Gokce, Burak; Kaya, Gizem; Kayalıca, M. Özgür et al.

Article

Impact of renewable energy resources on the Turkish power market

International Journal of Energy Economics and Policy

Provided in Cooperation with:
International Journal of Energy Economics and Policy (IJEEP)

Reference: Gokce, Burak/Kaya, Gizem et. al. (2024). Impact of renewable energy resources on the Turkish power market. In: International Journal of Energy Economics and Policy 14 (4), S. 294 - 304.
https://www.econjournals.com/index.php/ijeep/article/download/16204/7988/37887.
doi:10.32479/ijeep.16204.

International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2024, 14(4), 294-304.

Impact of Renewable Energy Resources on the Turkish Power Market

Burak Gokce[1]*, Gizem Kaya[2], M. Ozgur Kayalica[1], Gulgun Kayakutlu[1]

[1]Energy Science and Technology, Energy Institute, Istanbul Technical University, Istanbul, Turkey, [2]Management Engineering, Management Faculty, Istanbul Technical University, Istanbul, Turkey. *Email: bkgokce@gmail.com

Received: 17 February 2024 **Accepted:** 01 June 2024 **DOI:** https://doi.org/10.32479/ijeep.16204

ABSTRACT

Power plants using the renewable energy resources are the plants with low marginal costs, and that is why they are given the priority in electricity supply. Therefore, they have a negative impact on spot markets, reducing the market price of electricity, known as merit-order effect (MOE). However, the subsidization made through feed-in tariff (FIT) scheme puts a burden on the retail electricity costs. This paper tries to explain the net cost impact of FIT portfolio which consists of wind, solar, hydropower, geothermal, and biofuel sources used in electricity supply in Turkey. Turkish electricity market 2014–2020 period hourly data is analyzed using multiple linear regression model. The results show that MOE is lower than the FIT cost, so increases the total retail cost during the studied period. Moreover, it is important to assess the foreign currency-based scheme at the end of its life cycle and see whether lessons learnt are applied for the new local currency scheme. Additionally, the effect of renewable sources on the volatility of electricity prices are examined using financial time series methods with a focus on COVID-19 pandemic. The conclusion is renewables increase uncertainty, but COVID-19 has no impact.

Keywords: Renewable Energies, Power Price, Price Volatility, Feed-in tariff, Merit-order Effect.
JEL Classifications: Q21, Q28

1. INTRODUCTION

Renewable energy has become one of the most important sources for electricity generation. Though currently majority of the electricity produced is generated using fossil resources. The volatility in pricing of traditional fossil fuel resources has augmented the inclination towards alternative renewable energy sources (Tutar & Atas, 2022). Globally strong targets are set to decrease the carbon emissions and renewable resources are the main support for the related policies. Thus, countries will be able to leave a cleaner world for future generations. In recent years, the leading technologies in the spread of renewable energy have been solar and wind-based power generation facilities.

Mainly with the efforts of Germany and China, renewable power plant installation costs continue to decrease. Additionally, renewables are characterized by their negligible operational expenses (Karatekin and Celik, 2020). Yet, the return on investment is still above traditional electricity generation technologies. Governments implement renewable energy support schemes to remove the obstacles on the investments. One of the most common subsidies among those mechanisms is power purchasing agreements or feed-in tariffs (FITs). The tariff gives the opportunity of purchasing supplied energy for a certain period at a predetermined price. Because the tariff price is usually determined as higher than the spot market price average, renewable producers have the chance to get their investment in a shorter time. A second renewable energy support mechanism is renewable energy tenders. They are usually held by governments for large-scale renewable energy projects. Prices resulting from these auctions tend to be lower than the FITs through competition. On the other hand, guarantees of origin (GoO) mechanism tracks the source of renewable energy used in power generation and certifies it. End-consumers can prefer to be supplied by renewable sources by purchasing GoO certificates. Some states may indirectly contribute to this mechanism by providing a marketplace to exchange certificates. 2021.

Turkey has the geographical advantage and ambition to adopt various renewable sources widely (Karakas and Yildiran, 2019). It aims to minimize the reliance on foreign fuel sources, utilizing domestic resources in a manner that is environmentally conscientious (Gokirmak, 2017). In line with the government's national energy policy, the Law on the Use of Renewable Energy Resources for the Purpose of Generating Electrical Energy was enacted in 2005. It introduced incentives for the land use, license and a guarantee of purchase for renewable projects. In 2008, Electricity Market Law amended to give more incentives to the renewable energy resources by fiscal ways such as tax exemptions (Serim and Oran, 2017). Later and as the most significant one, the feed-in-tariff called Renewable Energy Resources Support Mechanism (YEKDEM) was implemented with a law and started to be effective from 2011. It enables hydroelectric, wind, geothermal, biofuel and solar energy-based power plants to sell their electricity at a certain price for 10 years. Tariff prices range from $ 73/MWh to $ 133/MWh depending on the renewable energy source. Moreover, the first renewables auction was initiated in 2017 and the others followed later. In August 2020, Energy Markets Regulatory Authority launched a green tariff, which enabled customers to consume energy only from renewable sources. To widen the scope to privately supplied consumers, Turkish Market Operator EXIST launched GoO marketplace to enable sales of green certificates.

Between the years of 2014–2020, dramatic increase of USD/TRY rate and decreasing investment costs made FIT participation more appealing for renewable energy producers. This led to a significant increase in new renewable capacity and majority of the eligible old plants to be included in YEKDEM. Increasing YEKDEM costs causes a burden on the economy. The YEKDEM cost is reflected to retail electricity companies, but indirectly affects the end-consumer. Therefore, as in other countries, this study aims to examine the costs in Turkey's electricity market. As there is no carbon market in Turkey, environmental impact is not included in the scope. As of 1st July 2021, the existing USD based FIT scheme has been replaced with a new Turkish Lira (TRY) based FIT. The incentive is applied for 10 years for the plants commissioned until the end of 2025. The prices vary from 320 TRY/MWh and 540 TRY/MWh depending on the renewable energy sources (RES) type. If domestic products are used in the construction, an additional 80 TRY/MWh is added for 5 years. The prices are updated each quarter in TRY with a cap of $ 51/MWh to $ 86/MWh (Official Gazette, 2021). The new tariff prices are lower in USD compared to the previous one. As it is the end of USD based scheme, it is the mission to evaluate the past scheme in the scope of this study.

The method of price formation in the Turkish day-ahead electricity market (DAM) is merit-order curve. It is based on the marginal cost of unit electricity generation including fuel costs. The merit-order curve allows lower marginal cost plants to generate prior to higher cost plants. Thus, total production costs are minimized. The shift from traditional to renewable plants cause a decrease in DAM price. This is called merit-order effect (MOE) in the literature. The study aims to analyze the YEKDEM renewable plants and their MOE to contribute to the literature. Using an ex-post approach, the study examines wind, solar, hydro, geothermal, and biofuel power plants in the 2014-2020 period. The second purpose is comparing monthly YEKDEM cost and MOE to find net renewable energy effect on retail costs. The model also shows the importance of other variables that affect spot prices. Intermittent RES does not only affect spot price level but also variance of prices because of the physical nature of solar and wind power. Solar radiation and wind force vary significantly during the year which causes price volatility. Therefore, the last purpose is determined to analyze the effect of renewables on the risk of electricity prices by using financial time series methods.

The COVID-19 pandemic has caused a downturn in economic expansion, a marked escalation in unemployment rates, and a deterioration in the fiscal standing of corporations (Myyas and Almajali, 2022). The energy sector has also been adversely affected by the pandemic. COVID-19 changed the electricity price and caused shifts in electricity demand. The restrictions led to a pronounced reduction in electricity usage. It is predominantly due to a slowdown in commercial and industrial sectors, notably within the cement, ceramics, glass, and iron-steel manufacturing areas (Kok et al., 2022). It also triggered changes in consumption patterns.

Differences in work-from-home policies and confinement measures resulted in variability in both weekly and daily electricity demand reductions. There was gradual decline in morning electricity use as a result of halted economic activities, while evening demand peaks were mitigated due to the stagnation of sectors such as hospitality and leisure (Lazo et al., 2022). Given its substantial effects, this paper incorporates the impacts of COVID-19 into the volatility analysis.

2. LITERATURE REVIEW

There is a varied literature on how electricity rates are influenced by generation from RES and the resulting impact on the merit order. The following review summarizes the research on MOE, which covers several different countries. As the use of RES has expanded exceptionally in Germany over the last 10 years, numerous studies have become the subject of simulation-based approaches. Sensfuß et al. (2008) studies what would happen whether renewables were in use or not, using a model of the power grid. They conclude that, in 2001 and again in 2004 and 2006, renewables were responsible for a 1.7 €/MWh drop in the price of power. Among renewables, the key contributor is wind power. Lise et al. (2006), on the other hand, uses a model in which all of European power grids operate as a single market, concluding that wholesale prices in Germany are lower, but that the prices charged to end-users are still marginally higher. Two separate scenarios on spot electricity prices in Germany in 2020 are modelled by Traber and Kemfert (2011). One in which renewable energy accounted for a higher percentage of electricity generation than at present and the other in which fossil fuel consumption is increased, but renewables are not. In the first case alone, a spot price drop of 3.2 €/MWh is expected. In addition, Olsina et al. (2007) uses a stochastic methodology to simulate how the pricing functions are affected by wind power. The model resembles the magnitude and characteristics of the German electricity grid. The addition of wind generation to the picture results in substantial decrease in the electricity prices paid. For Germany, Paraschiv et al. (2014) investigate how wind and solar power inputs influence the prices of the day-ahead market. The spot price fluctuation, individual crude, coal and gas prices, electricity load and the contribution of renewables are then used to carry out an analysis at a fundamental level. The study shows that, with a growing input from renewable sources, spot prices go down, but the cost to the end consumer goes up.

In Spain, numerous simulation-based studies are performed, where renewables are also supported widely. Linares et al. (2008) simulates the operation of the market. They find that rising renewable incentives lead to a forecast of 21.81 TWh coming from renewables in 2020. Such an estimate includes a decrease in the price of electricity of 1.74 €/MWh. In another Spanish study, De Miera et al. (2008) reports that there is a substantial decrease in the price charged for electricity from 2005 to 2007, owing to growth in wind power. On the other hand, Holttinen et al. (2001) models the electricity market in Scandinavia (Denmark, Norway, Sweden and Finland), known as Nordpool, with a view to understanding how wind power affects electricity prices. Every time an additional annual 10 TWh of wind-generated electricity is installed, they predict a spot price decrease of 2 €/MWh. Sá (2016) models the scheme for the Portuguese electricity market from the point of view of various agents and concludes that the rates fall by an average of 17 €/MWh over the first half of 2016 in response to the switch to wind power. For Australia, Bell et al. (2017) explores the impact of increasing number of wind turbine generators on wholesale spot prices from 2014 to 2025 and finds that strong wind power creates MOE on the Australian National Electricity Market. However, the retail prices increase.

There is a body of study, unlike the research mentioned above, which uses increasingly available retrospective data on electricity prices and the availability of renewable resources in a lot of countries. Such data can be evaluated from multiple econometric points of view through different approaches to derive the actual impact on prices of an increase in renewable energy. Cludius et al. (2014) investigates MOE of solar power and wind energy for Germany. Regressions of different specifications are carried out, explaining how a rise of 1 GWh in the output of renewables lowers the spot energy price by 1.1 €/MWh to 1.3 €/MWh. A later study explores how solar power and wind power generates variations in Germany's market prices between 2010 and 2015 (Kyritsis et al., 2017). The authors think that while the MOE is generated by photovoltaics and wind power, their propensity to generate price volatility is not the same. In fact, photovoltaic creates less electricity price fluctuation and lowers the probability of price increase, whereas wind power has exactly the opposite impact. On the other hand, to analyze the changing effects of photovoltaics and wind on the day-ahead market, Paschen (2016) employs structural vector autoregressive analysis and structural impulse response functions. The author, modeling the German market with regressions and taking data from July 2010 to March 2013, finds that both renewables have a negative effect on the merit order. A newer approach is to model solar and wind power data in Germany on a marginal cost basis between 2011 and 2013 by Dillig et al. (2016). Taking merit-order and FIT into account, the authors conclude that net savings of 6.1 €/MWh achieved by end-users in 2011, 11.4 €/MWh in 2012, and 11.2 €/MWh in 2013. Benhmadac and Percebois (2018) finds that, the increase in the share of wind and solar power generation lead to a sharp decline in electricity spot prices by using the SURE method for the German electricity market between 2012 and 2015. Besides, using the two-regime Markov switching model for Germany, De Lagarde and Lantz (2018) indicates that the MOE is more important in high price periods and renewable generation also causes more frequent and longer periods of low price. In another study, using quantile regression models, Maciejowska (2020) examines that the rise of wind and solar power leads to a decline in electricity prices and solar is better at reducing the occurrence of positive price increases. Lastly, employing an econometric instrumental-variables framework, Liebensteiner et al. (2023) demonstrates that renewables significantly depress energy storage profitability due to its price-lowering impact. Utilizing hourly data from German-Austrian electricity market between 2015 and mid-2018, it was found that renewable sources, particularly wind and solar power, exert substantial negative effects on the electricity wholesale price. Although solar electricity's marginal effect is more pronounced than wind's, the higher feed-in level of wind ultimately contributes more to the decline in pump storage profits.

Moving to Spain again, Gelabert et al. (2011) uses regression models to see the spot price contribution of renewables from 2005 to 2010. Every time renewables generate 1 GWh of electricity, rates drop by approximately 2 €/MWh. On the other hand, by using the M5P algorithm (an artificial intelligence implementation) on Spanish data obtained in 2012, Azofra et al. (2014) looks at how wind power impacts wholesale electricity prices. If the realized wind generation scenario varied by 10 percent less or more than it was, spot price drop would vary from 7.42 €/MWh and 10.94 €/MWh, respectively. The team later extends the scope to see the impact of small hydropower, biomass, and solar-thermal on spot prices in the same market. In the same order, the price decreases are: 1.48 €/MWh, 1.45 €/MWh, 1.05 €/MWh, resulting in savings of € 0.12, € 3.01 and € 12.39 for average households throughout 2012 (Azofra et al., 2014). Finally, they calculate the financial benefit to electricity customers received from wind and photovoltaics in 2012. Wind energy helps to reduce prices by 9.10 €/MWh and photovoltaics save 2.18 €/MWh (Azofra et al., 2015). In Portugal, Macedo et al. (2020) examines the MOE by using the daily data from 2011 to 2019. According to the results of their EGARCH model, there is a MOE in electricity generation by wind energy. On the other hand, using the GARCH model for 2008-2017 on Iberia, Figueiredo and da Silva (2019) find that MOE is positively affected by demand, wind and solar energy. Another study from a different country employing also GARCH, determines that the spot electricity price within the Brazilian market exhibits substantial volatility, thereby causing risks for market players (Leite and Lima, 2023). Using the GARCH model, a similar conclusion is reached for the Swedish market. Wind generation increases the volatility of long-term electricity prices, however, its impact on the short-term remains unclear (Alam, 2021).

For Denmark, earlier work on MOE to assess the financial effects of wind generation for the period 2001-2006 is reviewed by Munksgaard and Morthorst (2008). They match end-user wind-power subsidy payments and MOE to achieve a net amount for consumers, which is at 0.5-6 €/MWh. Furthermore, Jónsson et al. (2010) uses spot price, load, and wind generation forecasts of Western Denmark between 01/2006 and 10/2007. The authors conclude, using a model that uses non-parametric regression techniques, that wind has a substantial impact on DAM prices. Moving to Slovakia, Janda (2018) finds that photovoltaics exhibit a small statistically significant MOE by using multivariate regression analysis covering the period 2011–2016. For its neighbor, the Czech Republic, Luňáčková et al. (2017) finds that photovoltaic plants cause no merit order effect from 2010 to 2015.

Nicholson et al. (2010) zooms 2007 to 2009 in Texas, USA, using wind power contribution, natural gas production, temperature, and past electricity prices. The use of an ARMAX model leads the authors to believe that each additional 1 GWh of wind power decreases prices by 0.67–16.4 $/MWh. Alternatively, using a stationary AR-process, Woo et al. (2011) models wind power's effect on energy prices and their fluctuations in Texas between 2007 and 2010. The authors estimate that a 100 MWh increase in wind output indicates a 1.3 $/MWh to 4.4 $/MWh drop in prices. Finally, in the period of 2010–2012, Kaufmann and Vaid (2016) look at the generation of rooftop photovoltaics in Massachusetts, USA. The used regression technique indicates that renewable energy allows power prices to decrease by 0.26 $/MWh - 1.86 $/MWh. It can be also translated into $184 million fewer consumer cost. Moving to Australia, Csereklyei et al. (2019), investigates the effect of wind and solar power generation on wholesale electricity prices using the ARDL method in the 2010–2018 period. According to the results of the study, an extra GW wind capacity reduces the wholesale electricity price by 11 AUD/MWh, while an extra GW solar capacity reduces the wholesale electricity price by 14 AUD/MWh. However, increase in gas price eliminates the MOE. In another study, Gullì and Balbo (2015) investigate the change in the MOE. Agents become more familiar with the way renewables modify the scheme, so their behavior shifts to abolish the MOE in some situations. Research in Colombia also verifies MOE of RES and determines that the higher fluctuation in the renewable output compared to demand results in increased unpredictability in the spot electricity price (Perez et al., 2022).

The following studies stand out in the literature for Turkey. One of the initial studies examining the effects of renewable energy sources on prices, identifies the variables that influence the balancing electricity price through the application of the ordinary least squares model. The study reveals that a 1% rise in power generation from wind, geothermal, and reservoir hydro facilities corresponds to an anticipated increase in the balancing price by 0.23%, 0.71%, and 0.85%, respectively (Ozdurak and Ulusoy, 2017). Acar et al. (2019) finds that wind and river-type hydroelectric power plants reduce spot electricity prices in the period of 2012–2017, and although these resources receive the same incentives, their effects on spot prices and price volatility are different. In addition, more than 75% of the price reductions in Turkey stem from wind and river-type hydroelectric plants and they lead to a negative impact on final consumer prices. Similarly, based on daily data covering Turkish DAM prices and electricity generation from wind over the period between 2011 and 2018, Berk and Torun (2019) confirms the existence of the MOE of wind. It is also observed that the power of negative causality changes drastically in different sub-periods. Moreover, Sirin and Yilmaz (2020) states that more research is needed to understand the consequences of MOE for remuneration mechanisms. They establish a quantile regression analysis of the MOE to discuss the impact on the electricity market pricing mechanism in Turkey. The model results show a significant MOE for both wind and river type hydro technologies. However, this effect varies according to demand, price level and technology. A later study focuses on balancing market prices (system marginal price) and system imbalances, instead of the DAM (Sirin and Yilmaz, 2021). The study scrutinizes the influence of wind and run-of-river hydro on Turkish market. It reveals that increased renewable energy generation leads to a drop in system marginal prices and an increased probability of system surplus, especially noticeable during evening and night hours. However, these effects are less significant at noon. The research further mentions the distinct impacts of renewables on the DAM and balancing market, with the latter more affected by forecast errors and intermittency issues. A recent study investigates the volatility impact of renewables in the Turkish DAM from 2017 to 2020 (Oguz and Peker, 2023). The intermittency of RES, which enter the DAM at zero price, magnifies wholesale price volatility. This, coupled with the growing share of the YEKDEM in the DAM, leads to increased vulnerability to supply shocks and heightened supply volatility.

The reason that various studies obtain different MOE results might be unequal data frequency intervals, different methodologies, the amount of available data, and the length of the study being carried out. For example, a theoretical approach is taken by Denny et al. (2017) in Ireland to compare the effects of the simulation versus historical data analysis in 2009. Both methodologies produce similar conclusions, differing by only 25%. Another observation from the literature is that for countries that produce more from wind and solar energy, such as Germany, Spain, and the United States, the effect of renewables on the price of electricity is more of a concern. Moreover, there are many times more studies on wind power than other renewables.

Our study examines the effect of renewable energy on electricity prices in a multidimensional way. Instead of limiting scope to wind and photovoltaics, which is the case for most of the papers, the study includes a wide range of RES including hydro, wind, solar, biofuel (biomass, biogas, biowaste), and geothermal. Especially, geothermal technology has not been included in the most of the studies so far, because they don't have a significant share among renewable support schemes in the countries examined in the literature. Moreover, the study doesn't calculate only the MOE, but also the net renewables cost on end consumers, which has been done only in a limited number of studies. It also analyses the effect of RES on the risk and volatility of electricity prices, again analyzed by only a few papers in the MOE literature. Furthermore, this study makes a comprehensive analysis of renewables effect in Turkey and contributes to the limited number of studies for the country.

3. MATERIALS AND METHODS

In general, the literature defines two methods of looking at the MOE: simulation models, i.e. electricity market modelling; or statistically examining real historical data, i.e. an econometric approach. Price simulation relies on models that are supplied with historical or hypothetical data, whereas the econometric approach uses past price performance to evaluate patterns using econometric structures (Würzburg et al., 2013). If values are to be estimated with good accuracy, simulations need to be reasonable and realistic. Since the method needs a host of assumptions, it is possible that the derived results are tentative. Compared to simulation-based approaches, using actual past conditions in models that use regression techniques has the clear advantage of not depending on hypothetical developments, such as the building of new power stations or transmission networks. Moreover, simulations are unable to account for unexpected events. At the ex-post analysis, conclusions are reached based on what did occur, rather than what might occur (Gil, 2012). Furthermore, empirical approaches require fewer data and are easier to measure. An empirical approach is selected for this study, keeping this viewpoint into account.

Plenty of the ex-post literature studies are done through regression models. This study also applies it. Moreover, Macedo et al. (2020) and Figueiredo and da Silva (2019) prefer financial time series methods in their studies. This study also uses a time series method, because performing appropriate tests and applying the necessary criteria, the most suitable model is obtained as the Component ARCH (1,1) model. The 2014-2020 dataset is large due to its hourly nature. Therefore, its variance should be modeled. The selected model also allows modeling variance both in the long and short terms. Moreover, the model is used to analyze the risk/volatility in electricity prices by considering the effects of COVID-19 and renewables.

The Turkish Electricity Market data used in the study is publicly available and belongs to the Energy Market Regulatory Authority (EMRA), electricity market operator Energy Exchange Istanbul (EXIST), and transmission system operator TEIAS. The model variables are examined in hourly resolution. The FIT cost is taken in monthly resolution since it is published monthly. The dependent variable in the model is spot price (wholesale price or DAM Price). The variables are shown in Table 1. The source for these variables is EXIST Transparency Platform (EXIST, 2022).

4. RESULTS

Prior to the modeling, Augmented Dickey Fuller and Phillips Perron tests are used to check whether the independent variables are stationary or not. All variables are found to be stationary (I(0)). However, when the correlogram of spot electricity prices in Figure 1 is examined, it is observed that seasonality is dominant, and the dependent variable is not stationary. It is seen that the autocorrelation with the price of 24-h ago is high. Therefore, the difference between electricity prices and 24-h lagged ones are taken. The differences are used to build the first regression model. Hour, weekday, month, year, trend, and holiday dummies are also included in the model. Secondly, the Component ARCH (1,1) model is estimated with the error terms obtained from this regression. The regression results derived from the deseasonality process are shown in Table 2. Year, month, weekday and holiday effects on the daily change in spot prices are found to be generally significant ($p < 0.10$). The correlogram obtained for the error terms is presented in Figure 2. Although the autocorrelation effect continues, trend and seasonal effects are largely adjusted.

Engle's (1982) ARCH-LM is performed and the results indicate that conditional heteroscedasticity in error terms and variance/risk should be modeled with ARCH models ($n*R^2=33045.1$, p-value of Chi-square (24): 0.00). Therefore, the error terms obtained from this regression are used as a dependent variable in the Component ARCH (1,1) model. These values are the seasonally adjusted version of the daily change in the spot prices. The coefficients in the variance equation are given in Table 3. They show the effect on the daily spot price change and the GARCH shows the volatility. If a coefficient is positive and significant, the volatility/uncertainty in spot prices increase. The increase in renewable energy production (*LicRen*), generation of block sales in DAM (*BlockGen*), power

Table 1: Variables used in the analysis

Variable, units	Abbreviation	Description
Spot Price, TRY/MWh	SpotPrice	Spot price
Imported Coal Generation, GW	CoalGen	Imported coal power plants' planned generation after DAM results
Licensed Renewables Generation, GW	LicRen	Licensed renewables generation under FIT portfolio
Net Import, GW	NetIm	Import and export difference of cross border electricity trade
DAM Demand, GW	Demand	DAM matched volume
Block Generation, GW	BlockGen	Generation which is part of Block Sales in DAM
Lignite PPA, GW	LignitePPA	Power purchasing agreement amount for lignite (local coal) plants
Marginal Capacity	MarCap	Offline capacity divided by DAM demand. Offline capacity is the capacity of the natural gas and imported coal fired plants available for generation, but they are not planned to generate
EUAS Availability, GW	EUASAva	Capacity of natural gas, local coal, and reservoir hydro plants available for generation, owned by state owned generation company EUAS

FIT: Feed-in tariff

Figure 1: Correlogram of electricity spot prices

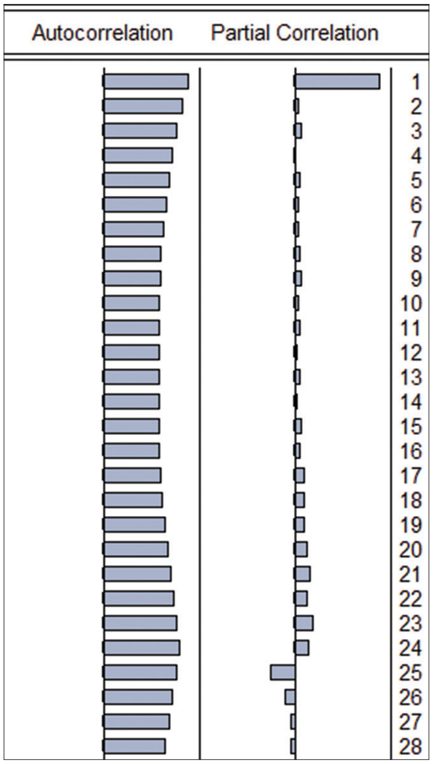
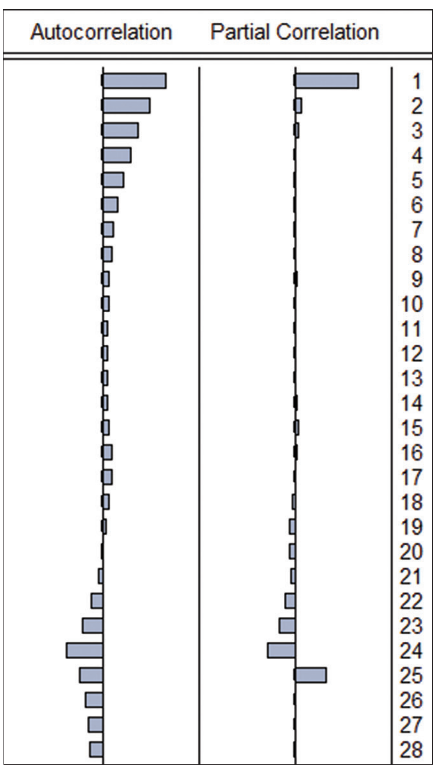


Figure 2: Correlogram of residuals after deseasonality



purchasing agreement amount for lignite plants (*LignitePPA*) and marginal capacity (*MarCap*) increase volatility in the short term. Whereas, DAM Demand (*Demand*) and EUAS Availability (*EUASAva*) significantly decrease the volatility in the short term ($P < 0.01$). This is expected as EUAS limits the volatility of prices and price level increase against demand increase, by increasing

Table 2: Result of regression model for deseasonality

Dependent Variable: SpotPrice-SpotPrice (-24)				
Method: Least Squares				
Sample (adjusted): 01/02/2014 00:00 12/31/2020 23:00				
Included observations: 61344 after adjustments				
Variable	**Coefficient**	**Standard Error**	**t**	**p**
Constant	29.16	1.34	21.83	0.00
@Trend	−0.002	0.00	−1.84	0.07
Year_Dummy=1	14.57	7.89	1.85	0.06
Year_Dummy=2	29.13	15.75	1.85	0.06
Year_Dummy=3	43.72	23.61	1.85	0.06
Year_Dummy=4	58.34	31.46	1.85	0.06
Year_Dummy=5	72.70	39.32	1.85	0.06
Year_Dummy=6	87.15	47.20	1.85	0.06
Month_Dummy=1	−0.24	1.14	−0.21	0.84
Month_Dummy=2	0.001	1.57	0.00	1.00
Month_Dummy=3	3.21	2.14	1.50	0.13
Month_Dummy=4	4.99	2.75	1.81	0.07
Month_Dummy=5	6.13	3.37	1.82	0.07
Month_Dummy=6	7.32	4.01	1.83	0.07
Month_Dummy=7	8.54	4.66	1.83	0.07
Month_Dummy=8	9.08	5.31	1.71	0.09
Month_Dummy=9	10.40	5.95	1.75	0.08
Month_Dummy=10	11.00	6.61	1.67	0.10
Month_Dummy=11	11.29	7.25	1.56	0.12
Weekday_Dummy=1	−22.97	0.71	−32.43	0.00
Weekday_Dummy=2	−27.03	0.71	−38.16	0.00
Weekday_Dummy=3	−26.94	0.71	−38.06	0.00
Weekday_Dummy=4	−28.30	0.71	−39.96	0.00
Weekday_Dummy=5	−34.80	0.71	−49.13	0.00
Weekday_Dummy=6	−53.01	0.71	−74.84	0.00
Hour_Dummy=1	0.005	1.31	0.00	1.00
Hour_Dummy=2	0.007	1.31	0.01	1.00
Hour_Dummy=3	0.023	1.31	0.02	0.99
Hour_Dummy=4	0.002	1.31	0.00	1.00
Hour_Dummy=5	0.003	1.31	0.00	1.00
Hour_Dummy=6	0.003	1.31	0.00	1.00
Hour_Dummy=7	0.008	1.31	0.01	1.00
Hour_Dummy=8	0.016	1.31	0.01	0.99
Hour_Dummy=9	0.008	1.31	0.01	0.99
Hour_Dummy=10	0.020	1.31	0.02	0.99
Hour_Dummy=11	0.018	1.31	0.01	0.99
Hour_Dummy=12	−0.005	1.31	0.00	1.00
Hour_Dummy=13	0.002	1.31	0.00	1.00
Hour_Dummy=14	0.009	1.31	0.01	0.99
Hour_Dummy=15	0.018	1.31	0.01	0.99
Hour_Dummy=16	0.018	1.31	0.01	0.99
Hour_Dummy=17	0.018	1.31	0.01	0.99
Hour_Dummy=18	0.021	1.31	0.02	0.99
Hour_Dummy=19	0.014	1.31	0.01	0.99
Hour_Dummy=20	0.016	1.31	0.01	0.99
Hour_Dummy=21	0.012	1.31	0.01	0.99
Hour_Dummy=22	0.010	1.31	0.01	0.99
Hour_Dummy=23	0.017	1.31	0.01	0.99
Holiday_Dummy=1	−11.80	1.02	−11.58	0.00
R-squared	0.09			
F-statistic	126.44			
Prob (F-statistic)	0.00			
Akaike info criterion	10.53			
Schwarz criterion	10.54			
Hannan-Quinn criterion	10.54			

available capacit y of its plants. On the other hand, *Dum* variable is added to the model to represent the outlier increase in the spot prices. Moreover, autoregressive (*Er*(*-1*), *Er*(*-2*), *Er*(*-3*) *and Er*(*-24*)) and moving average parameters (*Ma*(*24*)) are added, according to the significance and partial autocorrelation values in Figure 2.

$$Q = C(17) + C(18)*(Q(-1) - C(17)) + C(19) * (Resid(-1)^2 - GARCH(-1)) + C(20) * DumCov + C(21) * LicRen + C(22) * DumCov * LicRen \quad (1)$$

$$GARCH = Q + (C(23) + C(24) * (Resid(-1)<0)) * (Resid(-1)^2 - Q(-1)) + C(25) * (GARCH(-1) - Q(-1)) \quad (2)$$

The equation 1 represents the long-term variance. Because *C*(*18*) is close to 1, the long-term volatility in the spot prices is largely transferred to the next period. *DumCov* variable represents the time when COVID-19 is effective in Turkey. It is represented with a dummy variable which takes a value of 1 after 03/15/2020. This variable is found to be statistically insignificant on the volatility of spot prices (*C*(*20*)). Therefore, COVID-19 does not have a remarkable impact on the uncertainty of spot prices. The effect of renewable generation on the volatility of spot prices (*C*(*21*)) is found to be positive and significant. With the COVID-19, this effect decreases significantly (*C*(*22*)). Furthermore, *C*(*24*) coefficient explains that the uncertainty in electricity prices increases when there is a negative shock in spot prices. The standardized residuals correlogram obtained as the result of the model is given in Figure 3. As it is seen, autocorrelation and partial autocorrelations decrease significantly. Additionally, according to the ARCH-LM test, the conditional heteroscedasticity is found to be statistically insignificant $n * R^2 = 4.16$ (p-value of $\chi^2(24) = 1.00$).

Table 3: Results of component ARCH (1,1) model

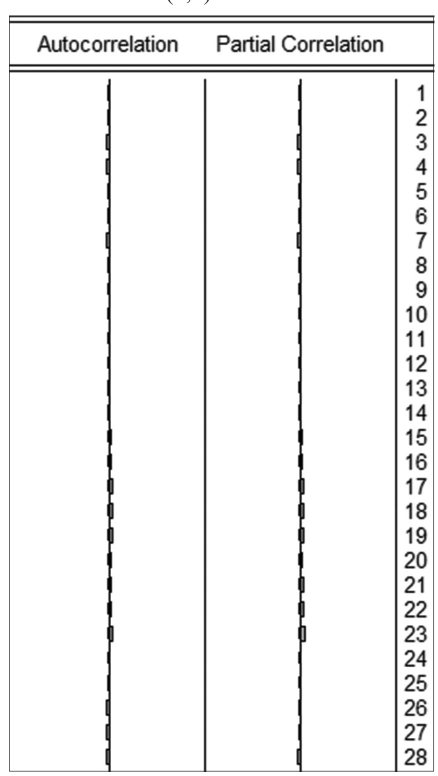
Dependent Variable: ER				
Method: ML ARCH - Student's t distribution (BFGS/Marquardt steps)				
Sample (adjusted): 1/03/2014 00:00 12/31/2020 23:00				
Included observations: 61320 after adjustments				
	Coefficient	Standard Error	Z	P
Mean equation				
GARCH	0.00	0.00	6.68	0.00
Constant	0.58	0.00	174.14	0.00
CoalGen	−0.01	0.01	−1.10	0.27
LicRen	0.01	0.00	3.77	0.00
NetIm	−0.03	0.02	−1.32	0.19
Demand	−0.03	0.00	−42.26	0.00
BlockGen	0.02	0.00	5.42	0.00
LignitePPA	0.04	0.01	6.31	0.00
MarCap	0.18	0.03	5.26	0.00
EUASAva	−0.04	0.00	−96.31	0.00
Er(-1)	0.73	0.00	300.59	0.00
Er(-2)	0.03	0.00	7.86	0.00
Er(-3)	0.04	0.00	12.09	0.00
Er(-24)	0.08	0.00	41.50	0.00
Dum	−94.86	19.53	−4.86	0.00
Ma (24)	−0.87	0.00	−702.8	0.00
Variance equation				
C (17)	855.92	392.70	2.18	0.03
C (18)	0.996	0.00	615.00	0.00
C (19)	0.09	0.01	12.97	0.00
C (20)	0.03	2.21	0.02	0.99
C (21)	0.61	0.07	8.48	0.00
C (22)	−0.60	0.35	−1.69	0.09
C (23)	0.28	0.01	29.11	0.00
C (24)	0.04	0.01	4.84	0.00
C (25)	0.43	0.01	32.15	0.00
T-DIST. DOF	3.47	0.05	68.70	0.00
R-squared	0.68			
Adjusted R-squared	0.68			
Durbin-Watson statistic	2.10			
Akaike info criterion	8.58			
Schwarz criterion	8.59			
Hannan-Quinn criterion	8.59			

The last model is built using the Multiple Linear Regression (MLR) method, to calculate MOE for renewables (Table 4). While creating the model, for the case of no renewables, below assumptions are held:

- Power capacity mix doesn't change. That means, the high spot prices when lack of renewables wouldn't affect the investment decisions
- Network costs and congestion are neglected, meaning other sources would be able to replace production from renewables.
- Below assumptions are also used for the sake of simplicity as they have negligible effect on the model in the examined term,
- Licensed renewable plants under the FIT portfolio bid all their generation to Day Ahead Market. They don't participate to the Balancing Power Market
- There is no unlicensed renewable generation used for internal consumption.

The impact of the model variables on the spot prices are explained below. The sign of the coefficients in Table 4 verifies the explained impact.

Figure 3: Correlogram of standardized residuals of component ARCH (1,1) model



- Imported coal (*CoalGen*) plants are one of the highest marginal cost plants in the seven years period. Therefore, their generation amount shows the price level.
- With the lowest marginal cost, licensed renewables (*LicRen*) create MOE. Therefore, it has a negative model coefficient against spot price (SpotPrice).
- The cross-border trades with neighboring countries, which are Georgia, Bulgaria, and Greece, in the examined period are also considered. Turkish market participants import cheaper electricity when there are higher prices in Turkey. Hence, net import (*NetIm*) increase is an indication of high spot prices in Turkey.
- As in other studies, *"Demand"* variable is used in the study. It doesn't represent the total electricity consumption of Turkey, but the matched volume of DAM. Because spot prices are formed in DAM. Demand is the main explanatory variable for price formation. Because the DAM merit-order curve intersects where the demand equals supply.
- The start-stop of CCGT and coal fired plants takes hours and it has a cost. Therefore, they run in block hours They take the average price of the block into consideration. Within the block, some hours individually may not cover their generation costs. Therefore, block orders on the supply side have a price reducing effect on hourly spot prices. Considering also limited usage of blocks for demand side, block generation (*BlockGen*) affects spot price negatively.
- Turkish state-owned wholesale company TETAS, which has become a part of EUAS later, initiated power purchasing agreements (PPA) for lignite-fired plants (*LignitePPA*) in 2016. The target is to increase usage of domestic coal and decrease dependency of imported fuels. PPA allows lignite power plants to sell a predetermined capacity at a predetermined price which is higher than the spot price average. Because TETAS resells the purchased volume in the market at a price covering incentive cost, (*LignitePPA*) causes price increase.
- Offline capacity of gas and imported coal fired plants, represents the amount available for generation, but they are not planned to generate. Marginal Capacity (*MarCap*) shows the ratio of the offline capacity divided by the DAM demand. In other words, Marginal capacity shows disposable available capacity ratio which is ready to generate if needed. Lower *MarCap* shows the capacity to be already used from high-cost plants which is a sign of higher spot price.
- EUAS owns more than 20% of the installed capacity of Turkey in the study period. Most of the capacity comes from reservoir hydro, CCGT, and lignite plants (TEIAS, 2021). Because of the dominant capacity share, EUAS bidding strategy has the power to change the spot prices. In the examined period, the pattern of the EUAS bidding shows that they limit the increase of power prices. They achieve it by adjusting the amount of its online capacity. Therefore, availability of EUAS (*EUASAva*) plants is an indicator showing higher spot prices.

Table 4: Results of MLR model

Dependent Variable: SpotPrice (TRY/MWh)				
	Coefficient	Standard Error	T	P
Intercept	−121.09	1.80	−67.39	0.00
CoalGen	10.81	0.19	55.97	0.00
LicRen	−7.05	0.11	−63.84	0.00
NetIm	24.53	0.62	39.41	0.00
Demand	9.39	0.09	100.24	0.00
BlockGen	−5.22	0.17	−30.81	0.00
LignitePPA	17.02	0.28	61.66	0.00
MarCap	−85.76	1.12	−76.25	0.00
EUASAva	13.00	0.11	114.70	0.00

To calculate the effect of licensed renewables on the spot price corresponding MLR model coefficient is used. Whereas, for the unlicensed renewables the coefficient of "Demand" variable is used with a conversion of its sign. Because the unlicensed generation is sold to authorized retail companies (ARC) at each

Table 5: MOE versus FIT cost

Year	Average Spot Price ($/MWh)	MOE of licensed renewables ($/MWh)	MOE of unlicensed renewables ($/MWh)	Total MOE ($/MWh)	FIT ($/MWh)
2014	75.07	−2.15	−0.02	−2.17	0.65
2015	51.03	−5.31	−0.09	−5.4	3.21
2016	46.33	−12.03	−0.4	−12.43	8.18
2017	45.01	−10.52	−0.9	−11.42	9.48
2018	47.43	−9.58	−1.8	−11.39	11.81
2019	46.03	−9.71	−1.85	−11.57	14.73
2020	40.09	−7.54	−1.72	−9.26	17.35

MOE: Merit-order effect, FIT: Feed-in tariff

Table 6: Renewables effect on retail costs

Year	Load-weighted MOE ($/MWh)	Load-weighted FIT ($/MWh)	Net unit renewables effect on costs ($/MWh)	Retail demand exposed to FIT cost (TWh)	Net total renewables effect on costs (m$)
2014	−2.16	0.65	−1.52	232.45	−353.05
2015	−5.38	3.17	−2.21	241.96	−534.68
2016	−12.43	8.06	−4.37	257.71	−1,125.28
2017	−11.48	9.36	−2.13	274.39	−584.17
2018	−11.54	11.79	0.25	283.85	71.05
2019	−11.74	14.64	2.9	280.53	814.19
2020	−9.31	16.7	7.39	282.45	2,087.07

MOE: Merit-order effect, FIT: Feed-in tariff local distribution region. Then, ARC subtracts the generation from the consumption of the region while offering the volume to DAM. In conclusion, 1 GWh in the hourly generation from licensed and unlicensed renewables reduces spot price by 8.28 $/MWh and 1.02 $/MWh, respectively.

Table 5 shows that FIT cost compared to spot price increases dramatically from 2014 to 2020. While the FIT ratio is negligible in (0.65 vs. 75.07) in 2014, later FIT becomes 30% (17.35 vs. 40.09) of the energy cost for end users. Between 2014 and 2017, MOE has a price reduction impact on the overall costs. However, starting from 2018, FIT cost increases dramatically so the MOE doesn't cover it anymore. The reason is the depreciation of TRY against USD, which is 93% between 2018 and 2020 (TCMB, 2021). The TRY is used for spot prices, whereas the USD is used for FIT incentive payments. To calculate the MOE on total retail costs, load-weighted averages are used. The load is not DAM load in this case, but the load on which the FIT is applied. Table 6 shows that renewables increased total retail costs by 375 m$ between 2014 and 2020.

5. CONCLUSIONS

The study first analyzes the electricity price volatility using financial time series methods. The effect of renewable resources-based power generation on the volatility of electricity prices is found to be positive and significant. Moreover, it is found that the uncertainty in spot prices increases when there is a negative shock in electricity prices. Finally, it can be said that COVID-19 does not have a significant effect on the uncertainty of electricity prices.

Renewable energy incentive mechanisms may create an economic burden for states. This burden directly or indirectly affects the end-consumer. Therefore, it is questioned and analyzed for plenty of countries. Using the MLR method, this study analyzes the renewable energy impact on the spot prices and shows the net burden on end-consumers. USD based FIT scheme makes FIT cost unpredictable due to volatile USD/TRY rate at the study period. In the 1st years, between 2014 and 2017, FIT cost is compensated by MOE effect. However, in the past 3 years TRY depreciates significantly and increasing FIT costs can't be covered anymore. Because the latter is larger, the FIT support scheme creates an overall burden for retail electricity companies and indirectly the end consumers in the 7-year period. Foreign exchange dependency of the FIT scheme harms the economy and increases the uncertainty in retail costs. Hence, it is important to have lower priced and local currency-based scheme. Fortunately, a new TRY-based FIT started on July 1st, 2021 comes as a solution to these main concerns. As the next step the authorized people, considering the results of this study, should further review the renewable energy support mechanisms and come up with a better mechanism after the TRY-based FIT ends in 2030.

Because of the wholesale price reduction effect, renewables cause high-marginal cost power plants to see depressed profits. Government tries to take a precaution with a capacity mechanism, which subsidizes some part of the generation of the plants. However, this creates another burden for the economy. In any case, generation capacity mix tends to shift to the low-marginal cost plants. The change in generation mix further changes the merit-order curve. An assumption of this study is to omit this effect. However, the Turkish market generation mix has already started to change to adapt to the MOE. This change should be examined in further studies.

Forecasting of renewable generation is difficult and causes significant imbalances. Run-of-river and wind plants are the most difficult ones to predict. As the last proposal, the effect of renewables on the Turkish Balancing Power Market should be analyzed. Because it causes additional renewable costs while providing instantaneous system balancing. The Turkish market would be a good case with its large renewable energy capacity.

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.

Alam, M.N. (2021), Accessing the effect of renewables on the wholesale power market. International Journal of Energy Economics and Policy, 11, 341-360.

Azofra, D., Jiménez, E., Martínez, E., Blanco, J., Saenz-Díez, J.C. (2014), Wind power merit-order and feed-in-tariffs effect: A variability analysis of the Spanish electricity market. Energy Conversion and Management, 83, 19-27.

Azofra, D., Martínez, E., Jiménez, E., Blanco, J., Azofra, F., Saenz-Díez, J.C. (2015), Comparison of the influence of photovoltaic and wind power on the Spanish electricity prices by means of artificial intelligence techinques. Renewable and Sustainable Energy Reviews, 42, 532-542.

Azofra, D., Martínez, E., Jiménez, E., Blanco, J., Saenz-Díez, J.C. (2014), Comparison of the influence of biomass, solar-thermal and small hydraulic power on the Spanish electricity prices by means of artificial intelligence techniques. Applied Energy, 121, 28-37.

Bell, W.P., Wild, P., Foster, J., Hewson, M. (2017), Revitalising the wind power induced merit order effect to reduce wholesale and retail electricity prices in Australia. Energy Economics, 67, 224-241.

Benhmad, F., Percebois, J. (2018), Photovoltaic and wind power feed-in impact on electricity prices: The case of Germany. Energy Policy, 119, 317-326.

Berk, I., Torun, E. (2019), Testing merit-order effect in Turkey's electricity market: The effect of wind penetration on day-ahead electricity prices. Akdeniz IIBF Dergisi, 19(1), 133-156.

Cludius, J., Hermann, H., Matthes, F.C., Graichen, V. (2014), The merit order effect of wind and photovoltaic electricity generation in Germany 2008-2016: Estimation and distributional implications. Energy Economics, 44, 302-313.

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.

De Lagarde, C.M., Lantz, F. (2018), How renewable production depresses electricity prices: Evidence from the German market. Energy Policy, 117, 263-277.

De Miera, G.S., del Rio Gonzalez, P., Vizcaino, I. (2008), Analysing the impact of renewable electricity support schemes on power prices: The case of wind electricity in Spain. Energy Policy, 36, 3345-3359.

Denny, E., O'Mahoney, A., Lannoye, E. (2017), Modelling the impact of wind generation on electricity market prices in Ireland: An econometric versus unit commitment approach. Renewable Energy, 104, 109-119.

Dillig, M., Jung, M., Karl, J. (2016), The impact of renewables on electricity prices in Germany - An estimation based on historic spot prices in the years 2011-2013. Renewable and Sustainable Energy Reviews, 57, 7-15.

Engle, R.F. (1982), Autoregressive conditional heteroscedasticity with estimates of the variance of United Kingdom inflation. Econometrica: Journal of the Econometric Society, 50, 987-1007.

EXIST. (2022), EXIST Transparency Platform. Available from: https://seffaflik.epias.com.tr [Last accessed on 2022 Feb 01].

Figueiredo, N.C., da Silva, P.P. (2019), The "Merit-order effect" of wind and solar power: Volatility and determinants. Renewable and Sustainable Energy Reviews, 102, 54-62.

Gazette, O. (2021), President's Decision. Available from: https://www.resmigazete.gov.tr/eskiler/2021/01/20210130-9.pdf [Last accessed on 2021 Jul 27].

Gelabert, L., Labandeira, X., Linares, P. (2011), An ex-post analysis of the effect of renewables and cogeneration on Spanish electricity prices. Energy Economics, 33, 59-65.

Gil, H.A., Gomez-Quiles, C., Riquelme, J. (2012), Large-scale wind power integration and wholesale electricity trading benefits: Estimation via an ex post approach. Energy Policy, 41, 849-859.

Gokirmak, H. (2017), International journal of energy economics and policy the energy policies for a sustainable economic growth in turkey. International Journal of Energy Economics and Policy, 7, 55-61.

Gullì, F., Balbo, A.L. (2015), The impact of intermittently renewable energy on Italian wholesale electricity prices: Additional benefits or additional costs? Energy Policy, 83, 123-137.

Holttinen, H., Vogstad, K.O., Botterud, A., Hirvonen, R. (2001), Effects of Large Scale Wind Production on the Nordic Electricity Market. In: European Wind Energy Conference EWEC'2001. Copenhagen, Denmark. p1-4.

Janda, K. (2018), Slovak electricity market and the price merit order effect of photovoltaics. Energy Policy, 122, 551-562.

Jónsson, T., Pinson, P., Madsen, H. (2010), On the market impact of wind energy forecasts. Energy Economics, 32(2), 313-320.

Karakas, E., Yildiran, O.V. (2019), Evaluation of renewable energy alternatives for Turkey via modified fuzzy ahp. International Journal of Energy Economics and Policy, 9, 31-39.

Karatekin, C., Celik, H. (2020), The effects of renewable energy sources on the structure of the Turkish electricity market. International Journal of Energy Economics and Policy, 10, 64-70.

Kaufmann, R.K., Vaid, D. (2016), Lower electricity prices and greenhouse gas emissions due to rooftop solar: Empirical results for Massachusetts. Energy Policy, 93, 345-352.

Kok, A., Yukseltan, E., Hekimoglu, M., Aktunc, E.A., Yucekaya, A., Bilge, A. (2022), Forecasting hourly electricity demand under covid-19 restrictions. International Journal of Energy Economics and Policy, 12, 73-85.

Kyritsis, E., Andersson, J., Serletis, A. (2017), Electricity prices, large-scale renewable integration, and policy implications. Energy Policy, 101, 550-560.

Lazo, J., Aguirre, G., Watts, D. (2022), An impact study of covid-19 on the electricity sector: A comprehensive literature review and ibero-american survey. Renewable and Sustainable Energy Reviews, 158, 112135.

Leite, A.L.S., de Lima, M.V.A. (2023), A garch model to understand the volatility of the electricity spot price in Brazil. International Journal of Energy Economics and Policy, 13, 332-338.

Liebensteiner, M., Haxhimusa, A., Naumann, F. (2023), Subsidized renewables' adverse effect on energy storage and carbon pricing as a potential remedy. Renewable and Sustainable Energy Reviews, 171, 112990.

Linares, P., Santos, F.J., Ventosa, M. (2008), Coordination of carbon reduction and renewable energy support policies. Climate Policy, 8(4), 377-394.

Lise, W., Linderhof, V., Kuik, O., Kemfert, C., Östling, R., Heinzow, T. (2006), A game theoretic model of the Northwestern European electricity market-market power and the environment. Energy Policy, 34(15), 2123-2136.

Luňáčková, P., Průša, J., Janda, K. (2017), The merit order effect of Czech photovoltaic plants. Energy Policy, 106, 138-147.

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, 101080.

Maciejowska, K. (2020), Assessing the impact of renewable energy sources on the electricity price level and variability-a quantile regression approach. Energy Economics, 85, 104532.

Munksgaard, J., Morthorst, P.E. (2008), Wind power in the Danish liberalised power market-policy measures, price impact and investor incentives. Energy Policy, 36(10), 3940-3947.

Myyas, R.N., Almajali, M.R. (2022), Effect of covid-19 on energy sector in Jordan. International Journal of Energy Economics and Policy, 12, 20-29.

Nicholson, E., Rogers, J., Porter, K. (2010), Relationship between Wind Generation and Balancing Energy Market Prices in ERCOT: 2007-2009. Golden, CO: United States Department of Energy.

Official Gazette. (2021), Cumhurbaskani Karari. Available from: https://www.resmigazete.gov.tr/eskiler/2021/01/20210130-9.pdf [Last accessed on 2021 Jul 27].

Oguz, F., Peker, M.C. (2023), Volatility in the Turkish wholesale electricity market: An assessment. Energy Sources, Part B: Economics, Planning, and Policy, 18, 2173340.

Olsina, F., Röscher, M., Larisson, C., Garcés, F. (2007), Short-term optimal wind power generation capacity in liberalized electricity markets. Energy Policy, 35(2), 1257-1273.

Ozdurak, C., Ulusoy, V. (2017), Impact of vertical integration on electricity prices in Turkey. International Journal of Energy Economics and Policy, 7, 256-267.

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

Paschen, M. (2016), Dynamic analysis of the German day-ahead electricity spot market. Energy Economics, 59, 118-128.

Perez, A., Carabali, J., Benavides-Franco, J. (2022), Competition and merit order effect in the Colombian electricity market. International Journal of Energy Economics and Policy, 12, 144-155.

Sá, J. (2016), The Merit Order Effect of Wind Power in Portugal: Quantifying the effect of Wind Energy in the Spot Market prices through Agent-based Simulations. (M.Sc. Thesis). Tecnico Lisboa, Electrical and Computer Engineering Department.

Sáenz de Miera, G., del Río González, P., Vizcaíno, I. (2008), Analysing the impact of renewable electricity support schemes on power prices: The case of wind electricity in Spain. Energy Policy, 36(9), 3345-3359.

Sensfuß, F., Ragwitz, M., Genoese, M. (2008), The merit-order effect: A detailed analysis of the price effect of renewable electricity generation on spot market prices in Germany. Energy Policy, 36(8), 3086-3094.

Serim, N., Oran, F.C. (2017), International journal of energy economics and policy the renewable energy policy convergence in the European Union: A comparison on Germany and Turkey's incentives for the wind and solar energy resources. International Journal of Energy Economics and Policy, 7, 308-320.

Sirin, 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, 111660.
TCMB. (2021), Central Bank Rates. Available from: https://evds2.tcmb.gov.tr [Last accessed on 2021 Jul 27].
TEIAS. (2021), Website of TEIAS. Available from: https://www.teias.gov.tr [Last accessed on 2021 Jul 27].
Traber, T., Kemfert, C. (2011), Gone with the wind? Electricity market prices and incentives to invest in thermal power plants under increasing wind energy supply. Energy Economics, 33(2), 249-256.
Tutar, H., Atas, M. (2022), A review on turkey's renewable energy potential and its usage problems. International Journal of Energy Economics and Policy, 12, 1-9.
Woo, C.K., Horowitz, I., Moore, J., Pacheco, A. (2011), The impact of wind generation on the electricity spot-market price level and variance: The Texas experience. Energy Policy, 39(7), 3939-3944.
Würzburg, K., Labandeira, X., Linares, P. (2013), Renewable generation and electricity prices: Taking stock and new evidence for Germany and Austria. Energy Economics, 40, S159-S171.