060
31	0.010	-0.049	42.929	0.075
32	-0.022	0.000	43.002	0.093
33	-0.015	-0.084	43.037	0.113
34	-0.008	-0.083	43.047	0.137
35	0.026	-0.017	43.152	0.162
36	0.004	0.002	43.155	0.192
37	-0.031	0.042	43.311	0.220
38	-0.004	0.020	43.314	0.255
39	0.009	0.084	43.326	0.292
40	0.006	-0.025	43.333	0.331
41	0.015	-0.009	43.372	0.371
42	-0.001	-0.092	43.372	0.413
43	-0.015	-0.063	43.412	0.454
44	-0.005	-0.038	43.417	0.496
45	0.009	-0.029	43.431	0.539
46	-0.001	0.016	43.431	0.580
47	-0.011	-0.003	43.454	0.620
48	0.005	0.048	43.460	0.659
49	0.002	-0.038	43.461	0.696
50	-0.004	-0.003	43.464	0.731

Correlogram of Residuals of 4 terms of equation 4.21

Correlogram of Residuals

Date: 03/20/21 Time: 19:46
Sample (adjusted): 1924 2020
Q-statistic probabilities adjusted for 4 ARMA terms

Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
		1	0.265	0.265	7.0353	
		2	-0.153	-0.240	9.4089	
		3	-0.110	0.004	10.654	
		4	0.125	0.141	12.269	
		5	-0.137	-0.285	14.225	0.000
		6	0.120	0.379	15.748	0.000
		7	0.184	-0.056	19.372	0.000
		8	0.033	-0.053	19.493	0.001
		9	-0.110	0.138	20.806	0.001
		10	0.275	0.220	29.150	0.000
		11	0.255	0.104	36.384	0.000
		12	0.017	0.004	36.416	0.000
		13	-0.153	-0.086	39.076	0.000
		14	0.034	0.037	39.208	0.000
		15	-0.056	-0.063	39.572	0.000
		16	-0.095	-0.137	40.644	0.000
		17	0.017	0.015	40.680	0.000
		18	0.169	0.014	44.145	0.000
		19	0.144	0.238	46.693	0.000
		20	0.107	-0.009	48.113	0.000
		21	0.092	0.020	49.194	0.000
		22	0.011	0.041	49.209	0.000
		23	-0.070	0.011	49.838	0.000
		24	-0.039	0.016	50.038	0.000
		25	-0.028	-0.147	50.139	0.000
		26	-0.026	0.011	50.228	0.001
		27	-0.032	-0.045	50.367	0.001
		28	0.001	-0.078	50.367	0.001
		29	0.014	-0.099	50.393	0.002
		30	0.029	-0.074	50.515	0.003
		31	0.001	-0.026	50.515	0.004
		32	-0.029	0.025	50.639	0.005
		33	-0.044	-0.022	50.926	0.007
		34	-0.034	0.035	51.106	0.009
		35	-0.014	0.126	51.137	0.013
		36	-0.025	-0.020	51.237	0.017
		37	-0.028	0.022	51.361	0.022
		38	-0.014	-0.071	51.393	0.028
		39	0.002	0.003	51.394	0.036
		40	0.002	-0.017	51.395	0.046
		41	0.003	-0.065	51.396	0.058
		42	-0.014	-0.027	51.432	0.072
		43	-0.042	-0.038	51.751	0.083
		44	-0.041	0.033	52.063	0.096
		45	-0.026	-0.043	52.189	0.113
		46	-0.027	0.003	52.329	0.132
		47	-0.038	0.015	52.604	0.150
		48	-0.031	0.055	52.787	0.171
		49	-0.030	-0.006	52.965	0.194
		50	-0.032	-0.002	53.180	0.217

The Equation Established by Eviews 11

Dependent Variable: D(GROSS_DEMAND)
Method: ARMA Maximum Likelihood (OPG - BHHH)
Date: 03/20/21 Time: 15:19
Sample: 1924 2020
Included observations: 97
Convergence achieved after 58 iterations
Coefficient covariance computed using outer product of gradients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	3110.761	3093.029	1.005733	0.3172
AR(2)	0.044571	0.078951	0.564538	0.5738
AR(3)	0.274329	0.083668	3.278799	0.0015
AR(5)	0.531747	0.076797	6.924062	0.0000
AR(9)	-0.085204	0.093766	-0.908693	0.3659
SIGMASQ	11909268	1304729.	9.127772	0.0000

R-squared	0.457473	Mean dependent var	3142.177
Adjusted R-squared	0.427664	S.D. dependent var	4709.579
S.E. of regression	3562.933	Akaike info criterion	19.28016
Sum squared resid	1.16E+09	Schwarz criterion	19.43942
Log likelihood	-929.0875	Hannan-Quinn criter.	19.34455
F-statistic	15.34671	Durbin-Watson stat	1.416422
Prob(F-statistic)	0.000000		

Inverted AR Roots	.93	.63	.29+.76i	.29-.76i
	-.05+.65i	-.05-.65i	-.59	-.72-.60i
	-.72+.60i			

Estimation Command:
=========================
LS(OPTMETHOD=OPG) D(GROSS_DEMAND) C AR(2) AR(3) AR(5) AR(9)

Estimation Equation:
=========================
D(GROSS_DEMAND) = C(1) + [AR(2)=C(2),AR(3)=C(3),AR(5)=C(4),AR(9)=C(5)]

Substituted Coefficients:
=========================
D(GROSS_DEMAND) = 3110.7613856 + [AR(2)=0.0445707814994,AR(3)=0.27432912726,AR(5)=0.531746599843,AR(9)=-0.085204360061]

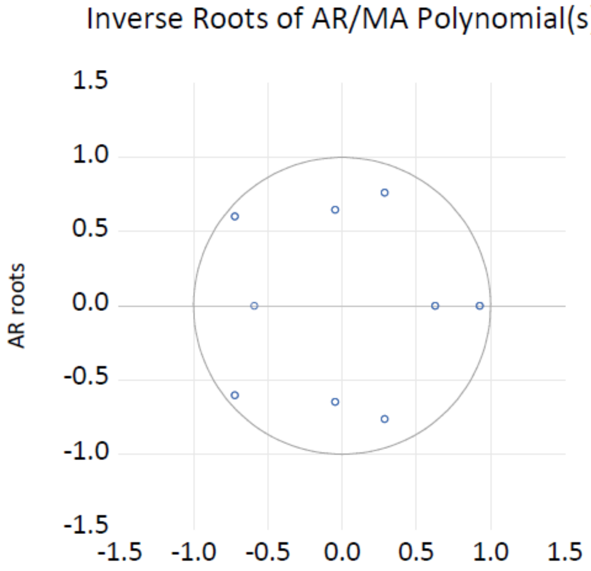
Actual (GROSS_DE) and Forecasted Demand (GROSS_DEMAF) Data Output by EViews 11

	GROSS_DEMAF	GROSS_DE
1923	44.50000	44.50000
1924	44.60000	44.60000
1925	45.30000	45.30000
1926	65.80000	65.80000
1927	70.10000	70.10000
1928	89.40000	89.40000
1929	97.80000	97.80000
1930	106.3000	106.3000
1931	117.9000	117.9000
1932	131.6000	131.6000
1933	151.9000	151.9000
1934	195.2000	195.2000
1935	212.9000	212.9000
1936	231.1000	231.1000
1937	289.8000	289.8000
1938	312.1000	312.1000
1939	353.3000	353.3000
1940	396.9000	396.9000
1941	415.2000	415.2000
1942	408.2000	408.2000
1943	457.4000	457.4000
1944	496.1000	496.1000
1945	527.8000	527.8000
1946	562.7000	562.7000
1947	625.0000	625.0000
1948	676.3000	676.3000
1949	736.6000	736.6000
1950	789.5000	789.5000
1951	887.9000	887.9000
1952	1020.200	1020.200
1953	1200.800	1200.800
1954	1402.500	1402.500
1955	1579.800	1579.800
1956	1819.100	1819.100
1957	2056.700	2056.700
1958	2303.400	2303.400
1959	2587.300	2587.300
1960	2815.100	2815.100
1961	3011.100	3011.100
1962	3559.800	3559.800
1963	3983.400	3983.400
1964	4450.900	4450.900
1965	4952.700	4952.700
1966	5576.200	5576.200
1967	6216.800	6216.800
1968	6935.800	6935.800
1969	7838.000	7838.000
1970	8623.000	8623.000
1971	9781.100	9781.100
1972	11241.90	11241.90
1973	12425.20	12425.20
1974	13477.00	13477.00
1975	15719.00	15719.00
1976	18615.00	18615.00
1977	21056.80	21056.80
1978	22347.10	22347.10
1979	23566.20	23566.20
1980	24616.60	24616.60
1981	26288.90	26288.90
1982	28324.90	28324.90
1983	29567.60	29567.60
1984	33266.50	33266.50
1985	36361.30	36361.30
1986	40471.40	40471.40
1987	44925.00	44925.00
1988	48430.00	48430.00
1989	52601.70	52601.70
1990	56811.70	56811.70

	GROSS_DEMAF	GROSS_DE
1991	60499.30	60499.30
1992	67216.80	67216.80
1993	73431.70	73431.70
1994	77783.00	77783.00
1995	85551.50	85551.50
1996	94788.70	94788.70
1997	105517.1	105517.1
1998	114022.7	114022.7
1999	118484.9	118484.9
2000	128275.6	128275.6
2001	126871.3	126871.3
2002	132552.6	132552.6
2003	141150.9	141150.9
2004	150017.5	150017.5
2005	160794.0	160794.0
2006	174637.3	174637.3
2007	190000.2	190000.2
2008	198085.2	198085.2
2009	194079.1	194079.1
2010	210434.0	210434.0
2011	230306.3	230306.3
2012	242369.9	242369.9
2013	252015.6	246356.6
2014	255686.0	257220.1
2015	267672.2	265724.4
2016	280469.5	279286.4
2017	288466.3	296702.1
2018	298524.8	304166.9
2019	303679.8	303320.4
2020	311731.9	304835.7

ARMA Structure

Unit Root Test of Raw Data of Gross Demand



Augmented Dickey-Fuller Unit Root Test on GROSS_DEMAND

Null Hypothesis: GROSS_DEMAND has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 2 (Automatic - based on SIC, maxlag=11)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		2.603382	1.0000
Test critical values:	1% level	-4.057528	
	5% level	-3.457808	
	10% level	-3.154859	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(GROSS_DEMAND)
Method: Least Squares
Date: 03/15/21 Time: 20:41
Sample (adjusted): 1926 2020
Included observations: 95 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GROSS_DEMAND(-1)	0.020612	0.007917	2.603382	0.0108
D(GROSS_DEMAND(-1))	0.380795	0.103407	3.682496	0.0004
D(GROSS_DEMAND(-2))	-0.393080	0.118073	-3.329134	0.0013
C	-1466.311	803.4481	-1.825023	0.0713
@TREND("1923")	69.69575	21.44177	3.250466	0.0016

R-squared	0.617741	Mean dependent var	3208.320
Adjusted R-squared	0.600752	S.D. dependent var	4736.836
S.E. of regression	2993.022	Akaike info criterion	18.89715
Sum squared resid	8.06E+08	Schwarz criterion	19.03157
Log likelihood	-892.6147	Hannan-Quinn criter.	18.95146
F-statistic	36.36061	Durbin-Watson stat	1.947917
Prob(F-statistic)	0.000000		

Unit Root Test of 1st Differenced

Augmented Dickey-Fuller Unit Root Test on D(GROSS_DEMAND)

Null Hypothesis: D(GROSS_DEMAND) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=11)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.506635	0.0000
Test critical values:	1% level	-4.057528	
	5% level	-3.457808	
	10% level	-3.154859	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(GROSS_DEMAND,2)
Method: Least Squares
Date: 03/15/21 Time: 20:42
Sample (adjusted): 1926 2020
Included observations: 95 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(GROSS_DEMAND(-1))	-0.794984	0.122181	-6.506635	0.0000
D(GROSS_DEMAND(-1),2)	0.249428	0.107649	2.317056	0.0227
C	-2282.729	762.8403	-2.992408	0.0036
@TREND("1923")	96.77570	19.33576	5.005013	0.0000

R-squared	0.339049	Mean dependent var	15.94357
Adjusted R-squared	0.317259	S.D. dependent var	3735.499
S.E. of regression	3086.573	Akaike info criterion	18.94870
Sum squared resid	8.67E+08	Schwarz criterion	19.05624
Log likelihood	-896.0634	Hannan-Quinn criter.	18.99215
F-statistic	15.56011	Durbin-Watson stat	1.921813
Prob(F-statistic)	0.000000		

Unit Root Test of 2nd Differenced

Augmented Dickey-Fuller Unit Root Test on D(GROSS_DEMAND,2)

Null Hypothesis: D(GROSS_DEMAND,2) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 8 (Automatic - based on SIC, maxlag=11)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.702495	0.0000
Test critical values:	1% level	-4.066981	
	5% level	-3.462292	
	10% level	-3.157475	

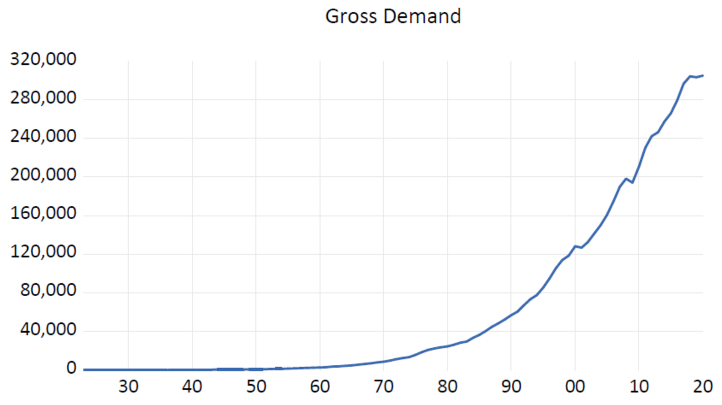
*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(GROSS_DEMAND,3)
Method: Least Squares
Date: 03/15/21 Time: 20:43
Sample (adjusted): 1934 2020
Included observations: 87 after adjustments

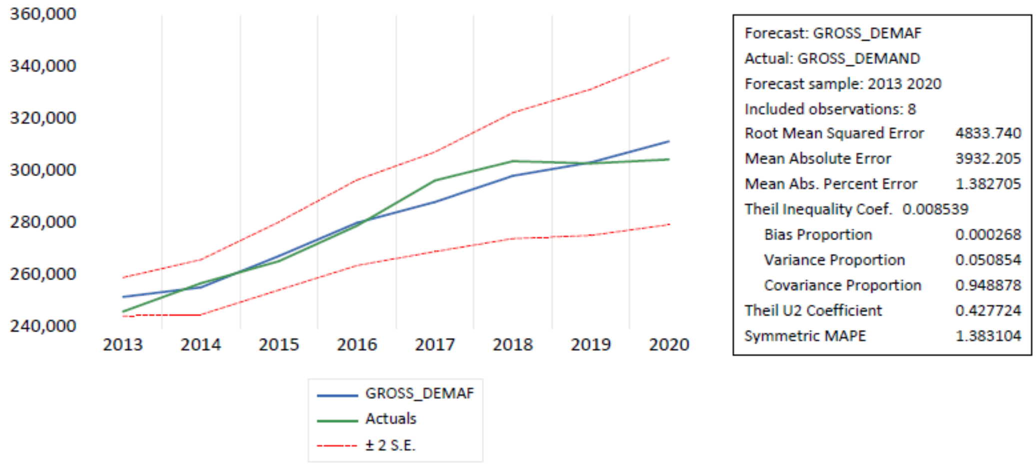
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(GROSS_DEMAND(-1),2)	-6.919298	1.213381	-5.702495	0.0000
D(GROSS_DEMAND(-1),3)	5.292330	1.170387	4.521864	0.0000
D(GROSS_DEMAND(-2),3)	4.333651	1.088798	3.980217	0.0002
D(GROSS_DEMAND(-3),3)	3.337473	0.955678	3.492258	0.0008
D(GROSS_DEMAND(-4),3)	2.518531	0.793984	3.172017	0.0022
D(GROSS_DEMAND(-5),3)	1.842484	0.621587	2.964159	0.0041
D(GROSS_DEMAND(-6),3)	1.286108	0.431625	2.979689	0.0039
D(GROSS_DEMAND(-7),3)	0.911953	0.268185	3.400461	0.0011
D(GROSS_DEMAND(-8),3)	0.569461	0.135812	4.193000	0.0001
C	-173.7563	730.9432	-0.237715	0.8127
@TREND("1923")	17.10684	13.03671	1.312205	0.1934

R-squared	0.800581	Mean dependent var	27.07210
Adjusted R-squared	0.774342	S.D. dependent var	5980.573
S.E. of regression	2840.981	Akaike info criterion	18.85939
Sum squared resid	6.13E+08	Schwarz criterion	19.17117
Log likelihood	-809.3833	Hannan-Quinn criter.	18.98493
F-statistic	30.51075	Durbin-Watson stat	2.033433
Prob(F-statistic)	0.000000		

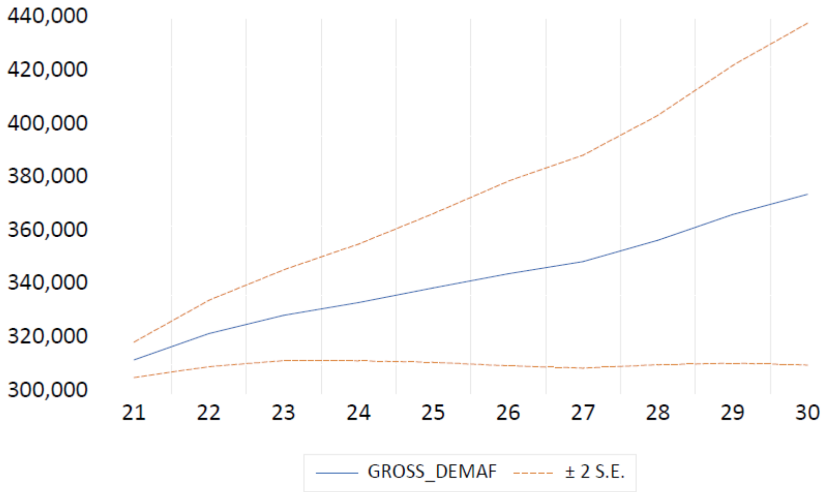
Trend of Gross Demand Produced by EViews



Actual and Forecasted Gross Demand 2013-2020 Produced by EViews



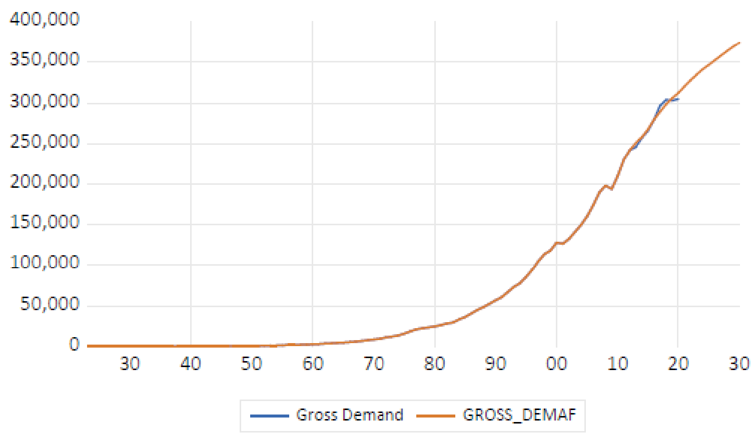
Forecasted Demand 2021-2030 Produced by EViews



Gross Demand Forecasting

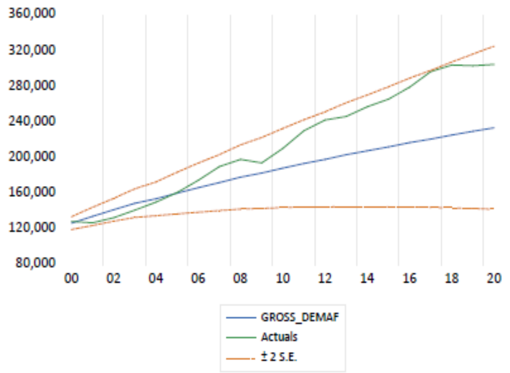
	GROSS_DEMAND	GROSS_DE
1923	44.50000	44.50000
1924	44.60000	44.60000
1925	45.30000	45.30000
1926	65.80000	65.80000
1927	70.10000	70.10000
1928	89.40000	89.40000
1929	97.80000	97.80000
1930	106.3000	106.3000
1931	117.9000	117.9000
1932	131.6000	131.6000
1933	151.9000	151.9000
1934	195.2000	195.2000
1935	212.9000	212.9000
1936	231.1000	231.1000
1937	289.8000	289.8000
1938	312.1000	312.1000
1939	353.3000	353.3000
1940	396.9000	396.9000
1941	415.2000	415.2000
1942	408.2000	408.2000
1943	457.4000	457.4000
1944	496.1000	496.1000
1945	527.8000	527.8000
1946	562.7000	562.7000
1947	625.0000	625.0000
1948	676.3000	676.3000
1949	736.6000	736.6000
1950	789.5000	789.5000
1951	887.9000	887.9000
1952	1020.200	1020.200
1953	1200.800	1200.800
1954	1402.500	1402.500
1955	1579.800	1579.800
1956	1819.100	1819.100
1957	2056.700	2056.700
1958	2303.400	2303.400
1959	2587.300	2587.300
1960	2815.100	2815.100
1961	3011.100	3011.100
1962	3559.800	3559.800
1963	3983.400	3983.400
1964	4450.900	4450.900
1965	4952.700	4952.700
1966	5576.200	5576.200
1967	6216.800	6216.800
1968	6935.800	6935.800
1969	7838.000	7838.000
1970	8623.000	8623.000
1971	9781.100	9781.100
1972	11241.90	11241.90
1973	12425.20	12425.20
1974	13477.00	13477.00
1975	15719.00	15719.00
1976	18615.00	18615.00
1977	21056.80	21056.80
1978	22347.10	22347.10
1979	23566.20	23566.20
1980	24616.60	24616.60
1981	26288.90	26288.90
1982	28324.90	28324.90
1983	29567.60	29567.60
1984	33266.50	33266.50
1985	36361.30	36361.30
1986	40471.40	40471.40
1987	44925.00	44925.00
1988	48430.00	48430.00
1989	52601.70	52601.70
1990	56811.70	56811.70

	GROSS_DEMAF	GROSS_DE
1991	60499.30	60499.30
1992	67216.80	67216.80
1993	73431.70	73431.70
1994	77783.00	77783.00
1995	85551.50	85551.50
1996	94788.70	94788.70
1997	105517.1	105517.1
1998	114022.7	114022.7
1999	118484.9	118484.9
2000	128275.6	128275.6
2001	126871.3	126871.3
2002	132552.6	132552.6
2003	141150.9	141150.9
2004	150017.5	150017.5
2005	160794.0	160794.0
2006	174637.3	174637.3
2007	190000.2	190000.2
2008	198085.2	198085.2
2009	194079.1	194079.1
2010	210434.0	210434.0
2011	230306.3	230306.3
2012	242369.9	242369.9
2013	252015.6	246356.6
2014	255686.0	257220.1
2015	267672.2	265724.4
2016	280469.5	279286.4
2017	288466.3	296702.1
2018	298524.8	304166.9
2019	303679.8	303320.4
2020	311731.9	304835.7
2021	321227.8	NA
2022	327160.9	NA
2023	335558.6	NA
2024	340877.5	NA
2025	346800.4	NA
2026	354438.9	NA
2027	359189.5	NA
2028	365910.7	NA
2029	371089.8	NA
2030	375762.6	NA



ARIMA MODEL FORECASTING PRACTICES

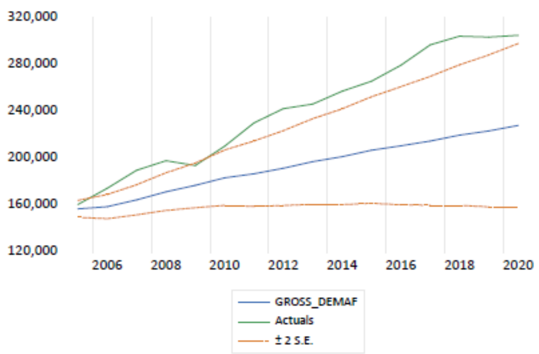
2000 – 2020 Forecasting of ARIMA



Forecast: GROSS_DEMAF	
Actual: GROSS_DEMAND	
Forecast sample: 2000 2020	
Included observations: 21	
Root Mean Squared Error	42790.77
Mean Absolute Error	33280.02
Mean Abs. Percent Error	13.11423
Theil Inequality Coef.	0.103690
Bias Proportion	0.514110
Variance Proportion	0.463975
Covariance Proportion	0.021915
Theil U2 Coefficient	2.974321
Symmetric MAPE	14.42000

2000	126353.4
2001	133954.8
2002	141434.5
2003	148813.6
2004	153672.8
2005	160180.3
2006	166278.7
2007	171884.0
2008	178214.2
2009	182780.1
2010	188142.3
2011	193417.5
2012	197990.6
2013	203378.4
2014	207632.5
2015	212188.5
2016	216913.3
2017	220905.4
2018	225571.4
2019	229580.3
2020	233586.3

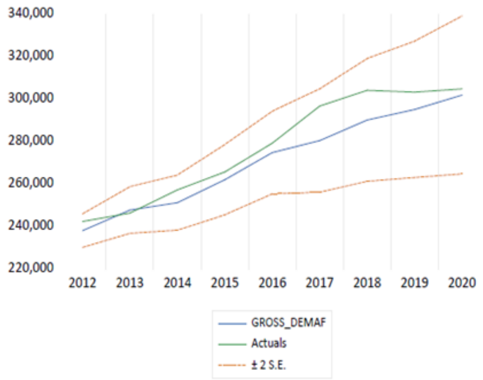
2005- 2020 Forecasting of ARIMA



Forecast: GROSS_DEMAF	
Actual: GROSS_DEMAND	
Forecast sample: 2005 2020	
Included observations: 16	
Root Mean Squared Error	54064.93
Mean Absolute Error	47734.21
Mean Abs. Percent Error	18.38868
Theil Inequality Coef.	0.122744
Bias Proportion	0.779522
Variance Proportion	0.213211
Covariance Proportion	0.007267
Theil U2 Coefficient	3.812727
Symmetric MAPE	20.60812

2005	157108.1
2006	158930.8
2007	164705.2
2008	171653.1
2009	177020.8
2010	183534.2
2011	186894.3
2012	191724.6
2013	197330.0
2014	201446.8
2015	207059.5
2016	210805.1
2017	214890.8
2018	219850.4
2019	223423.8
2020	228193.6

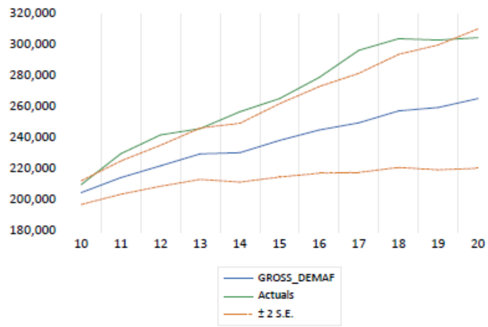
2010 – 2020 Forecasting of ARIMA



Forecast: GROSS_DEMAF	
Actual: GROSS_DEMAND	
Forecast sample: 2012 2020	
Included observations: 9	
Root Mean Squared Error	8327.919
Mean Absolute Error	6791.106
Mean Abs. Percent Error	2.373789
Theil Inequality Coef.	0.015115
Bias Proportion	0.605801
Variance Proportion	0.113070
Covariance Proportion	0.281128
Theil U2 Coefficient	0.848123
Symmetric MAPE	2.414639

2010	205233.6
2011	214879.7
2012	222444.1
2013	230207.4
2014	230871.9
2015	238774.6
2016	245483.9
2017	250081.5
2018	257747.6
2019	259925.7
2020	265638.6

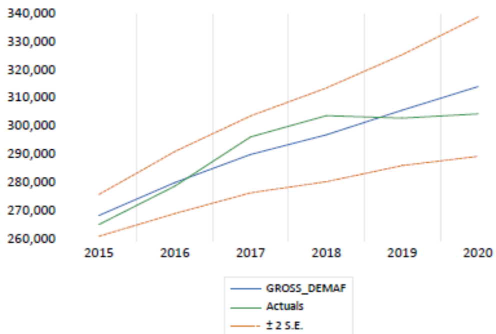
2012 - 2020 Forecasting of ARIMA



Forecast: GROSS_DEMAF	
Actual: GROSS_DEMAND	
Forecast sample: 2010 2020	
Included observations: 11	
Root Mean Squared Error	31956.98
Mean Absolute Error	29039.48
Mean Abs. Percent Error	10.41579
Theil Inequality Coef.	0.062883
Bias Proportion	0.825745
Variance Proportion	0.160707
Covariance Proportion	0.013548
Theil U2 Coefficient	2.562367
Symmetric MAPE	11.07926

2012	238102.4
2013	247748.1
2014	251228.4
2015	262043.8
2016	274832.7
2017	280455.8
2018	290192.9
2019	295138.6
2020	301902.7

2015 -2020 Forecasting of ARIMA



Forecast: GROSS_DEMAF	
Actual: GROSS_DEMAND	
Forecast sample: 2015 2020	
Included observations: 6	
Root Mean Squared Error	5726.664
Mean Absolute Error	4979.439
Mean Abs. Percent Error	1.676551
Theil Inequality Coef.	0.009771
Bias Proportion	0.012902
Variance Proportion	0.005696
Covariance Proportion	0.981403
Theil U2 Coefficient	0.545185
Symmetric MAPE	1.674164

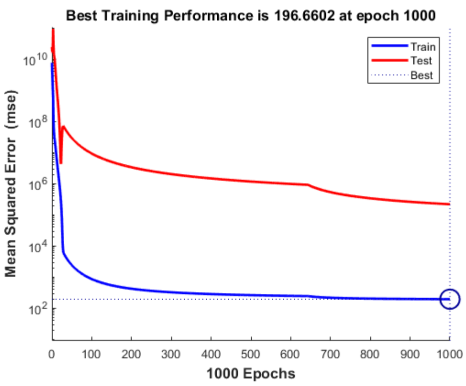
2015	268954.0
2016	280519.6
2017	290478.4
2018	297403.7
2019	306133.1
2020	314449.7

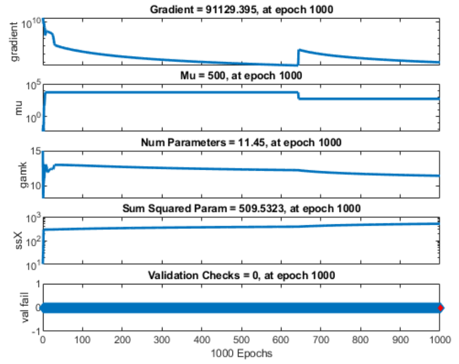
APPENDIX B: 2- ANN OUTPUT of MATLAB® R2020a

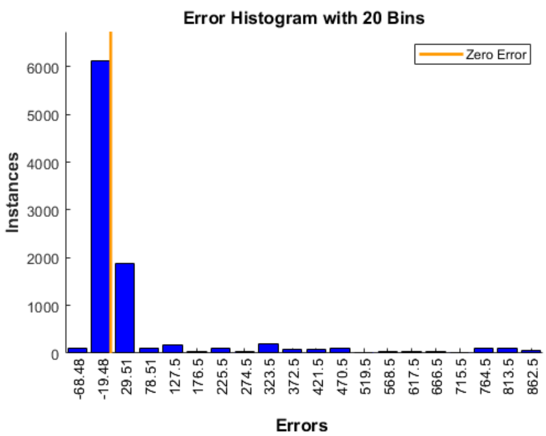
actual_data =	forecast_data =
1.0e+05 *	1.0e+05 *
0.0004	0.0005
0.0005	0.0005
0.0007	0.0007
0.0007	0.0007
0.0009	0.0009
0.0010	0.0010
0.0011	0.0011
0.0012	0.0012
0.0013	0.0013
0.0015	0.0015
0.0020	0.0020
0.0021	0.0021
0.0023	0.0023
0.0029	0.0029
0.0031	0.0031
0.0035	0.0035
0.0040	0.0040
0.0042	0.0042
0.0041	0.0041
0.0046	0.0046
0.0050	0.0050
0.0053	0.0053
0.0056	0.0056
0.0063	0.0063
0.0068	0.0068
0.0074	0.0074
0.0079	0.0079
0.0089	0.0089
0.0102	0.0102
0.0120	0.0120
0.0140	0.0140
0.0158	0.0158
0.0182	0.0182
0.0206	0.0206
0.0230	0.0231
0.0259	0.0259
0.0282	0.0282
0.0301	0.0301
0.0356	0.0356
0.0398	0.0399
0.0445	0.0445
0.0495	0.0496
0.0558	0.0558
0.0622	0.0622
0.0694	0.0694
0.0784	0.0784
0.0862	0.0863
0.0978	0.0979
0.1124	0.1125
0.1243	0.1243
0.1348	0.1349
0.1572	0.1573
0.1862	0.1863
0.2106	0.2107
0.2235	0.2236
0.2357	0.2358
0.2462	0.2463
0.2629	0.2631
0.2832	0.2835
0.2957	0.2959
0.3327	0.3330
0.3636	0.3640
0.4047	0.4051
0.4492	0.4498
0.4843	0.4847
0.5260	0.5265

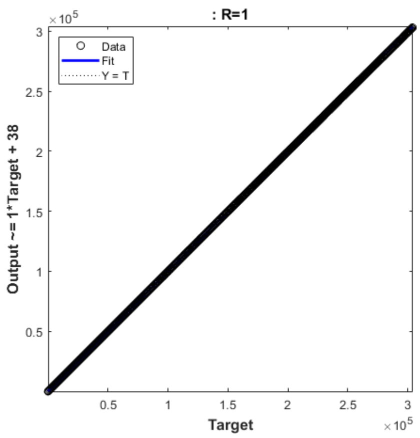
0.5681	0.5688
0.6050	0.6054
0.6722	0.6727
0.7343	0.7350
0.7778	0.7782
0.8555	0.8564
0.9479	0.9488
1.0552	1.0561
1.1402	1.1410
1.1848	1.1853
1.2828	1.2833
1.2687	1.2690
1.3255	1.3264
1.4115	1.4123
1.5002	1.5012
1.6079	1.6089
1.7464	1.7471
1.9000	1.9005
1.9809	1.9810
1.9408	1.9406
2.1043	2.1052
2.3031	2.3033
2.4237	2.4225
2.4636	2.4627
2.5722	2.5703
2.6572	2.6546
2.7929	2.7887
2.9670	2.9607
3.0417	3.0336
3.0333	3.0251

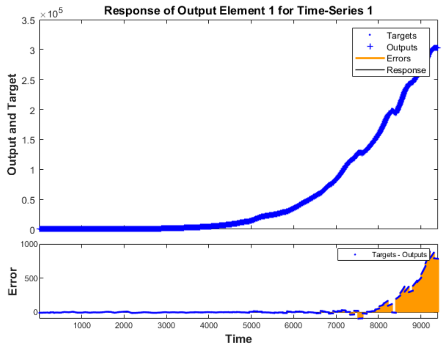
MSE: 1.8388e+04
PSNR: 5.4855
Rvalue: 1.0000
RMSE: 135.6019
NRMSE: 4.4588e-04
MAPE: 0.3279

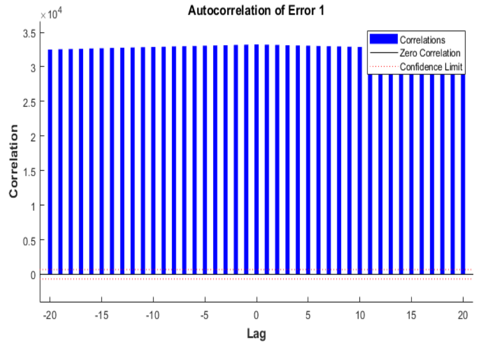


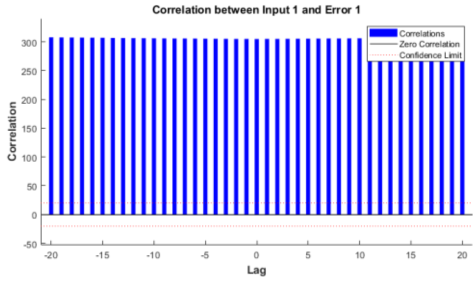


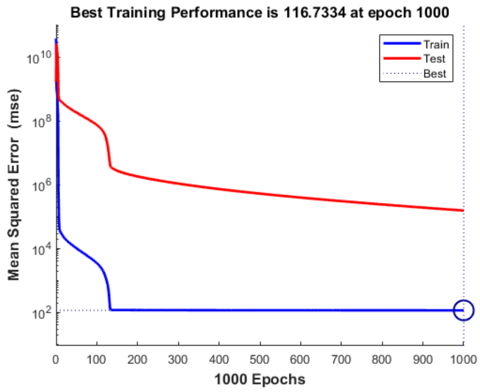


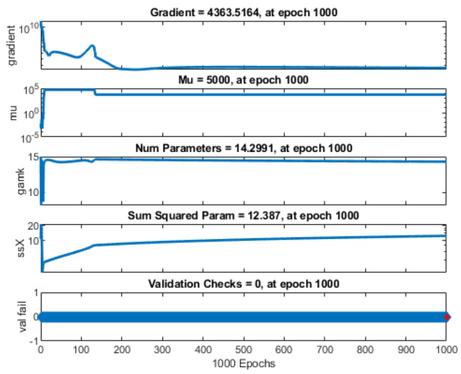


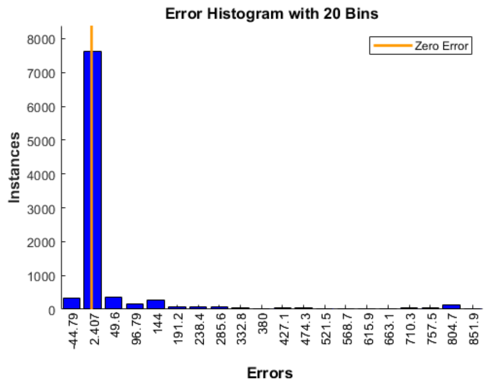

Response of Output Element 1 for Time-Series 1
Targets
Outputs
Errors
Response
Output and Target
Targets - Outputs
Error
Time

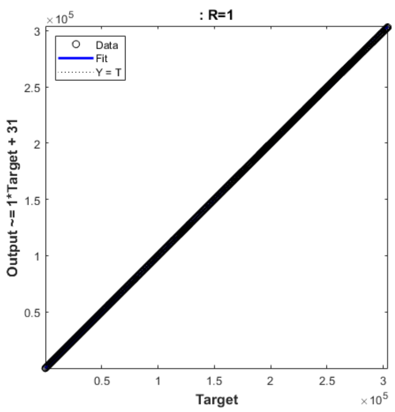

Autocorrelation of Error 1
Correlations
Zero Correlation
Confidence Limit
Correlation
Lag

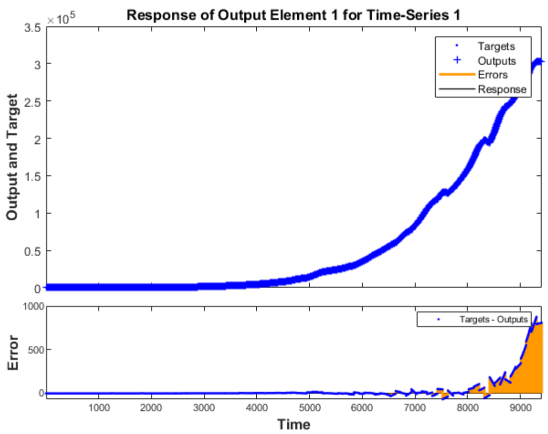

Correlation between Input 1 and Error 1
Correlations
Zero Correlation
Confidence Limit
Correlation
Lag

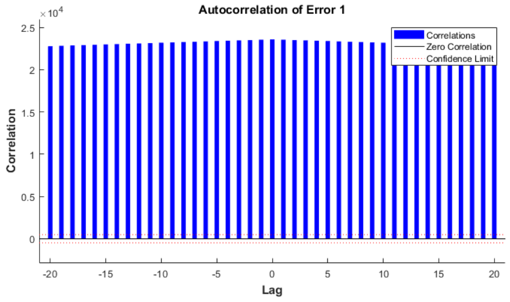

Best Training Performance is 116.7334 at epoch 1000
Train
Test
Best
Mean Squared Error (mse)
1000 Epochs

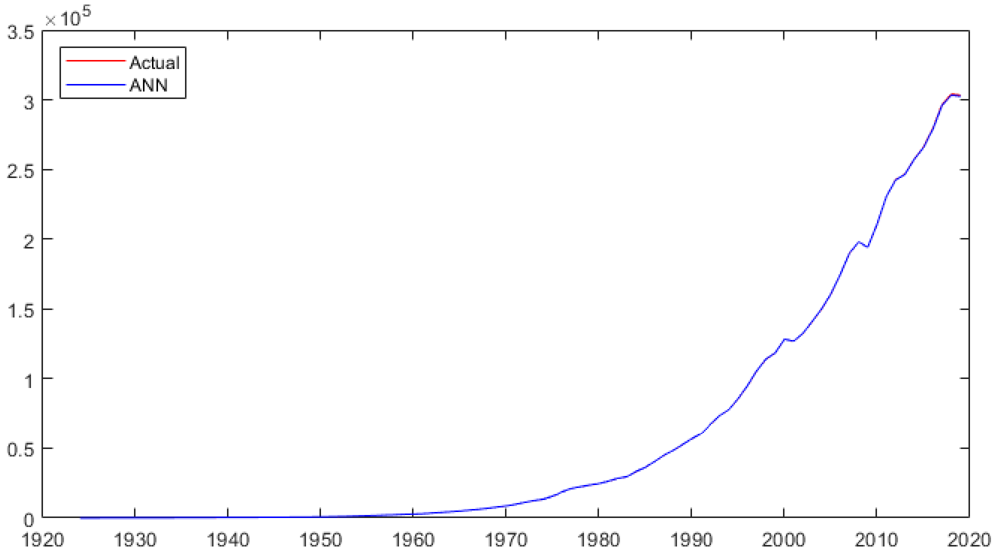

Gradient = 4363.5164, at epoch 1000
gradient
Mu = 5000, at epoch 1000
mu
Num Parameters = 14.2991, at epoch 1000
gamk
Sum Squared Param = 12.387, at epoch 1000
ssX
Validation Checks = 0, at epoch 1000
val fail
1000 Epochs


Error Histogram with 20 Bins
Zero Error
Instances
Errors


: R=1
Data
Fit
Y = T
Output ~= 1*Target + 31
Target


Response of Output Element 1 for Time-Series 1
Targets
Outputs
Errors
Response
Output and Target
Targets - Outputs
Error
Time





Published with MATLAB® R2020a

```
function [y1,xf1,xf2] = myNeuralNetworkFunction(x1,x2,xi1,xi2)
%MYNEURALNETWORKFUNCTION neural network simulation function.
%
% Auto-generated by MATLAB, 27-Feb-2021 17:16:46.
%
% [y1,xf1,xf2] = myNeuralNetworkFunction(x1,x2,xi1,xi2) takes these arguments:
%   x1 = 4xTS matrix, input #1
%   x2 = 1xTS matrix, input #2
%   xi1 = 4x1 matrix, initial 1 delay states for input #1.
%   xi2 = 1x1 matrix, initial 1 delay states for input #2.
% and returns:
%   y1 = 1xTS matrix, output #1
%   xf1 = 4x1 matrix, final 1 delay states for input #1.
%   xf2 = 1x1 matrix, final 1 delay states for input #2.
% where TS is the number of timesteps.

% ===== NEURAL NETWORK CONSTANTS =====

% Input 1
x1_step1.xoffset = [-15.3;0.53;-28.37;-45.91];
```

```
x1_step1.gain =
[0.0423728813559322;0.269179004037685;0.0221486667733084;0.0131847847583888];
x1_step1.ymin = -1;

% Input 2
x2_step1.xoffset = 44.6070707070707;
x2_step1.gain = 6.57630185783517e-06;
x2_step1.ymin = -1;

% Layer 1
b1 = [0.71225848571446914725;0.56677303851680926883];
IW1_1 = [-0.0014759451492975723431 -0.0034472846268250737292 0.00012937531988079284785
-0.00056938682988007434122;-0.00023436784870940492037 -0.00054726573032258898389
2.0926967402348979098e-05 -9.0944098773079195294e-05];
IW1_2 = [-0.43209365499763374707;0.29086385500115563563];

% Layer 2
b2 = -0.72540333995547601198;
LW2_1 = [-1.3262142693080378741 3.0003517043105145667];

% Output 1
y1_step1.ymin = -1;
y1_step1.gain = 6.57630185783517e-06;
y1_step1.xoffset = 44.6070707070707;

% ===== SIMULATION ========

% Dimensions
TS = size(x1,2); % timesteps

% Input 1 Delay States
xd1 = mapminmax_apply(xi1,x1_step1);
xd1 = [xd1 zeros(4,1)];

% Input 2 Delay States
xd2 = mapminmax_apply(xi2,x2_step1);
xd2 = [xd2 zeros(1,1)];

% Allocate Outputs
y1 = zeros(1,TS);

% Time loop
for ts=1:TS

     % Rotating delay state position
     xdts = mod(ts+0,2)+1;

   % Input 1
   xd1(:,xdts) = mapminmax_apply(x1(:,ts),x1_step1);

   % Input 2
   xd2(:,xdts) = mapminmax_apply(x2(:,ts),x2_step1);

   % Layer 1
   tapdelay1 = reshape(xd1(:,mod(xdts-1-1,2)+1),4,1);
   tapdelay2 = reshape(xd2(:,mod(xdts-1-1,2)+1),1,1);
   a1 = tansig_apply(b1 + IW1_1*tapdelay1 + IW1_2*tapdelay2);

   % Layer 2
```

```
   a2 = b2 + LW2_1*a1;

   % Output 1
   y1(:,ts) = mapminmax_reverse(a2,y1_step1);
end

% Final delay states
finalxts = TS+(1: 1);
xits = finalxts(finalxts<=1);
xts = finalxts(finalxts>1)-1;
xf1 = [xi1(:,xits) x1(:,xts)];
xf2 = [xi2(:,xits) x2(:,xts)];
end

% ===== MODULE FUNCTIONS ========

% Map Minimum and Maximum Input Processing Function
function y = mapminmax_apply(x,settings)
  y = bsxfun(@minus,x,settings.xoffset);
  y = bsxfun(@times,y,settings.gain);
  y = bsxfun(@plus,y,settings.ymin);
end

% Sigmoid Symmetric Transfer Function
function a = tansig_apply(n,~)
  a = 2 ./ (1 + exp(-2*n)) - 1;
end

% Map Minimum and Maximum Output Reverse-Processing Function
function x = mapminmax_reverse(y,settings)
  x = bsxfun(@minus,y,settings.ymin);
  x = bsxfun(@rdivide,x,settings.gain);
  x = bsxfun(@plus,x,settings.xoffset);
end
```

Forecasting_2013_ 2020 and 2021_2030

actual_Values

actual_2013_2018 =

```
  1.0e+05 *

   2.4636
   2.5722
   2.6572
   2.7929
   2.9670
   3.0417
   3.0332
   3.0484
```

articial neural network output_values

ann_2013_2018 =

```
  1.0e+05 *

   2.4889
   2.5913
```

2.6863
2.8317
2.9850
3.0398
3.0358
3.0476

2020-2030 forecasting_values

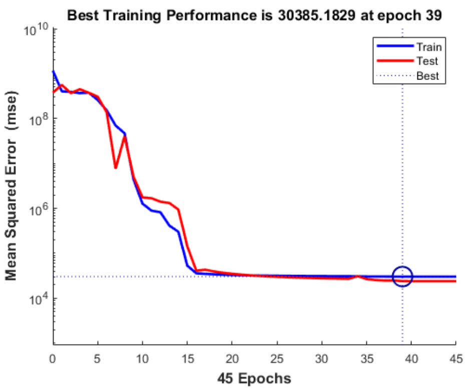
future_forecasting =

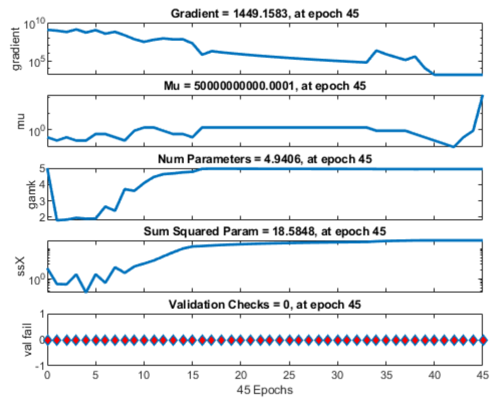
1.0e+05 *

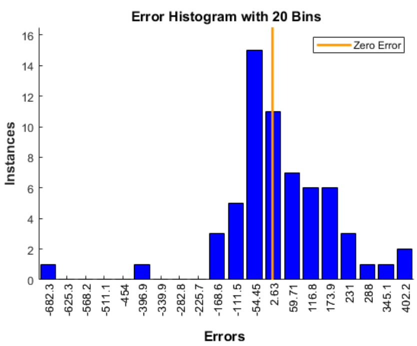
3.1381
3.2397
3.3228
3.3954
3.4639
3.5334
3.6057
3.6798
3.7543
3.8284

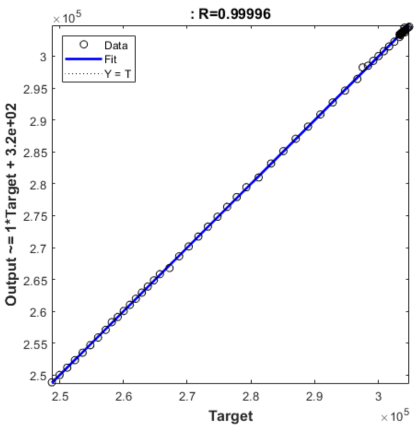
Result =

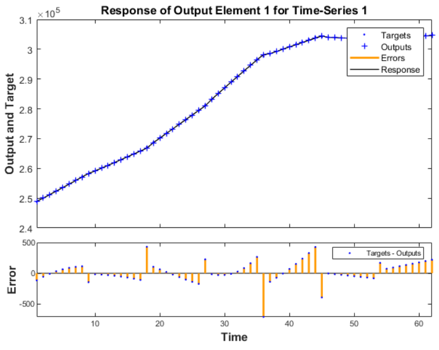
MSE: 4.6166e+06
PSNR: -18.5124
Rvalue: 0.9999
RMSE: 2.1486e+03
NRMSE: 0.0367
MAPE: 0.6289

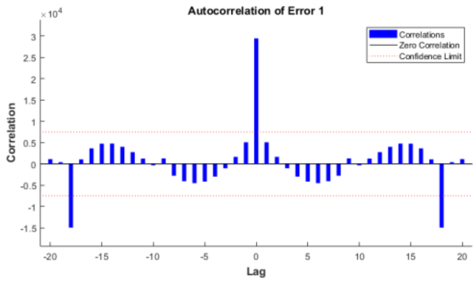


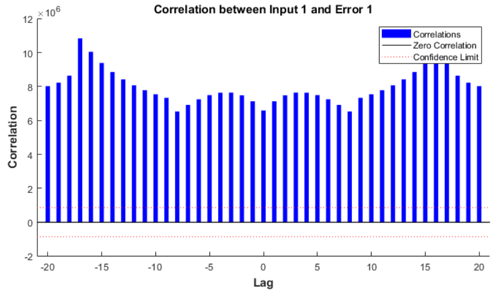


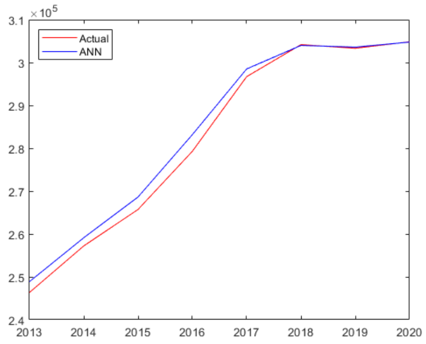


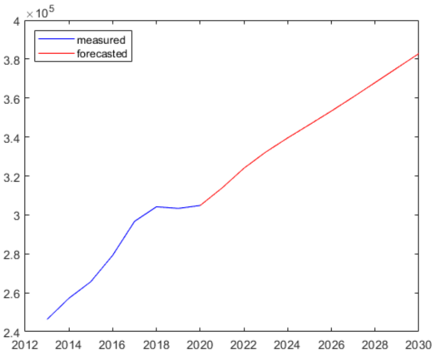












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```
function [y1,xf1] = myNeuralNetworkFunction(x1,xi1)
%MYNEURALNETWORKFUNCTION neural network simulation function.
%
% Auto-generated by MATLAB, 27-Feb-2021 14:33:57.
%
% [y1,xf1] = myNeuralNetworkFunction(x1,xi1) takes these arguments:
%   x1 = 1xTS matrix, input #1
%   xi1 = 1x2 matrix, initial 2 delay states for input #1.
% and returns:
%   y1 = 1xTS matrix, output #1
%   xf1 = 1x2 matrix, final 2 delay states for input #1.
% where TS is the number of timesteps.

% ===== NEURAL NETWORK CONSTANTS =====

% Input 1
x1_step1.xoffset = 284190.708781362;
x1_step1.gain = 5.11020858395237e-05;
x1_step1.ymean = 0;
```

```
% Layer 1
b1 = 0.15868328888008012556;
IW1_1 = [0.36287371267925155882 -0.12070003174227822429];
 % Layer 2
b2 = -0.61718008571776161 73;
LW2_1 = 4.2465669632065612404;

% Output 1
y1_step1.ymean = 0;
y1_step1.gain = 5.11020858395237e-05;
y1_step1.xoffset = 284190.708781362;

% ===== SIMULATION ========

% Dimensions
TS = size(x1,2); % timesteps

% Input 1 Delay States
xd1 = mapstd_apply(xi1,x1_step1);
xd1 = [xd1 zeros(1,1)];

% Allocate Outputs
y1 = zeros(1,TS);

% Time loop
for ts=1:TS

     % Rotating delay state position
     xdts = mod(ts+1,3)+1;

   % Input 1
   xd1(:,xdts) = mapstd_apply(x1(:,ts),x1_step1);

   % Layer 1
   tapdelay1 = reshape(xd1(:,mod(xdts-[1 2]-1,3)+1),2,1);
   a1 = tansig_apply(b1 + IW1_1*tapdelay1);

   % Layer 2
   a2 = b2 + LW2_1*a1;

   % Output 1
   y1(:,ts) = mapstd_reverse(a2,y1_step1);
end

% Final delay states
finalxts = TS+(1: 2);
xits = finalxts(finalxts<=2);
xts = finalxts(finalxts>2)-2;
xf1 = [xi1(:,xits) x1(:,xts)];
end

% ===== MODULE FUNCTIONS ========

% Map Standard Deviation and Mean Input Processing Function
function y = mapstd_apply(x,settings)
  y = bsxfun(@minus,x,settings.xoffset);
  y = bsxfun(@times,y,settings.gain);
  y = bsxfun(@plus,y,settings.ymean);
end
```

```
% Sigmoid Symmetric Transfer Function
function a = tansig_apply(n,~)
  a = 2 ./ (1 + exp(-2*n)) - 1;
end

% Map Standard Deviation and Mean Output Reverse-Processing Function
function x = mapstd_reverse(y,settings)
  x = bsxfun(@minus,y,settings.ymean);
  x = bsxfun(@rdivide,x,settings.gain);
  x = bsxfun(@plus,x,settings.xoffset);
end
```

APPENDIX C: Generation and Capacity Factor of Sources

YEARS	AVERAGE CAPACITY FACTOR – THERMAL											
	Natural Gas Av. Cap. Fac. (%)	Natural Gas Ins. Power (MW)	Natural Gas Generation (MWh)	Lignite Av. Cap. Fac. (%)	Lignite Ins. Power (MW)	Lignite Generation (MWh)	Hardcoal/Imp. Coal/Asph.Av. Cap. Fac. (%)	Hardcoal/Imp. Coal/Asph. Ins. Power (MW)	Hardcoal/Imp. Coal/Asph Generation (MWh)	Fuel-Oil/Diesel Av. Cap. Fac. (%)	Fuel-Oil/Diesel Ins. Power (MW)	Fuel-Oil/Diesel Generation (MWh)
2013	69,88	17.170,6	105.116.347,0	42,01	8.223,2	30.262.043,0	87,32	4.382,5	33.524.033,0	32,21	616,3	1.738.826,0
2014	73,51	18.724,4	120.576.000,0	50,47	8.281,3	36.615.400,0	69,28	6.532,6	39.647.300,0	19,74	594,9	1.028.748,0
2015	61,55	18.527,6	99.898.528,2	42,57	8.696,5	32.430.705,0	58,92	6.825,2	35.224.769,9	55,84	522,7	2.556.886,5
2016	51,26	19.563,6	87.848.838,7	48,21	9.126,5	38.543.567,0	74,78	8.228,9	53.908.331,7	67,97	445,3	2.651.206,8
2017	56,33	22.002,2	108.569.680,6	50,74	9.129,1	40.581.021,7	67,97	9.576,4	57.020.718,1	59,12	380,2	1.968.881,9
2018	48,21	21.479,9	90.704.460,8	54,39	9.456,1	45.055.287,8	81,40	9.576,4	68.283.694,5	29,57	370,6	960.084,0
2019	29,10	21.843,6	55.687.914,9	53,72	9.966,1	46.897.978,7	78,71	9.604,4	66.218.205,9	44,27	189,4	734.571,0

YEARS	AVERAGE CAPACITY FACTOR – RENEWABLES											
	WIND Av. Cap. Fac. (%)	Wind Ins. Power (MW)	Generation (MWh)	Solar Av. Cap. Fac. (%)	Solar Ins. Power (MW)	Generation (MWh)	Hydraulic Av. Cap. Fac. (%)	Hydraulic Ins. Power (MW)	Generation (MWh)	Geothermal Av. Cap. Fac. (%)	Geothermal Ins. Power (MW)	Generation (MWh)
2013	31,26	2.759,7	7.557.500,0	-	-	-	30,43	22.289,0	59.420.468,0	50,08	310,8	1.363.500,0
2014	26,80	3.629,7	8.520.100,0	4,94	40,2	17.400,0	19,62	23.643,2	40.644.700,0	66,65	404,9	2.364.000,0
2015	29,54	4.503,2	11.652.500,0	8,90	248,8	194.060,2	29,63	25.867,8	67.145.827,1	62,66	623,9	3.424.500,0
2016	30,80	5.751,3	15.517.086,8	14,30	832,5	1.043.138,3	28,76	26.681,1	67.230.883,2	67,01	820,9	4.818.523,7
2017	31,37	6.516,2	17.903.815,1	9,64	3.420,7	2.889.301,7	24,37	27.273,1	58.218.462,4	65,76	1.063,7	6.127.481,9
2018	32,51	7.005,4	19.949.206,2	17,59	5.062,8	7.799.798,0	24,19	28.291,4	59.938.425,6	66,14	1.282,5	7.430.975,6
2019	32,75	7.591,2	21.779.876,7	18,24	5.995,2	9.577.602,1	35,60	28.503,1	88.886.236,7	67,30	1.514,7	8.929.728,9

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<u>Laws and Regulations</u>

Electricity Market Law No. 4628

Electricity Market Law No. 6446

Electricity Demand Forecasting Regulation

Grid Regulation

Capacity Utility Mechanism Regulation