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Comments on Main Factors Affecting Electricity Price Risk in Turkish Electricity Market

Türkiye Elektrik Piyasasında Elektrik Fiyat Riskini Etkileyen Temel Faktörler Hakkında Yorumlar

Mustafa Gözen [a,*]

[a] Dr., Retired, Head of Group, Energy Market Regulatory Authority, Electricity Market Department, 06510, Ankara/Turkey.
ORCID: 0000-0002-5195-757X

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ABSTRACT

One of the most important changes brought about by the liberalization process in Turkish electricity market that started in 2001, is the emergence of electricity price risk. Since 2003, eligible consumers have been able to purchase electricity at a price agreed upon under a bilateral agreement with their suppliers. In addition to this, electricity prices, which are outside the prices determined by Energy Market Regulatory Authority (EPDK) for non-eligible consumers and vulnerable consumers, have been formed under free market conditions since May 2006. In this respect, the purpose of this article is to examine the main factors that lead to price risk in Turkish electricity market. The factors classified under six headings in the article were examined in detail.

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ÖZ

Türkiye elektrik piyasasında 2001 yılında başlayan serbestleşme sürecinin getirdiği en önemli değişikliklerden biri, elektrik fiyat riskinin ortaya çıkmasıdır. 2003 yılından itibaren, serbest tüketiciler tedarikçileri ile ikili anlaşma kapsamında uzlaştıkları fiyattan elektrik satın alabilmektedir. Bunun yanında, serbest olmayan tüketiciler ile kırılgan tüketiciler için Enerji Piyasası Düzenleme Kurumu (EPDK) tarafından belirlenen fiyatlar dışında kalan elektrik fiyatları, 2006 yılı Mayıs ayından itibaren serbest piyasa koşullarında oluşmaktadır. Bu itibarla, bu makalenin amacı; Türkiye elektrik piyasasında fiyat riskine neden olan ana faktörlerin incelenmesidir. Bu makalede altı başlık altında toplanan faktörler ayrıntılı olarak incelenmiştir.

1. Introduction

Electricity has become an indispensable energy source of our age. Factors such as ease of use, comfort, and quality make electricity different from other types of energy. As a demand of modern lifestyle for end user and considering the progress achieved in science and technology, life without electricity cannot be considered for industrial development and human life. Although none of other sources of energy have such a wide range of uses, the main disadvantage of electricity is that it cannot be stored economically in large quantities. Therefore, electricity demand and supply should be balanced every second. Electricity, which is very important for both end users and the national economy, needs to be provided at affordable price, reliable, constant frequency, and voltage. However, it is not always possible to provide these technical conditions for reasons such as unexpected circumstances and

* Sorumlu yazar/*Corresponding author*
e-posta: mgozen@gmail.com

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extraordinary conditions. In addition, electricity markets are restructured in many countries, meaning that new uncertainities are introduced in the market (Chawda and Deshmukh, 2012). These lead to volatilities of electricity prices. As a result of price fluctuations, electricity price risk arises. Understanding the volatility of electricity price is important for managing price risk. To reduce the high price volatility, governments or regulators are trying to increase network and storage capacities, and use capacity reserves.

Therefore, the main purpose of this article is to analyze the key driving factors affecting electricity price risk in Turkish electricity market. The electricity price subject to this study is not the prices regulated by Energy Market Regulatory Authority (EPDK), but the electricity prices determined under free market conditions in the organized wholesale market. There are many factors that are thought to affect the price of electricity. The aim of this article is not to reveal all factors, but to identify and examine the important ones in detail.

In this study, the literature on price risk in the electricity market has been reviewed and the factors causing price risk are classified accordingly. In the light of these factors, evaluations were made on factors which could lead to price risk in Turkish electricity market. For this purpose, the second section focuses on the importance of price risk and provides a literature review of factors affecting electricity price risk. The third section summarizes the reform and structural changes in Turkish electricity market from 1900 to 2019. The fourth section explains the price formation in the electricity market. The fifth section introduces and evaluates key driving factors affecting electricity price risk in the market. The sixth and last section discusses the key factors covered and concludes the article.

2. Importance of price risk and literature review

The prices of energy sources such as electricity, crude oil, and natural gas fluctuate much more than the prices of other commodities and financial products (EIA, 2002). Especially electricity prices are one of the most variable prices in global and local markets. Chawda and Deshmukh (2012) report that price of electricity is more volatile than any other commodity. In addition, Souhir et al. (2019) underline the same by highlighting the impossibility of electricity storage, the technical limits imposed on the electricity network, and the difficulty of predicting the demand for electricity. This makes price risk as the most important risk in the electricity market. Thus, both producers and consumers are at high price risk and primarily want to protect themselves from this risk. As a risk management strategy, the stakeholders are diversifying businesses by investing in various unrelated business areas, using long term fixed-price contracts, insurance contracts, etc. or using derivative instruments. The legal entities try to eliminate the price risk by trading in the stock market or over-the-counter derivatives markets.

On the other hand, since spot prices affect the prices of electricity derivatives, they need to be well understood in order to better manage the price risks of these financial products. While spot prices vary from day to day, the magnitude of the change is random. When supply exceeds demand, electricity is sold at marginal cost in the free market. However, when demand exceeds supply, electricity prices show a jump. Understanding this volatile structure is extremely important to keep price risk manageable (Alaçam, 2014). The related literature about the factors affecting electric price risk is summarized in Table 1.

Table 1. Factors affecting electricity price risk

Year	Author(s)	Main factors affecting electricity price risk
2001	Blonco & Soronow	• Volatility due to seasonal changes in energy prices and temporary price fluctuations tend to return quickly to the average cost of the product concerned.
2002	Douglas	• Difficulties in predicting the values of cash and credits management, and expected investments • Average annual volatilities in energy products are larger than those in other commodities. • Importance of interconnection in electricity trade
2003	Biewald	• Supply and demand imbalance • Increasing energy demand • Transmission constraints
2004	Bağcı	• Uncertainty in fuel prices, imbalances between supply and demand, irregularity in electricity generation for technical reasons, rapid increase in the demand for electricity due to weather conditions, limited and expensive generation opportunities to meet the increasing demand, failure of timely completion of electricity investments, political or other problems that arise in countries where fuel sources are imported to generate electricity, difficulties in supplying electricity for regions where demand increases unexpectedly, and local storage costs
2004	Hinz	• The demand elasticity of electricity is extremely limited, meaning that there is no decrease in electricity demand, independently from the level of increase in electricity prices.
2005	Hiroaki	• Unexpected temperature changes • Failures in power plants • Disruptions in transmission lines
2011	Bhattacharyya	• High import reliance leads to increase in price risk.
2016	Jones	• Generation mix • Renewable energy • Natural gas prices • Interconnectors
2019	USA EIA	• Fuels, power plants, electricity network, weather conditions, regulations

Regarding the factors affecting electricity price, Blonco and Soronow (2001) focus on volatilities due to seasonal characteristics of electricity demand. EIA (2002) points to difficulties in predicting values of cash and credit managements, and expected investments. In addition, EIA (2002) states that average annual volatilities in energy products are larger than those in other commodities. Biewald (2003) emphasizes imbalance of supply and demand and increases in the demand for energy.

Another structural feature of electricity prices is that the demand elasticity of electricity price is almost absent (Hinz, 2004). Storing electricity on a large scale is costly, so the usual trade cannot meet the demand by maintaining the balance in the electricity system. That is why the demand elasticity of electricity is extremely limited. Demand for electricity is inflexible because electricity is a product that is the compulsory commodity that everyone needs and does not have substitution. Accordingly, no matter how high the increase in electricity prices, there is no decrease in electricity demand due to the necessity of goods. In addition, only a few large industrial consumers have the flexibility to adjust the electricity demand that occurs in market conditions. In recent years, the focus has been on making prices more transparent. Thus, when supply decreases, users limit their consumption and try to protect themselves from price increases (EIA, 2002).

Hiroaki (2002) mentions about unexpected temperature changes, failures in power plants, and disruptions in transmission lines. Bhattacharyya (2011) states that higher dependency on import generally tends to increase price risk and emphasizes that at a more disaggregated level, the import dependency by origin of supply could provide a more accurate picture about the risk.

Regarding the driving factors of wholesale electricity prices in Great Britain, Jones (2016) focuses on the risk factors as, "electricity generation mix, renewable energy, gas prices, and interconnectors." Jones (2016) arrives to some conclusions such as that the fuel mix affects the wholesale price, the use of renewable sources instead of conventional sources leads to lower wholesale prices, and the price of electricity depends partly on the price of natural gas. In addition, Jones (2016) emphasizes, "interconnections allow the trade of electricity in the form of export and import, importing electricity when the price of electricity is high in the local market and exporting electricity when the price in neighboring countries is high."

The United States Energy Information Administration (EIA) lists some factors that influence electricity prices (EIA, 2019). EIA focuses on key factors such as, "fuels, power plants, regulations, electricity network, weather conditions, and regulations." EIA reports that high electricity demand can incraese fuel demand, which can result in higher fuel prices and higher electricity prices. In addition, EIA states, "both power plants and electricity networks have construction, maintenance, and operating costs." EIA underlines that higher temperatures may increase the demand for electricity, particularly for cooling, and that demand may also increase prices. In addition, EIA notes, "in some cases, regulatory agencies regulate prices entirely, and in other cases, prices have a dual structure, regulated for transmission and distribution activities and not regulated for electricity generation."

Some country experiences regarding electricity price volatilities are summarized in Table 2. As can be seen from this table, the selected literature covers seven countries, namely Australia, Denmark, Germany, Ireland, Spain, Portugal, and Turkey.

- *Australia*: Three studies on Australia were reviewed. Ignatieva et al. (2016) examine whether there is a dependence between electricity spot prices and regional markets in Australia. The authors report a positive dependence between the prices for all markets considered in their work. They also emphasize that markets connected via interconnector transmission lines have the strongest dependence.

Worthington and Higgs (2017) state the resource mix used for electricity generation has a strong effect on electricity prices. Prices are generally lower with the use of brown and black coal and rise with the use of gas and renewable technologies. According to the authors, this shows, "the likelihood that wholesale prices will rise as the electricity industry moves towards renewable energy targets in the development of low-emission technologies such as gas and wind power."

Csereklyei et al. (2019) report that an additional 1 GW of dispatched wind capacity decreases the wholesale electricity price by 11 AUD/MWh at the time of generation. This value for 1 GW of solar capacity addition is calculated to be 14 AUD/MWh. These effects for both wind and solar capacity are called merit order effect in the literature. Importantly, the authors note that the wind merit order effect increases over time as a function of dispatched wind capacity. On the other hand, despite of the merit order effect in the market, electricity spot prices have been increasing primarily driven by the increase in gas prices in the country.

- *Denmark:* Rintamaki et al. report that renewable energy generation can both increase and decrease electricity price volatility depending on the renewable energy source. According to the same authors, wind power generation increases volatility, while solar energy generation decreases price volatility.

- *Germany*: Six studies on Germany were reviewed; namely Frank et al. (2007), Paraschiv et al. (2014), Rintamaki et al. (2017), Goodarzi et al. (2019), and Maciejowska (2020). In the studies on Germany, the impact of renewable electricity generation on the spot market was examined. The common point of the studies is that the increase in renewable electricity generation causes a price decrease in the spot market.

Frank et al. (2007) examine the impact of the supported renewable electricity generation on electricity spot market prices in Germany. Their work is based on the detailed electricity market simulation platform, PowerACE Cluster System. The results of their analysis provide that the renewable electricity generation has a considerable impact on market prices. For example, the reduction of the unweighted average price reached 7.8 Euro/MWh in 2006.

Table 2. Summary of some country experiences on electricity price risks

Year	Author(s)	Country	Explanation
2016	Ignatieva et al.	Australia	A positive dependence between spot market prices and regional markets included in the study. The strongest dependence between markets connected via interconnector lines.
2017	Worthington and Higgs	Australia	The mix of resources used for electricity generation has a strong effect on electricity prices. Prices are generally lower with the use of brown and black coal and are rising with the use of gas and renewable technologies.
2019	Csereklyei et al.	Australia	An additional 1 GW of dispatched wind capacity decreases the wholesale electricity price by 11 AUD/MWh at the time of generation. This figure for solar capacity is calculated to be 14 AUD/MWh.
2017	Rintamaki et al.	Denmark	Renewable energy generation may increase or decrease electricity price volatility, depending on the renewable energy source.
2007	Frank et al.	Germany	Renewable electricity generation has a considerable impact on spot market prices.
2014	Paraschiv et al.	Germany	Renewable electricity generation decrease spot market prices and shift the merit order curve.
2016	Benhmad and Percebois	Germany	The increase in wind power generation results in a decrease of spot market prices, but an increase of spot market prices volatility. In addition, the relationship between wind power and spot market prices are strongly impacted by European electricity grids interconnections.
2017	Rintamaki et al.	Germany	Wind power generation increases the volatility. On the other hand, solar power generation decreases price volatility.
2019	Goodarzi et al.	Germany	Higher wind and solar forecast errors increase the absolute values of imbalance volumes, resulting in higher spot market prices. Wind forecast errors have larger impacts on spot market prices than solar forecasting errors.
2020	Maciejowska	Germany	The increase in wind and solar based electricity generations has a similar, negative impact on the level of spot market price.
2014	O'Flaherty et al.	Ireland	Increase in wind power generation has little impact on average market prices.
2020	Macedo et al.	Portugal	Electricity generation from wind power is decreasing the spot market price of electricity but is increasing its volatility.
2013	Moreno and Garcia-Alvarez	Spain	The use of wind power in electricity generation contributes to the reduction of electricity market prices. In addition, energy dependence has an important impact on electricity market prices.
2020	Ciarreta et al.	Spain	The regulatory system for the promotion of renewable electricity plays an important role. Stable regulatory policies reduce volatilities. Market-based policy measures result in lower volatility.
2016	Özçakmak	Turkey	Electricity prices are not mainly defined by merit order in Turkish electricity market. Price formation curve in Turkish electricity market is mainly defined by the feed in tariff supports, mandatory purchase contracts, fuel prices and hydropower seasonality.
2019	Berk and Torun	Turkey	The existence of the merit-order effect of wind in Turkish electricity market based on daily data set of day-ahead market clearing prices and electricity generation from wind for the period of 2011-2018.
2019	Gayretli et al.	Turkey	The most drastic price differences in the market are due to natural gas. Key reasons for price spikes are supply problems in international markets, shortage problems, cold winter, and air conditioner usage.
2019	Acar et al.	Turkey	Wind and river type hydro power plants reduced the spot electricity prices for the period of 2012-2017. Their impacts on the spot market prices and price volatilities are different.
2020	Şirin and Yilmaz	Turkey	Significant negative merit-order effect for both wind and run-of-river hydro technologies. This effect varies with respect to demand, price level and technology.

Paraschiv et al. (2014) analyze whether the introduction of renewable electricity generation increases the price changes in the market. The authors report that renewable electricity generation shifts the merit order curve and lowers spot market prices. According to the authors, "off-peak hours are most sensitive to downward pressure in prices, and wind power is, on average, highest during these hours."

Benhmad and Percebois (2016) report that the increase in the share of wind power generation causes a decrease in spot market prices but increase volatility in spot market prices. In addition, the authors underline that the relationship between wind power and spot electricity prices is strongly influenced by the interconnection of European electricity grids. As noted by the authors, interconnection

functions as a security that reduces volatility and limits price decreases.

Rintamaki et al. (2017) report that depending on the renewable energy source, renewable energy generation may increase or decrease the volatility in electricity prices. For instance, wind power generation increases the volatility, on the other hand, solar power generation decreases price volatility.

Goodarzi et al. (2019) used data from the German electricity spot market. The authors state that higher wind and solar forecast errors increase the absolute values of imbalance volumes, leading to higher spot prices. In other words, wind forecast errors in Germany affect spot market prices more than solar forecasting errors.

Maciejowska (2020) reports, "the increase in the intermittent wind and solar generation significantly affects the distribution of electricity prices." In addition, the author indicates that both wind and solar based renewable electricity generations have a similar, negative impact on the market price.

- *Ireland:* O'Flaherty et al. (2014) state that the increase in wind power generation has little impact on average market prices. According to the authors, 48% of electricity is generated mainly from natural gas imported from UK, and the changes in Irish wholesale electricity prices are primarily determined by UK gas prices.

- *Portugal:* Macedo et al. (2020) examined the Portuguese case. They point out that electricity generation from wind power reduces the price of electricity and increases its volatility. The authors highlight, "the negative impact of electricity generation from wind power on the wholesale electricity price."

- *Spain:* Two studies on Spain were reviewed. Moreno & Garcia-Alvarez (2013) state that wind power generation can contribute to the reduction of electricity prices. The authors draw attention to the fact that energy dependence also has a significant impact on electricity market prices.

Ciarreta et al. (2020) conducted an experimental analysis with Spanish data. Unlike other authors, Ciarreta et al. (2020) claim that the development of the regulatory system promoting renewable electricity plays an important role. The authors analyze possible structural changes in Spanish electricity spot price volatility from January 2002 to December 2017. They identify, "two structural breaks linked to important measures related to renewable electricity: (a) the removal of the feed-in tariff; and (b) the establishment of a more market-oriented regulation based on investment and operating costs." The authors conclude that stable regulatory policies reduce volatility despite greater availability of renewable energy sources. In addition, market-based policy measures encourage good integration of intermittent renewable electricity, resulting in lower volatility.

In addition to the above explanations, Würzburg et al. (2013) state in their comparative studies that merit-order effects are quite similar in many European countries. As a justification, they point out that the merit order effect is the case for electricity systems with large fossil capacities, such as Germany, Spain, the Netherlands, Ireland, and Denmark. In these countries, as stated by Würzburg et al. (2013), fossil power plants are marginal power plants that still determine the price, at least at the peak of demand. In addition, the authors underline that the merit-order effect varies depending on the region and the assessment method selected in the study.

- *Turkey*: Five studies were reviewed regarding Turkey. Özçakmak (2016) states, "electricity prices are not primarily defined by merit order in the electricity market." On the contrary, the author notes, "price formation curve in the electricity market is mainly defined by the renewable support mechanism by feed in tariff, mandatory purchase contracts, fuel prices, and hydropower seasonality." In addition, the author underlines, "after the end of these BO (Build Operate) and BOT (Build Operate Transfer) power plants, these plants will lose priority in merit order and will be dispatched by relatively high efficiency natural gas and fossil fuel power plants." As pointed out by Özçakmak (2016), this structural change in electricity generation is expected to have a downward impact on spot electricity prices.

Berk & Torun (2019) used a daily data set covering Turkish day-ahead market clearing prices and electricity generation from wind over the period between 2011 and 2018. The results of their study confirm the existence of the merit-order effect of wind in Turkey's electricity market.

Gayretli et al. (2019) report "problems in the generation of natural gas-based power plants, 29.2% of the spikes are due to power plant and system failures that affect only real time prices." According to the calculations by Gayretli et al. (2019), the share of high temperature-based spikes is 13.9%, which is a result of air conditioner usage. The authors have found, "the most drastic price differences are due to natural gas." In addition, their study indicates that other reasons for spikes in electricity prices are supply problems in international markets and shortage problems.

Acar et al. (2019) rely on the EPİAŞ (electricity market operator located in Istanbul) data to check, "if wind and river type hydro plants, both of which are supported by feed-in-tariffs, reduce the electricity prices in the spot market." The authors applied price regressions and confirmed that wind and river type hydro plants reduced the spot electricity prices around 5.78 TL/GWh (3.15 US$/GWh) and 6.57 TL/GWh (3.58 US$/GWh) respectively covering the period 2012 to 2017.

Şirin and Yilmaz (2020) used quantile regression model and welfare analysis. The authors discuss the effect of variable renewable energy technologies in Turkish electricity market by examining the day-ahead market dynamics for the period of 2016-2019. Their study reveals significant negative merit-order effect for both wind and run-of-river hydro technologies. However, as reported by the authors, this effect varies with respect to demand, price level, and technology.

In addition to the above studies about Turkey, there are also other studies worth mentioning. For example, Uyanık (2018) points out that the contribution of renewable energy on reliable power supply will be limited because of their inherent deficiencies related to intermittency. Uyanık (2018) suggests that the thermal backup capacity must be

sufficiently present until the intermittency problem can be solved.

Dastan and Selçuk (2016) draw attention to the fact that electricity and gas markets are highly intertwined in Turkey and consequently Turkey's security of gas and electricity problems is intertwined. On the other hand, Palmer et al. (2012) state that the increase in domestic natural gas supply will significantly reduce retail electricity prices in the next 20 years. Shahidehpour et al. (2005) note, "a significant reliance on the natural gas supply could seriously impact the security and the market price of electricity." Moreover, Shahidehpour et al. (2005) report, "the utilization of distributed and renewable energy in electric power system could reduce the power flow congestion when the supply of gas is scarce or the market price for gas is high."

Ocakoğlu and Tolga (2018) report that electricity spot prices may change even if there is fluctuation in electricity generation or load. In this context, the authors point out that four main characteristics of electricity are grouped under seasonality, volatility, mean reversion, and spikes. In addition, the authors note, "electricity market faces many internal and external risks, such as breakdowns, maintenances, fossil fuel supply reliability, commodity prices, weather conditions, water inflow, currency risk, credit risk, and political etc."

In Turkey, electricity companies are able to trade electricity in the day ahead and intraday markets. In day ahead market, generators can set their prices one day in advance and make transactions (Özpınar, 2020). According to the legislation in effect, this price is called market clearing price and is determined on an hourly basis. Changes in supply and demand in the market affect the spot market price. The intraday market enables generators to trade in near real-time and dynamic free market conditions (Özpınar, 2020). This market enables generations to balance the fluctuations in their portfolios planned in the short term (Özpınar, 2020).

The markets, which are run by EPİAŞ is operated according to market rules. When price fluctuations and risks are analyzed, it is seen that renewable based generators participating in RESUM are not exposed to spot price risk, but only to price fluctuations due to changes in US exchange rate. However, other generation companies are subject to spot market price risk. Electricity trading companies are the companies which are the most open to price fluctuations and US exchange rate changes.

In Turkish electricity market, among other factors, factors such as the number of power plants participating in the renewable support mechanism (RESUM), the delay in completing the investments within the anticipated period, and the unbalanced distribution of generation and consumption units across the country are thought to have an impact on electricity price fluctuations. It is seen that these issues are not addressed in the relevant literature and in the studies mentioned above.

A specific issue regarding the support mechanism for electricity generation from renewable energy sources (RESUM) in Turkey is that the support price is denominated in US Dollars, but the actual payment is made in TL. The increase in the US exchange rate against TL increases the burden on suppliers under the current law no. 5346 and creates uncertainty when making bilateral agreements with eligible customers. In other words, the exchange rate risk is reflected on consumers.

All the factors discussed above can be classified based on whether they are systematic risk factors. Some of these factors are systematic risk factors and cannot be avoided. For example; economic growth, the volatilities in oil and natural gas prices, US Dollar exchange rate against TL, adverse weather conditions, are all systematic risk factors. In addition, the merit order effect in the day ahead market, the number of renewable power plants participated in the renewable support mechanism, delays in the completion of investments within the anticipated time, and the uneven distribution of generation and consumption units all over the country, are all unsystematic risk factors. Since these unsystematic risk factors are specific to both the electricity market and the natural gas market, the effect of unsystematic risk factors on the price of electricity can be reduced by appropriate tools and methods.

3. A summary of Turkish electricity market

The history of first organized initiatives in the electricity sector in Turkey dates back to the Ottoman Empire. In this context, for the first time, the concession was granted to the Hungarian Ganz electricity partnership for a period of 50 years in order to provide the electricity services of Istanbul in 1910 (Dolun, 2002; Özdemir, 2016). The installed power capacity, which was 13.7 MW in 1913, increased to 32.8 MW in 1923 (Erol, 2007).

When the Republic of Turkey was proclaimed, only Istanbul, Tarsus, and Adapazarı could benefit from electricity (Aslan et. al., 2007). During the period of 1923 to 1930, the electricity sector was dominated by foreign investors, mostly German, Belgian, Italian, and Hungarian investors (Hepbaşlı, 2005; Alaçam, 2014). Turkey's first private company, Kayseri and Vicinity Electricity Company was found in 1926 in Kayseri (Hepbaşlı, 2005). After the 1940s, the state started to operate electricity generation and transmission activities, and make investments in the sector as well (Alaçam, 2014). Until 1953, Etibank, İller Bank, municipalities, and many industrial companies had been active in the generation and distribution of electricity (Kulalı, 1997; Alaçam, 2014). General Directorate of State Hydraulic Works (DSI General Management) was established in 1953 for the construction of large dams (Kulalı, 1997). Between 1945 and 1960, electricity investments were carried out by companies established together by the state and private sector.

With the establishment of the Ministry of Energy and Natural Resources in 1963, the state increased its share in the electricity sector (Alaçam, 2014). During the period of 1950 to 1960, all investments and services were realised by the state (Alaçam, 2014). But the active participation of the state in the sector could not prevent the effects of the energy crisis between the 1970s and 80s in Turkey (Hepbaşlı, 2005). During this period, the balance of public finance had deteriorated, and financial measures such as additional budgetary searches and domestic borrowing had started to be applied to attract the private sector (Şahin, 2006).

In light of these developments, the privatisation of electricity assets was on the agenda of the Turkish government. Two special reasons contributed to the growing interest in the privatization of the sector. The first was the general tendency to transition to the free market structure, and the second was the concern that increasing electricity demand could not be met by limited public funds (Atiyas, 2006).

In 1982, in Turkey, all electricity related assets were transferred to Turkey Electricity Authority (TEK) with the Law No. 2705 in order to centralize the electricity system. In addition, the law no. 2705 allowed private companies to establish power plants and sell electricity to TEK, a vertically integrated state-owned enterprise. TEK became a monopoly on electricity sector (Hepbaşlı, 2005).

With the law no. 3096 in 1984, the Turkish government decided to open the electricity sector to the interest of private investors. In 1993, TEK was divided into two companies, Turkey Electricity Generation and Transmission Company (TEAŞ) and Turkey Electricity Distribution Company (TEDAŞ) (DPT, 2001). In this period, private enterprise was encouraged to invest by using BO, BOT, Transfer of Operating Rights (ToOR), and autoproducer models.

In 1999, inefficiency in the public sector and the effect of ongoing reform movements in the world leaded to studies to design a competitive electricity sector in the country. Within the scope of studies, Electricity Market Law No. 4628 was adopted and came into force on 2001 (Çetin and Oğuz, 2006; EPDK, 2003).

The main principles and legal infrastructure of the law no. 4628 are adapted from those of the European Union. The main purpose of the law no. 4628 is a transition to a liberal market structure from a vertically integrated state monopoly. The government issued strategy documents in 2004 and 2009 to further improve the reform process (ETKB, 2004; ETKB, 2009). Within the scope of the law no. 4628, EPDK was established in 2001. EPDK is in charge of issuing secondary legislation, issuing licenses, approving tariffs, monitoring, auditing, implementing sanctions etc.

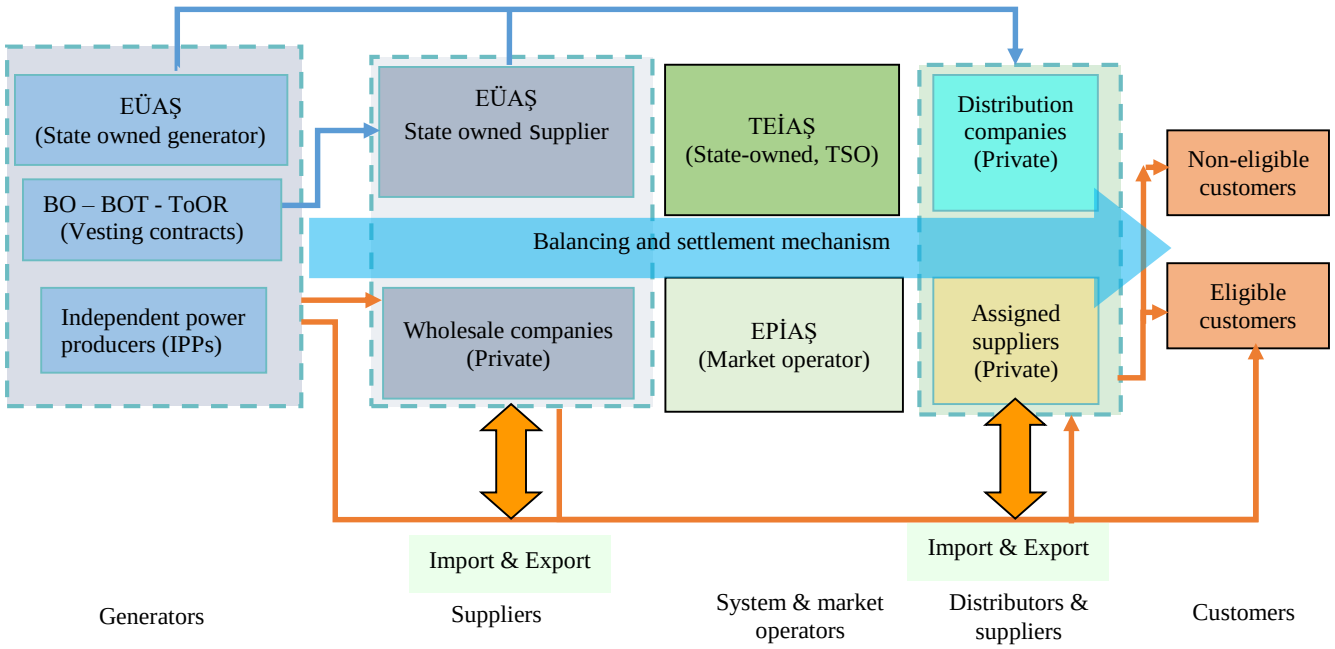
In addition, in 2001, TEAŞ was divided into three separate economic state organizations, Turkey Electricity Transmission Company (TEİAŞ), Electricity Generation Company (EÜAŞ) and Turkey Electricity Trading and Contracting Company (TETAŞ). In 2004, TEDAŞ was divided into 21 regions. Currently, all regional distribution companies are run by private hands. TEİAŞ remains in the hands of the state and functions as market and transmission system operator (TSO). Retail unbundling was completed in 2013.

In 2013, taking into account the experience gained in the electricity market for a period of about 12 years, a new market law no. 6446 was accepted and became in effect (E-mevzuat, 2013). By the law no. 6446, the activities in the electricity market, except for network activities are open to competition and they are under the supervision of, and regulated by EPDK.

On March 3, 2003, the first time in the electricity market, eligible customers were allowed to select their own suppliers in the market. All customers directly connected to the transmission network as well as consumers with consumption of more than 1.400 kWh per year for 2020 are deemed as eligible customers (EPDK, 2020a).

Electricity market structure, market players, and the relation among them are given in detail in Fig. 1.

Fig. 1. Electricity market structure in Turkey



According to law no. 6446, the electricity market structure is based on bilateral contracts market complemented by day ahead market (DAM), intraday market, and residual balancing market. The law no. 6446 foresees an introduction of a power exchange in the medium-term as well. Regarding network access, regulated third party access is applied. Transmission and distribution companies should allow open, guaranteed, and non-discriminatory access to their networks, which is backed by EPDK's oversight. Network tariffs and sales to captive customers as

well as tariffs for last resort customers are regulated by EPDK. Legal separation must be implemented between market activities.

All market activities must be licensed by EPDK with some exemptions. In Turkey, renewable based power plants with a generation license issued by EPDK are supported by fixed feed-in tariff depending on source and technology, with an additional premium for locally manufactured equipment usage. Renewable power plants up to 5 MW, micro-cogeneration facilities up to 100 kW, cogeneration facilities with above certain efficiency values, generation facilities for municipal waste disposal and treatment facilities, and isolated generation are exempted from licensing and establishing companies. Excess generation from unlicensed renewable power plants are priced at fixed feed-in prices. But, for generation facilities completed after June 2018, the support tariff is determined by the President of Turkey as the retail sales tariff for the subscriber group corresponding to the consumption unit associated with the unlicensed generation facility (EPDK, 2019a).

As can be seen from Fig.1, non-eligible customers (*captive consumers*) can only only purchase electricity from assigned suppliers. The most free part of the electricity market is generation and supply activities. Wholesale suppliers and assigned suppliers can export and import electricity. Generation companies are allowed to export electricity they generate. In the electricity market, there are 3 group of generators: EÜAŞ, vesting contract holders, and independent power producers (IPPs). EÜAŞ is the state owned generator together with a supplier license after the merge of TETAŞ under EÜAŞ in 2019 (E-mevzuat, 2013).

Vesting contract holders are those companies which have a long term agreement with the Turkish government for the sale of electricity they generate. When the duration of the contracts ends, they become IPPs in accordance with the regulations in law no. 6446. Independent power producers are privately owned generators that can sell their output in the free market. EPİAŞ is the market operator and runs the organised wholesale electricity market including DAM and intraday market.

TEİAŞ is responsible for the transmission of electricity in all over Turkey and operates real time balancing and ancillary services markets as well. Distribution companies are natural monopolies for the electricity distribution in their designated regions. Electricity tariffs for non-eligible customers and last resort customers are regulated by EPDK. Electricity prices in organised wholesale markets are not regulated by EPDK and are formed under the free market conditions. The tariffs for the use of electricity networks are regulated by EPDK as well.

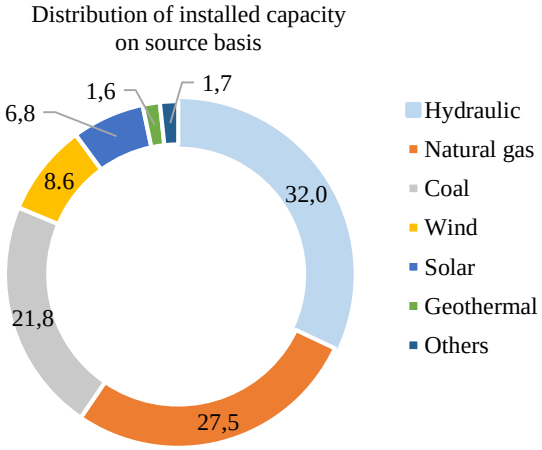
Turkey has a growing electricity market and, as end of August 2020, the total installed capacity of electricity reached 93 GW in Turkey (TEİAŞ, 2020a). Currently, EÜAŞ continues to dominate the electricity market with a 26% share in installed capacity basis in generation (TEİAŞ, 2020a). Distribution of installed capacity on source basis in GW is given in Table 3.

Table 3. Distribution of installed capacity on source basis (GW), (TEİAŞ, 2020a)

Source	GW	%
Hydraulic	29.8	32.0
Natural gas	25.6	27.5
Coal	20.3	21.8
Wind	8.0	8.6
Solar	6.3	6.8
Geothermal	1.5	1.6
Biomass	0.84	0.9
Waste heat	0.37	0.4
Fuel oil	0.31	0.3
Others	negligible	negligible
Total	93.02	100

The distribution of installed capacity as a percentage on source basis is given in Fig. 2. Hydraulic, natural gas, and coal power plants account for 81.3% of the total installed capacity. Wind and solar power plants have a share of 8.6% and 6.8% respectively.

Fig. 2. Distribution of installed capacity on source basis (%), data from (TEİAŞ, 2020a)

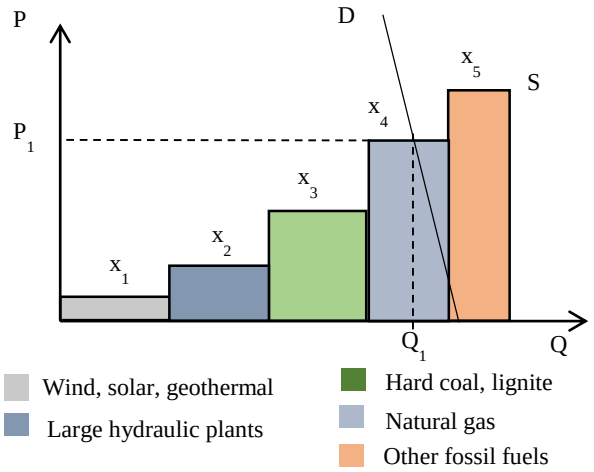


On the other hand, in 2018, the share of sources in electricity generation is 30.3% for natural gas, 19.6% for hydro, 6.5% for wind, 2.4% for geothermal, 16.5% for domestic coal (*lignite, coal and asphaltite*) and 20.7% for imported coal. The share of other resources is negligible (TEİAŞ, 2020b). In the present case, the share of electricity trade through the interconnection lines is negligible in Turkey (TEİAŞ, 2020b).

4. Electricity price formation in the market

Marginal pricing is implemented in organized wholesale market in Turkey. In this method, price bids are ranked from small to large. The bid price at the point where the supply is equal to the demand is considered as the market clearing price. The market clearing price is applied to all generators that meet the demand. In Turkey, the marginal units that bid to the market where prices are formed, are mostly natural gas and hydroelectric power plants, and therefore the power plants that determine the market price are mostly natural gas and hydroelectric power plants (see Fig. 3).

Fig. 3. Price formation in organised wholesale electricity market in Turkey



In Fig.3; P, Q, D, and S refer to DAM price, quantity in kWh, demand, and supply respectively. X_1, X_2, X_3, X_4, X_5 refer to bids from different fuels and sources and are illustrated in different colors in Fig.3. Importantly, among these X values, the following can be written.

$$X_1 < X_2 < X_3 < X_4 < X_5$$

As can be seen from Fig. 3, the electricity prices in the market are mainly influenced by power generators from natural gas and dam-type power plants. In addition, it can be said that the effects of power plants generating electricity from other sources are negligible.

Since electricity prices arise due to supply and demand realized in the market, it is not only the supply side that affects the formation of prices, but also the continuous change in demand side due to seasonal factors on a daily, weekly, monthly basis and economic growth shapes the formation of electricity prices. In this context, changes in economic growth and the level of seasonal events will likely affect electricity prices on the demand side. Since dams have an impact on price formation in the electricity market, the situation of hydraulic resources used in electricity generation is also a critical issue to be examined. In addition, if there is a dominant position in the market, it will not be possible to form a price under competitive conditions.

5. Key driving factors affecting electricity price risk in Turkey

As outlined above, considering the price formation and market structure of Turkish electricity market, the key driving factors affecting electricity price risk in Turkey are summarised in Table 4. These factors can be grouped under six headings; a) The design and operation of electricity market, b) The design and operation of natural gas market, c) Macroeconomic factors, d) Policy and regulations, e) Weather events, and f) Force majeure. Each factor in Table 4 is examined in detail below.

Table 4. Factors affecting electricity price risk in Turkey

Main factors	Subheadings of main factors
a) The design and operation of electricity market	• The functioning of organised wholesale electricity market (*Merit order effect*) • The attractiveness and volume of renewable energy support mechanism • Generation investments - The uneven regional distribution of generation and consumption units - Delays in the completion of generation investments - Fuel mix
b) The design and operation of natural gas market	• Delays in the liberalisation of natural gas market • Import dependency on natural gas market • Crude oil price • Natural gas price in foreign currency • Natural gas storage
c) Macroeconomic factors	• Economic growth and economic cycles
d) Policy and regulations	• Policy and regulations related to electricity market • Policy and regulations related to other sectors
e) Weather events	• Precipitation, water regime • Wind speed • Solar radiation • Seasonal effects
f) Force majeure	• Natural and social events such as earthquake, epidemic disease, strike, flood etc.

Source: Adapted from Alaçam (2014), developed and expanded by the author

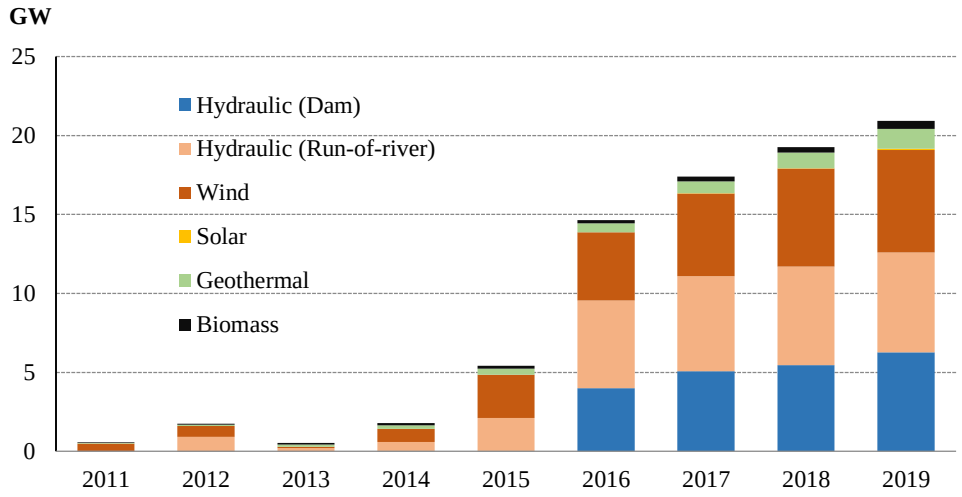
5.1. The design and operation of electricity market

- *The functioning of organised wholesale electricity market (Merit order effect):* As highlighted earlier, marginal pricing methodology is applied in DAM in Turkey. Referring to Fig.3, the market price is generally determined by natural gas fired power plants or hydroelectric power plants with dams. Since the variable cost in electricity generation from renewable energy sources is low or negligible compared to fossil sources, natural gas fired power plants and hydroelectric plants with dams are the price determinants in merit order structure. But, the limited natural gas supply and volatility in the water regime cause uncertainties in the price of electricity. Regarding Turkish electricity market for the past 4 years, the reason that dams and natural gas power plants determine the marginal price is not because renewables have lower variable full costs but because they are not real bidders for the price but their

volume affect the price due to regulation. Regardless of variable fuel cost of renewables in the RESUM regime, they have no price risk. According to Law No. 5346, renewable power generators are guaranteed a fixed price which is indexed to the US exchange rate. On the contrary, Hildmann et al. (2013) argue that energy only markets can remain functional despite high RES power generation if the necessary regulatory measures are taken, for example increasing the spot market's share of overall load demand and using the true marginal costs of renewable power units in the merit-order.

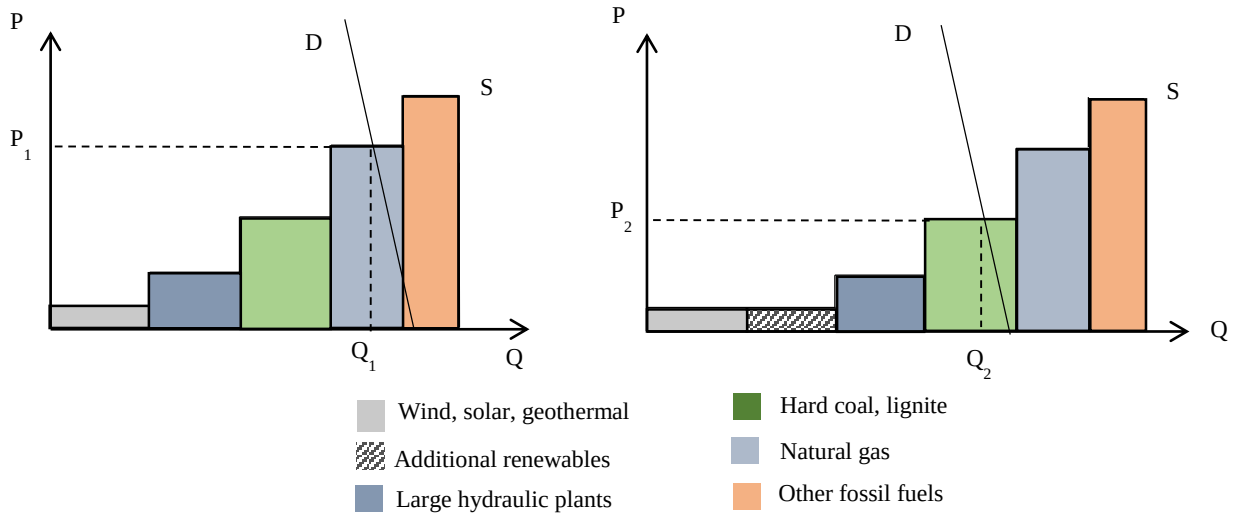
- *The attractiveness and volume of renewable energy support mechanism*: The total installed capacity participating in renewable energy support mechanism (RESUM) by years is given in Fig.4. After 2015, there is a significant increase in the capacity participated in RESUM. This increase is expected to continue in the coming years. However, it is unpredictable how many renewable power plants will participate in the support mechanism each year.

Fig. 4. The total installed capacity participating in RESUM, including only licensed power plants, data from (EPDK, 2019b)



If more RES power plants participate in RESUM, the market price will likely fall. In fact, as pointed out by Acar et al. (2019) and Berk and Torun (2019), Sirin and Yilmaz (2020), a negative merit order effect is shown in the Turkish electricity market. In this case, the electricity generated from the base power plants in the system, in particular coal or natural gas fired power plants, are forced to be traded at market prices below their generation costs (see Fig. 5). Since these power plants are expected to bid according to their generation costs, they cannot be expected to continue operating at a market price below their generation costs. In this business environment, renewable power plants could replace the traditional power plants. In such a case, problems may arise in terms of supply and system security in the country as electricity cannot be stored economically yet and generation based on renewable energy sources have an unstable structure.

Fig. 5. Merit order effect in organized wholesale electricity markets
Note: P, Q, D, and S have the same meaning as in Fig. 3.



- *Generation investments:* Three issues related to generation investments can be discussed. These are the uneven regional distribution of power plants and consumption units, delays in the completion of generation investments, and fuel mix.

- *The uneven regional distribution of power plants and consumption units*: Another factor for price risk is the difficulty in supplying electricity to regions where electricity demand unexpectedly increases. Large hydraulic power plants generating high amounts of electricity are located in the eastern part of Turkey (Alaçam, 2014). However, industrial plants with high electricity consumption are in the western part of the country where electricity demand is high. In this context, if there is a problem in transporting the electricity from east to west via transmission lines, unexpected increases in demand in the western region may inevitably lead to fluctuations in electricity prices in the current market structure. Although there is only one market price in the electricity market, it is considered that price fluctuations may occur in case of an increase in demand for electricity in the western regions and problems in the transmission of electricity from east to west since the distributed generation in Turkey is still not widespread.

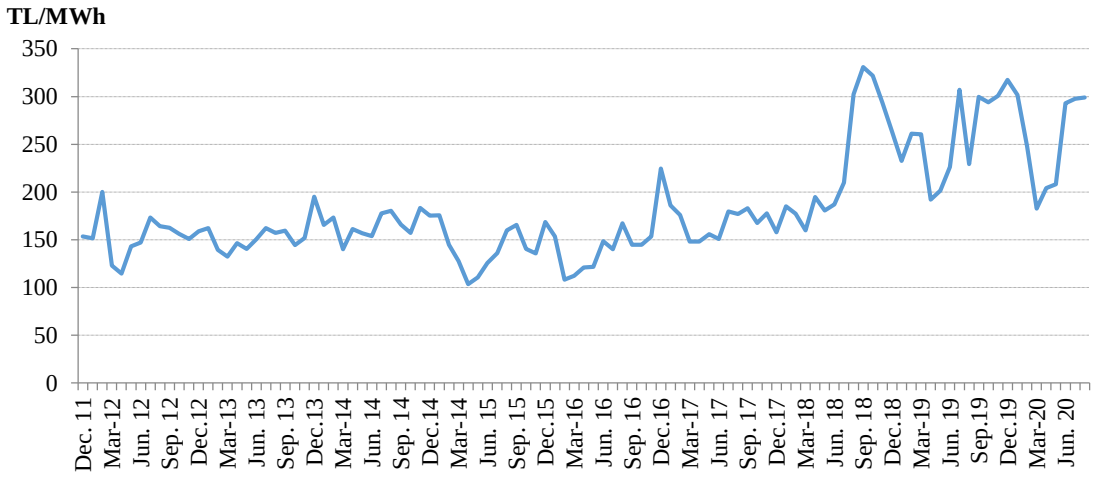
- *Delays in the completion of generation investments*: The delay in a planned investment in an electricity generation investment, which is guaranteed to be connected to the electricity grid, has a negative impact on the future supply and demand balance and leads to fluctuations in electricity prices. In addition, the lack or delay in the planned investment may delay the entry of serious investors into the market. In the generation license issued to the investors by EMRA, the connection of the power plant subject to the license to the electricity network is guaranteed and this issue is written in the relevant license. If the license holder does not install the power plant to be installed, it means that it keeps the network capacity allocated to it. Therefore, if investors hold the right to connect to the network without realising the relevant investment, this may lead to price fluctuations in the market in the long term. For this reason, it is important to monitor generation investments and to complete them within the anticipated time.

- *Fuel mix*: In electricity generation in Turkey; natural gas, coal, and hydraulic possess significant shares. The share of renewable energy is increasing. The electricity system continues to use less carbon intensive fuel sources and is undergoing significant changes. Fuel costs in conventional power facilities vary depending on natural gas and coal prices, and exchange rates. Renewable energy sources have no fuel costs. Therefore, fuel mix in electricity generation affects the wholesale price in the market.

5.2. The design and operation of natural gas market

- *Delays in the liberalisation of natural gas market*: The natural gas market in Turkey does not have a competitive structure in its present form. On the other hand, almost half of the electricity generation comes from natural gas in Turkey. Natural gas shortages pose unmanageable crisis in the electrcity market. In normal winter conditions in Turkey, natural gas outages are experienced due to lack of storage capacity. This poses a serious pressure on electricity prices. Price increases due to natural gas outages are shown in Fig. 6.

Fig. 6. Monthly average DAM prices of recent years (TL/MWh), TL stands for Turkish Lira. Monthly data from Dec. 2011 to August 25, 2020, Source: EPİAŞ (2019)



As can be seen in Fig. 6, the main point of price movements is the rise in electricity prices in certain periods, especially in harsh weather conditions in winter. In general, demand for electricity is not elastic, and when demand is low, the power plants produce the electricity at the lowest marginal cost. However, when demand increases during certain periods of winter, in summer or even at certain times of the day, electricity generators which produce electricity with higher marginal costs step in and raise prices. On the other hand, Turkey has another major problem that causes a sudden peak in the price of electricity caused by the natural gas market. This is natural gas shortages due to insufficient capacity of natural gas transmission lines, especially in difficult winter days. In winter, generation plants with high marginal costs run at certain times because the flow of natural gas is not enough to meet the demand for the electricity generation due to harsh winter conditions. High-cost power plants replace natural gas power plants and cause prices to rise. In summer, the same may be due to an increase in cooling requirements.

As stated earlier, Jones (2016) states that the price of electricity is in part driven by the price of natural gas. This is because gas-fired electricity generation is often the marginal source of electricity generation. As the price of natural gas rises and falls, so does the cost of natural gas fired power plants. When electricity demand is low it is met by cheap sources of power. This has traditionally included coal fired and nuclear power plants whereas renewables are now playing an increasing role as explained earlier. However, when demand increases in Great Britain, electricity generation from the combustion of natural gas, relatively more expensive production, is added to the fuel mix as the source of marginal electricity generation and sets the wholesale electricity price Jones (2016).

- *Import dependency on natural gas*: High import reliance normally tends to increase price (Bhattacharyya, 2011). Bhattacharyya (2011) emphasizes that at a more disaggregated level, the import dependency by origin of supply could provide a more accurate picture about the risk.

Political or other problems that arise in countries that produce fuel sources used to generate electricity are also important in terms of price movements. Nearly half of the natural gas consumed in Turkey is imported from the Russian Federation. Political stability in the Russian Federation and other international events will result in volatilities in natural gas prices.

- *Crude oil price*: The cost of natural gas consumed in electricity generation is reflected in the electricity tariff as it is. Natural gas prices are indexed to crude oil prices. In this context, natural gas prices are expected to be affected by price changes in global oil markets. Therefore, the change in crude oil prices is expected to lead to changes in electricity prices.

- *Natural gas price in foreign currency*: Another parameter affecting natural gas prices is the exchange rate. Natural gas prices will be affected by the changes in US Dollar exchange rate against TL as natural gas is purchased in US Dollar from the source countries and sold to Turkish electricity generation plants and other consumers in TL. In electricity generation from natural gas, the variable generation cost is the price of natural gas. 30.3% of electricity production in Turkey is natural gas (TEİAŞ, 2020b). In this respect, changes in the price of natural gas will be reflected in the price of electricity. As the natural gas import price is in foreign currency, the change in foreign exchange is expected to cause fluctuations in electricity prices.

- *Natural gas storage:* In addition to its contribution to security of supply, storage activity in the natural gas market also has a feature of providing price balance in the market. The increase in storage capacity to reduce fluctuations in natural gas supply will ultimately be reflected as a less serious change in electricity prices.

5.3. Macroeconomic factors

- *Economic growth and economic cycles*: Turkey has a growing economy. It is inevitable that there will be an increase in the demand for electricity with economic growth. Moreover, per capita electricity consumption in Turkey still has the potential to increase compared to OECD countries (Yıldırım & Dağdemir, 2018). All these issues will increase demand during periods of economic growth and will lead to fluctuations in electricity prices. Depending on the economic cycles, there will be changes in electricity demand. It is expected that decreases in demand will probably lead to a decrease in prices, increases will cause an increase in prices and therefore prices will fluctuate.

5.4. Policy and regulations

As noted in the literature review section, priority access granted to renewable technologies has resulted in lower prices in major European wholesale markets, mainly sourced from traditional sources. Indeed, in Turkey, priority is given to renewable energy in balancing and settlement process within the scope of Law No. 5346. As mentioned above, this priority leads to the merit order effect. Also, as stated by Ciarreta et al. (2020) in the case of Spain, the transition from a fixed price guarantee to a market-based support method may result in a decrease in price fluctuations. Hence, it is understood that the policies and regulations followed in the electricity market have an impact on the market price. In addition, provisions that prevent or encourage investments outside the electricity market can affect the investments positively or negatively. It is thought that this problem may cause imbalances and price fluctuations on the supply and demand sides in the long run.

5.5. Weather events

- *Water regime*: As demand of electricity can increase rapidly due to adverse weather conditions, and in this case, additional generation plants in the market would be limited and expensive to run, adversely hydroelectric generation could also increase in the spring with the melting of snow and this causes a decrease in electricity prices. Looking at the monthly change in electricity prices, it can be concluded that the fall in prices until May each year is the result of electricity generation from hydraulic power plants due to precipitation and melting of snow. Rain and snow provide water for low-cost hydropower generation. Wind can provide low-cost electricity generation from wind turbines when wind speeds are favorable. However, extreme temperatures can increase the demand for electricity, especially for cooling, and demand can drive prices up (EIA, 2019).

- *Wind speed and solar radiation*: As seen from Fig.2, the shares of wind and solar power plants in total installed capacity are 8.6% and 6.8% respectively. Volatilities in wind speed and solar radiation would likely change the electricity generation from wind and solar power plants. As both types of plants are geographically well distributed, changes in wind speed and solar radiation are not expected to cause large fluctuations in electricity prices throughout the country. However, it is valid in the case of Turkey that the increase in the installed capacity of renewable energy power plants leads to a decrease in price with the effect of merit order given above.

- *Seasonal effects*: Electricity prices in Turkey, mainly affected by fluctuations in temperature depending on the winter and summer months. This fluctuation is due to the need for heating in winter and cooling in summer (Alaçam,

2004). Therefore, electricity prices fluctuate depending on the seasonal effect.

5.6. Force majeure

It is thought that unpredictable and unavoidable events such as earthquakes, epidemics, and floods, which are called force majeure, may cause fluctuations in electricity prices. However, there are no studies on this subject in Turkey.

The changes in monthly electricity consumption and day-ahead market price for the period in which some measures were implemented in Turkey due to the Covid-19 pandemic are given in Table 5. Especially from March to May, there was a decrease in both electricity consumption and the market price. With the partial removal of the measures since the beginning of June, consumption and price increases draw attenttion.

Table 5. Electricity consumption and day ahead market prices during January - June in 2020 in Turkey

	January	February	March	April	May	June
Consumption (TWh)	27	25	24.8	20.3	21	24
Weighted average of day ahead market price (TL/MWh)	301.6	248	182.6	204.2	208	292.8

Source: EPDK (2020b) and EPİAŞ (2020)

6. Discussion and conclusion

With the liberalization movement that started in 2001 in the electricity market in Turkey, electricity price risk emerged in the free market structure. Except for regulated prices for non-eligible and vulnerable customers, electricity prices have been formed in the free market since 2006 in Turkey. Before 2001, there was no electricity price risk due to the purchasing guarantee in the old structure based on BO, BOT, and ToOR. Therefore, it is necessary to understand which factors lead to electricity price risk in terms of effective price risk management. Considering the fuel mix in the electricity generation in Turkey, natural gas and water regime appear to be the main indicators of electricity price risk in the country. In this respect, natural gas price, crude oil price, US Dollar exchange rate against TL, and natural gas storage are considered as critical parameters within the framework of the natural gas market. In Turkey, electricity market is integrated with natural gas market in terms of electricity generation. In the liberalization process in the electricity market, significant success has been achieved within the framework of the objective of creating a free market since 2001. The same success needs to be achieved in the natural gas market as well. For this reason, a liberalized natural gas market is considered to have positive contributions in terms of price formation in the electricity market.

On the other hand, since hydraulic resources have an important share in the country, sufficient and regular water income comes to the forefront in electricity generation. The irregularity in the water regime may cause fluctuations on the supply side in electricity generation, and the excess water level after heavy rainfall may lead to a decline in electricity prices.

Regarding electricity generation investments, it may be considered to obtain a relatively high amount of collateral from related investors for the timely completion of investments and to convert the collateral into cash when the investment is not completed on time.

As mentioned earlier, there is a high demand for RESUM. The main reason for this is thought to be the fixed support tariff in US Dollar. The continuation of this situation may lead to a fall in electricity prices, which may result in the closure or discontinuation of conventional power facilities. However, in case of an increase in demand, electricity prices may fluctuate due to lack of supply to meet increasing demand. According to the law no. 5346, feed-in tariffs will only be implemented to renewable power plants which are completed and in operation before the end of 2020 (E-mevzuat, 2011). Since the law no. 5346 regulates a fixed feed-in tariff, it is recommended that market based mechanisms such as feed-in premium or auctioning feed-in prices can be a choice following the period starting the year 2021. In this way, a market-based solution would also be a suitable solution in terms of electricity price risk management. Thus, as underlined by Ciarreta et al. (2020), the transition to a less volatile market structure is realized.

As can be seen from Table 5 and Fig. 6, during January-April, 2020, both electricity consumption and electricity price decreased, largely due to the lockdown during the Covid-19 outbreak. Both values have increased since June, 2020, with the removal of some restrictions. As discussed in detail in the literature section for Turkey, several studies point out the decrease in the spot price of electricity due to merit order effect.

The negative merit order effect is important in terms of supply security in Turkish electricity market. This effect could adversely affect the security of electricity supply. As emphasized by Uyanık (2018), it is beneficial to have sufficient thermal backup capacity for more renewable energy use depending on the technological developments to eliminate the negative aspects of renewable energy use.

As a summary, the main driving factors of electricity price risks in Turkey are factors related to the design and operation of electricity and natural gas markets, macroeconomic factors, and weather conditions. These factors, regardless of their importance, can be listed as follows: The merit order effect in DAM, the volatilities in oil and natural gas prices, US Dollar exchange rate against TL, the number of renewable power plants participating in RESUM, adverse weather conditions, force majeure events, the delays in the completion of investments, the uneven distribution of generation and consumption units, policies and regulations on the electricity market, and other issues. In conclusion, in this study, the main factors affecting electricity price risk in Turkey were first classified and then analyzed. It is thought that this study will shed light on detailed studies to be carried out on each factor mentioned above.

References

Acar, B., Selcuk, O. & Dastan, S.A. (2019). The merit order effect of wind and river type hydroelectricity generation on Turkish electricity prices. *Energy Policy*, 132, 1298-1319.

Alaçam, V. (2014). *Elektrik piyasasında fiyat riski: Kavramsal analiz ve Türkiye için öneriler*. Uzmanlık tezi, Ankara: Enerji Piyasası Düzenleme Kurumu.

Aslan, İ.Y., Altınay, G., Ilıcak, A., Önal, E., Katırcıoğlu, E., Ardıyok, Ş., Gültekin, B. & Akçaoğlu, C. (2007). *Enerji hukuku cilt-1 elektrik piyasasında rekabet ve regülasyon*. Ankara: Ekin Basın Yayın Dağıtım.

Atiyas, I. (2006). *Elektrik sektöründe serbestleşme ve düzenleyici reform*. İstanbul: TESEV Yayınları.

Bağcı, H. (2004). *Enerji borsaları ve bu borsaların Türkiye'de kullanımı*. Türkiye enerji forumu, 16.

Behmand, F. & Percebois, J. (2016). Wind power feed-in impact on electricity prices in Germany 2009-2013. *The European Journal of Comparative Economics*, 13(1), 81-96.

Berk, İ. & Torun, E. (2019). Testing Merit-Order Effect in Turkey's Electricity Market: The Effect of Wind Penetration on Day-Ahead Electricity Prices. *Akdeniz İİBF Dergisi*, 19(1), 133-156.

Bhattacharyya, S.C. (2011). *Energy economics: Concepts, issues, markets and governance*. London: Springer-Verlag London Limited.

Biewald, B. (2003). Risk management of the electricity portfolia. *Regulatory Assistance Project Issues Letter*, 1.

Blonco, C. & Soronow, D. (2001). Mean reverting process-Energy price processes used for derivatives pricing & risk management. *Commodities Now*, 5(2), 68-74.

Chawda, S. & Deshmukh, S. (2012). Assessment of price risk of power under Indian electricity market. *International Journal of Computer Applications*, 59(11), 12-17.

Ciarreta, A., Pizarro-Irizar, C. & Zarraga, A. (2020). Renewable energy regulation and structural breaks: An empirical analysis of Spanish electricity price volatility. *Energy Economics*, 88, 1-11.

Csereklyei, Z., Qu, S. & Ancev, T. (2019). The effect of wind and solar power generation on wholesale electricity prices in Australia. *Energy Policy*, 131, 358-369.

Çetin, T. & Oğuz, F. (2007). The politics of regulation in the Turkish electricity market. *Energy Policy*, 35(3), 1761-1770.

Dastan, S. A. & Selçuk, O. (2016). Review of the security of supply in Turkish energy markets: Lessons from the winter shortages. *Renewable and Sustainable Energy Reviews*, 59, 958-971.

Dolun, L. (2002). *Türkiye'de Elektrik Enerjisi Üretimi ve Kullanılan Kaynaklar*. Uzmanlık Tezi, Ankara: Türkiye Kalkınma Bankası A.Ş.

DPT, Devlet Planlama Teşkilatı (2001). *Sekizinci beş yıllık kalkınma planı, Elektrik Enerjisi Özel İhtisas Komisyonu Raporu*. DPT: 2569 - OİK: 585. Ankara: DPT. (Accessed: 03/08/2019), https://www.sbb.gov.tr/wp-content/uploads/2018/11/08_ElektrikEnerjisi.pdf

EIA, Energy Information Administration U.S. Department of Energy (2002). *Derivatives and risk management in the petroleum, natural gas and electricity industries*. Washington, D.C.: U.S. Department of Energy, 9-10.

EIA, Energy Information Administration U.S. Department of Energy (2019). *Factors affecting electricity prices*. Washington, D.C.: U.S. Department of Energy (Accessed: 10/09/2019), https://www.eia.gov/energyexplained/electricity/prices-and-factors-affecting-prices.php

E-mevzuat, Mevzuat Bilgi Sistemi (2011). *5346 sayılı Yenilenebilir Enerji Kaynaklarının Elektrik Enerjisi Üretimi Amaçlı Kullanımına İlişkin Kanun*, (Accessed: 08/05/2019), https://www.mevzuat.gov.tr/Metin1.Aspx?MevzuatKod=1.5.5346&MevzuatIliski=0&sourceXmlSearch=&Tur=1&Tertip=5&No=5346

E-mevzuat, Mevzuat Bilgi Sistemi (2013). *6446 sayılı Elektrik Piyasası Kanunu*. (Accessed: 27/07/2019), https://www.mevzuat.gov.tr/Metin1.Aspx?MevzuatKod=1.5.6446&MevzuatIliski=0&sourceXmlSearch=&Tur=1&Tertip=5&No=6446

EPDK, Enerji Piyasası Düzenleme Kurumu (2003). *4628 sayılı Elektrik Piyasası Kanunu*. (Accessed: 19/07/2019), https://www.epdk.org.tr/Detay/Icerik/3-0-0-2256/kanun lar

EPDK, Enerji Piyasası Düzenleme Kurumu (2019a). *Elektrik piyasasında lisanssız elektrik üretimi*. (Accessed: 24/08/2019), https://www.epdk.org.tr/Detay/Icerik/3-0-92/elektriklisanssiz-uretim

EPDK, Enerji Piyasası Düzenleme Kurumu (2019b). *Elektrik piyasası YEKDEM listesi*, (Accessed: 11/02/2019), https://www.epdk.org.tr/Detay/Icerik/3-0-72/elektrikyekdem/

EPDK, Enerji Piyasası Düzenleme Kurumu (2020a). *Serbest tüketici limitine ilişkin 26/12/2019 tarihli ve 9019 sayılı kurul kararı*. (Accessed: 25/08/2019), https://www.epdk.org.tr/Detay/Icerik/23-2-3/mevzuat

EPDK, Enerji Piyasası Düzenleme Kurumu (2020b). *Elektrik Piyasası Aylık Sektör Raporları*. (Accessed: 25/08/2019), https://www.epdk.gov.tr/Detay/Icerik/3-0-23-3/elektrikaylik-sektor-raporlar

EPİAŞ, Enerji Piyasaları İşletme A.Ş. (2019). *Piyasa takas fiyatı (PTF), Şeffaflık platformu*. (Accessed: 04/09/2019), https://seffaflik.epias.com.tr/transparency/piyasalar/gop/ptf.xhtml

EPİAŞ, Enerji Piyasaları İşletme A.Ş. (2020). *Piyasa takas fiyatı (PTF), Şeffaflık platformu*. (Accessed: 24/08/2020), https://seffaflik.epias.com.tr/transparency/

Erol, E. (2007). *Türkiye'de elektrik enerjisinin tarihi gelişimi: 1902-2000*. Doktora Tezi, İstanbul: İstanbul Üniversitesi.

ETKB, Enerji ve Tabii Kaynaklar Bakanlığı (2004). *Elektrik enerjisi sektörü reformu ve özelleştirme strateji belgesi.* (Accessed: 02/06/2019), https://www.enerji.gov.tr/File/?path=ROOT%2F1%2FDocuments%2FBelge%2FElektrik_Enerjisi_Sektoru_Reformu_ve_Ozellestirme_Strateji_Belgesi.pdf

ETKB, Enerji ve Tabii Kaynaklar Bakanlığı (2009). *Elektrik enerjisi piyasası ve arz güvenliği strateji belgesi.* (Accessed: 01/08/2019), https://www.enerji.gov.tr/File/?path=ROOT%2F1%2FDocuments%2FSayfalar%2FElektrik+Enerjisi+Piyasas%C4%B1+ve+Arz+G%C3%BCvenli%C4%9Fi+Strateji+Belgesi.pdf

Frank, S., Mario, R. & Massimo, G. (2007). *The merit-order effect: a detailed analysis of the price effect of renewable electricity generation on spot market prices in Germany*. Fraunhofer ISI, Karlsruhe, Working Paper Sustainability and Innovation, No. S7/2007.

Gayretli, G., Yucekaya, A. & Bilge, A.H. (2019). An analysis of price spikes and deviations in the deregulated Turkish power market. *Energy Strategy Reviews*, 26, 1-17

Goodarzi, S., Perera, H.N. & Bunn, D. (2019). The impact of renewable energy forecast errors on imbalance volumes and electricity spot prices. *Energy Policy*, 134, 1-11.

Hepbaşlı, A. (2005). Development and restructing of Turkey's electricity sector: A review. *Renewable and Sustainable Energy Reviews*, 9, 317.

Hildmann, M., Ulbig, A. & Andersson, G. (2013). *Revisiting the Merit-Order Effect of Renewable Energy Sources*. ETH Zurich, Working Paper, DOI: 10.1109/PESGM. 2015.7286477

Hinz, J. (2004). Challenges in Pricing of Electricity Risk. *Houston Business Journal*, 31(5), 1.

Hiroaki, S. (2005). *Spot - forward price relationships in the restructured electricity markets*, University of California, Davis, 19.

Ignatieva, K. & Trück, S. (2016). Modeling spot price dependence in Australian electricity markets with applications to risk management. *Computers & Operations Research*, 66, 415-433.

Jones, T. (2016). *What drives wholesale electricity prices in Britain?* (Accessed: 10/09/2019), https://www.ofgem.gov.uk/news-blog/our-blog/what-drives-wholesale-electricity-prices-britain

Kulalı, İ. (1997). *Elektrik sektöründe özelleştirme ve Türkiye uygulaması*. Uzmanlık Tezi, Ankara: Devlet Planlama Teşkilatı.

Macedo, D.P., Marques, A.C. & Damette, O. (2020). The impact of the integration of renewable energy sources in the electricity price formation: is the Merit-Order Effect occurring in Portugal? *Utilities Policy*, 66, 1-11.

Maciejowska, K. (2020). Assessing the impact of renewable energy sources on the electricity price level and variability - A quantile regression approach. *Energy Economics*, 85, 10.

Ocakoğlu, K.O. & Tolga, A.C. (2018). *Effective Trading in Turkish Electricity Market: Hedging with Options*. Proceedings of the World Congress on Engineering 2018, Vol. I, London, United Kingdom.

O'Flaherty, M., Riordan, N., O'Neill, N. & Ahern, C. (2014). A quantitative analysis of the impact of wind energy penetration on electricity prices in Ireland, *Energy Procedia*, 58, 103-110.

Özçakmak, E. (2016*). Impact of Wind Energy Generation on Wholesale Electricity Prices in Turkish Electricity Markets*. Master Thesis, The University of Tweente, Netherlands.

Özdemir, N. (2016). İmparatorluktan cumhuriyete Türkiye'de elektriğin tarihsel gelişimi (1850-1938). *Osmanlı Medeniyeti Araştırmaları Dergisi*, 2(3), 17-32.

Özpınar, A. (2020). Dinamik Tüketici Talep Yönetimi Yapabilen Blokzincir/Kripto Para Tabanlı Elektrik Piyasası İşletme Modeli. *Avrupa Bilim ve Teknoloji Dergisi*, Özel Sayı, 434-441.

Palmer, K, Burtraw, D., Woerman, M. & Beasley, B. (2012). *The Effect of Natural Gas Supply on Retail Electricity Prices. Resources for the Future*, Issue Brief 12-05, 1-13, (Accessed: 22/08/2020), https://www.ourenergypolicy.org/wp-content/uploads/2012/08/RFF-IB-12-05.pdf

Paraschiv, F., Erni, D. & Pietsch, R. (2014). The impact of renewable energies on EEX day-ahead electricity prices. *Energy Policy*, 73, 196-210.

Rintamaki, T., Siddiqui, A.S. & Salo, A. (2017). Does renewable energy generation decrease the volatility of electricity prices? An analysis of Denmark and Germany. *Energy Economics*, 62, 270-282.

Shahidehpour, M, Fu, Y. & Wiedman, T. (2005). *Impact of Natural Gas Infrastructure on Electric Power Systems*. Proceedings of the IEEE, 93(5), 1042-1056.

Shouir, B.A., Heni, B. & Lotfi, B. (2019). Price risk and hedging strategies in Nord Pool electricity market evidence with sector indexes. *Energy Economics*, 80, 635.

Şahin, V. (2006). *Enerji sektöründe yeniden yapılanma: sorunlar ve çözüm önerileri*. İstanbul: Yerküre Kitaplığı.

Şirin, S.M. & Yilmaz, B.N. (2020). Variable renewable energy technologies in the Turkish electricity market: Quantile regression analysis of the merit-order effect. *Energy Policy*, 144, 1-15.

TEİAŞ, Türkiye Elektrik İletim A.Ş. (2020a). *Santral Kurulu Güç Raporları*. (Accessed: 19/08/2020), https:// www.teias.gov.tr/tr-TR/kurulu-guc-raporlari

TEİAŞ, Türkiye Elektrik İletim A.Ş. (2020b). *III-Elektrik Enerjisi Üretimi - Tüketimi - Kayıplar 2018*. (Acessed: 19/08/2020), https://www.teias.gov.tr/tr-TR/turkiye-elektrik-uretim-iletim-istatistikleri

Uyanık, S. (2018). The Future Role of Renewables in Turkey's Electricity Supply Security. *International Journal of Energy Economics and Policy*, 8(5), 89-96.

Worthington, A.C, Higgs, H. (2017). The impact of generation mix on Australian wholesale electricity prices. *Energy Sources, Part B: Economics, Planning and Policy*, 12(3), 223-230.

Würzburg, K., Labandeira, X. & Linares, P. (2013). Renewable Generation and Electricity Prices: Taking Stock and New Evidence for Germany and Austria. *Energy Economics*, 40, 159-171.

Yıldırım, C. & Dağdemir, Ö. (2018). Türkiye'de ekonomik büyüme ve elektrik tüketimi ilişkisi. *Sakarya İktisat Dergisi*, 7(4), 60.