COVID-19 Lockdown Impact to Electricity Consumption and Generation: The Case of Turkey

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Abstract

In order to reduce the negative impact of the coronavirus (COVID-19), which first emerged in Wuhan, China measures such as distance education and curfews were taken by governments to reduce the negative impact on human health. These precautions had an impact on electricity consumption. Turkey was one of the countries adversely affected by COVID-19. Therefore, the objective of this paper analyze the variation of electricity consumption and generation in Turkey depending on the COVID-19 outbreake. For this purpose, residential, industrial, business and total electricity consumption of six provinces was analyzed in order to examine the variation in electricity consumption in Turkey. Considering the ten months of the year, with March when the first case occurred in 2020 compared to 2019, it was observed that residential electricity consumption increased in the six provinces studied. Industrial electricity consumption decreased in March and the following months, but increased in the following months. On the other hand, it was observed that there was a decrease in the business electricity consumption in almost all ten months. In the per capita electricity generation estimation study in Turkey, it was calculated that the electricity generated in 2020 is 5.89% more than the estimated value obtained by the curve fitting method. In addition, according to the study of coverage the electricity consumption and generation per capita for the years 2019 and 2020, it was calculated that generation could not coverage the consumption by 0.22% in 2019 and 0.27% in 2020.

Keywords: COVID-19, Electricity Consumption, Electricity Generation, Per Capita Electricity, Residential Electricity

COVID-19 Karantinasının Elektrik Tüketimi ve Üretimine Etkisi: Türkiye Örneği

Özet

İlk olarak Çin'in Wuhan kentinde ortaya çıkan koronavirüsün (COVID-19) insan sağlığı üzerindeki olumsuz etkisini azaltmak için hükümetler tarafından uzaktan eğitim ve sokağa çıkma yasakları gibi önlemler alındı. Bu önlemler elektrik tüketimini etkiledi. Türkiye, COVID-19'dan olumsuz etkilenen ülkelerden biri oldu. Bu nedenle, bu makalenin amacı, Türkiye'de elektrik tüketiminin ve üretiminin COVID-19 salgınına bağlı olarak değişimini analiz etmektir. Bu amaçla, Türkiye'deki elektrik tüketimindeki değişimi incelemek için altı ilin konut, sanayi, iş yeri ve toplam elektrik tüketimi analiz edilmiştir. 2020 yılında ilk vakanın görüldüğü Mart ayı ile birlikte yılın on ayına bakıldığında 2019 yılına göre incelenen altı ilde konut elektrik tüketiminin arttığı gözlemlenmiştir. Sanayi elektriği tüketimi Mart ve sonraki aylarda azalmıştır, ancak sonraki aylarda artmıştır. Öte yandan, neredeyse on ayın tamamında işyeri elektrik tüketiminde azalma olduğu gözlenmiştir. Türkiye'de kişi başına elektrik üretimi tahmini çalışmasında, 2020 yılında üretilen elektriğin eğri uydurma yöntemiyle elde edilen tahmini değerden %

5,89 daha fazla olduğu hesaplanmıştır. Ayrıca 2019 ve 2020 yılları elektrik tüketimini ve kişi başına üretimi karşılama çalışmasına göre 2019 yılında % 0,22, 2020 yılında ise % 0,27 oranında üretimin tüketimi karşılayamadığı hesaplanmıştır.

Anahtar Kelimeler: Covid-19, Elektrik Tüketimi, Elektrik Üretimi, Kişi Başına Düşen Elektrik, Konut Elektriği

1. INTRODUCTION

The infectious disease known as COVID - 19 caused by the SRA-CoV-2 coronavirus was first detected in Wuhan, China. COVID-19 is an acute respiratory disease. The outbreak significantly affected all aspects of life since its first appearance. Following the first cases, people started to experience unexpected changes in their lives. Health facilities had to work intensely during this period. Country governments had to take social and economic outbreakes to reduce the spread of COVID-19 and its adversities. Some of these outbreakes were distance education in schools, flexible working in the public sector, daytime curfews and closure of workplaces [1-3]. Those who were out of their mandatory work areas had to continue their jobs from home. Most educational institutions transformed education activities into online distance education. Due to these transformations and restrictions on a global scale, electrical energy consumption shifted from places such as industry, business and educational institutions, especially to homes and hospitals. This transition in work and lifestyle has led to a significant change in the level of electricity demand. The slowing down of generation in all sectors or the cessation at some points caused the electricity consumption used in the industry to decrease significantly. These changes have an impact on electricity demand. Turkey has also been one of the countries affected by this outbreake. The first case in Turkey was announced on 11 March 2020. Energy supply is one of the sectors considered critical. Energy demand is closely related to people's activities [4-6]. Due to the continuous increase in per capita electricity consumption in developed countries around the world, the total electricity consumption and the amount of electricity used per capita are increasing every year. Turkey is a country with a dynamic economy and rapid population growth. In parallel with the economic development in Turkey, the energy demand is constantly increasing. For Turkey, increasing the diversity of energy generation is also of great importance in terms of coverage energy consumption due to both economic development and the outbreake. Due to the scarcity of fossil resources, Turkey's dependence level on imported energy is around 70%, and it is estimated that this rate could rise to over 80% by 2030 [7, 8].

Guler et al. (2020) analyzed the direction and strength of the relationship between daily coronavirus cases in Turkey and daily electricity consumption. "Hendry General-to-Specific Modeling" method was used. It was determined that there was a negative relationship between the increase in the number of cases and electricity consumption, and the effect of the changes in the number of cases on electricity consumption emerged after two days [9]. Ozbay et al. (2021) examined electricity consumption data in Turkey during the outbreak period. It was observed that electricity consumption decreased significantly on days of restrictions. NARX and LSTM methods were used to estimate energy consumption [7]. A study was conducted by The Economic Policy Research Foundation of Turkey (TEPAV) (2021) in Turkey to reveal the economic impact, taking into account the effect of COVID-19 on electricity consumption. It was concluded that the electricity consumption in Turkey between 30-31 March 2020 decreased by 12% compared to the previous year [10]. Firik et al. (2021) conducted a study that was investigated to COVID-19 early effects of the outbreak process in Turkey's electricity sector. Compared to the previous year, it had been observed that electricity consumption had decreased on weekdays and consumption hours had also changed. When evaluated according to the consumer group, it was observed that the most serious decrease was experienced in the industry and business group, while residential consumption increased [11]. Delgado et al. (2021) calculated the electricity load trend for Brazil depending on the COVID-19 outbreak. Weekly electricity loads before and after the restrictions were compared. The biggest decrease was calculated as 19% in the southern regions and 3% in the northern regions [12]. Santiago et al. (2021) conducted a study on how restrictions change electricity consumption in Spain. It was calculated that

between March 14 and April 30, electricity consumption decreased by 13.49% compared to the average value of the previous five years. A decrease of 10.62% on weekends and 14.53% on weekdays was calculated [5]. Abu-Rayash et al. (2020) analyzed hourly electricity demand data for the province of Ontario. It was determined that the general electricity demand decreased by 14% in April. After the outbreake, they concluded that the highest demand for electricity occurred early in the week [13]. Edmarh et al. (2020) examined the change of electricity consumption in the days of curfew in Nigeria. According to the results, they found that residential consumption increased by 49% and industrial electricity consumption decreased by 18% [14]. Ghiani et al. (2020), the changes in electrical energy consumption due to the outbreake in Italy were examined. It had been determined that the amount of consumption has decreased by around 37%. Generation from renewable energy sources had been observed to increase from 23% to 40% [15]. Aruga et al. (2020), the changes in the amount of energy consumption in India were examined. The number of tests and case situations were also taken into account in the study. According to the results obtained, it was concluded that household income level was related to electricity consumption [16]. Carvalho et al. (2021) [17], Geraldi et al. (2021) [18] and [19-27] had also studied the impact of the COVID-19 lockdown process on electricity consumption and production.

The purpose of this article is to reveal to what extent the restrictions applied to cope with the COVID-19 outbreak affect Turkey's electricity consumption and generation. In this respect, analyzes were made on electricity consumption and generation data before and after COVID-19. While analyzing, criteria such as the number of consumers, population and the number of days in a year were also taken into consideration. In addition, curve fitting method was used while estimating generation. The main contribution of this study is to reveal how the electricity consumption and generation during the lockdown changes according to the non-lockdown periods. The effect of the COVID-19 outbreak had been investigated with the obtained variation rates. The next part of the study after this stage consists of four sections. The materials used in the study are explained in the second chapter, and the method in the third chapter. In the fourth chapter, the findings obtained in the study are included. Finally, in the fifth chapter, the effects of changes in electricity consumption and generation due to the COVID-19 outbreak in Turkey are presented.

2. MATERIALS

The data used in this study were obtained from various publicly available sources. Electricity consumption, electricity generation and consumer number data were taken from the website of Energy Exchange Istanbul (EXIST) and population data were taken from the website of Turkish Statistical Institute (TSI) [28-31].
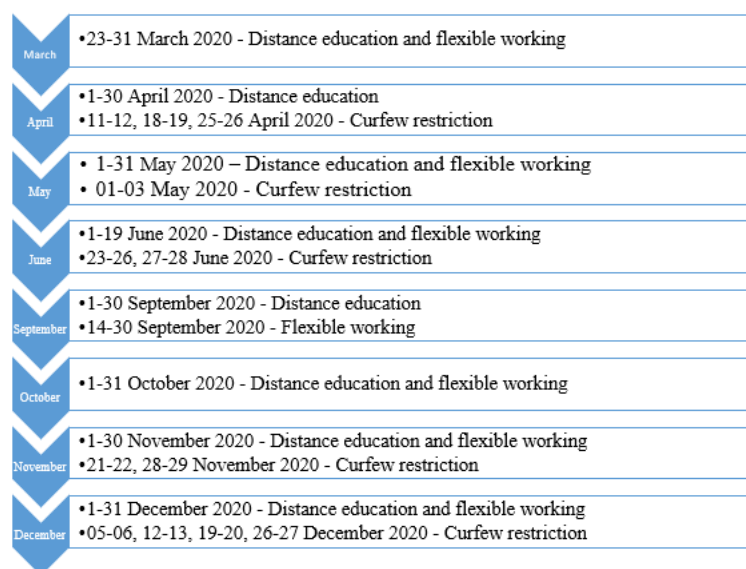

Figure 1. COVID-19 restrictions timeline in Turkey during March to December in 2020 [32].

Figure 1 shows the timeline of the restrictions imposed in 2020 due to COVID-19. The first COVID-19 case in Turkey was announced on March 11, 2020. Since March, restrictions on distance education in schools, flexible working in the public sector and curfew had been imposed. The type of restriction and the number of days varied from month to month. The study was carried out with data belonging to six provinces of Turkey. Each of the selected provinces are leading cities in terms of both population density and industrial and business sectors in their regions. These provinces were Istanbul (Europe), Izmir, Antalya, Malatya, Denizli and Trabzon.

3. METHODS

In this study, in order to determine the effect of the COVID-19 lockdown process on electricity in Turkey, consumption and total generation analyzes were made in the total, residential, industrial and business sectors, and graphical tools were used to interpret the analyzes. The curve fitting method was used while estimating the total generation.

3.1 Residential Electricity Consumptions

Residence refers to home, where people live day to day. Residential electricity is different from industrial and business electricity [33]. In Figure 2, residential electricity consumption graphs of six provinces analyzed are given.
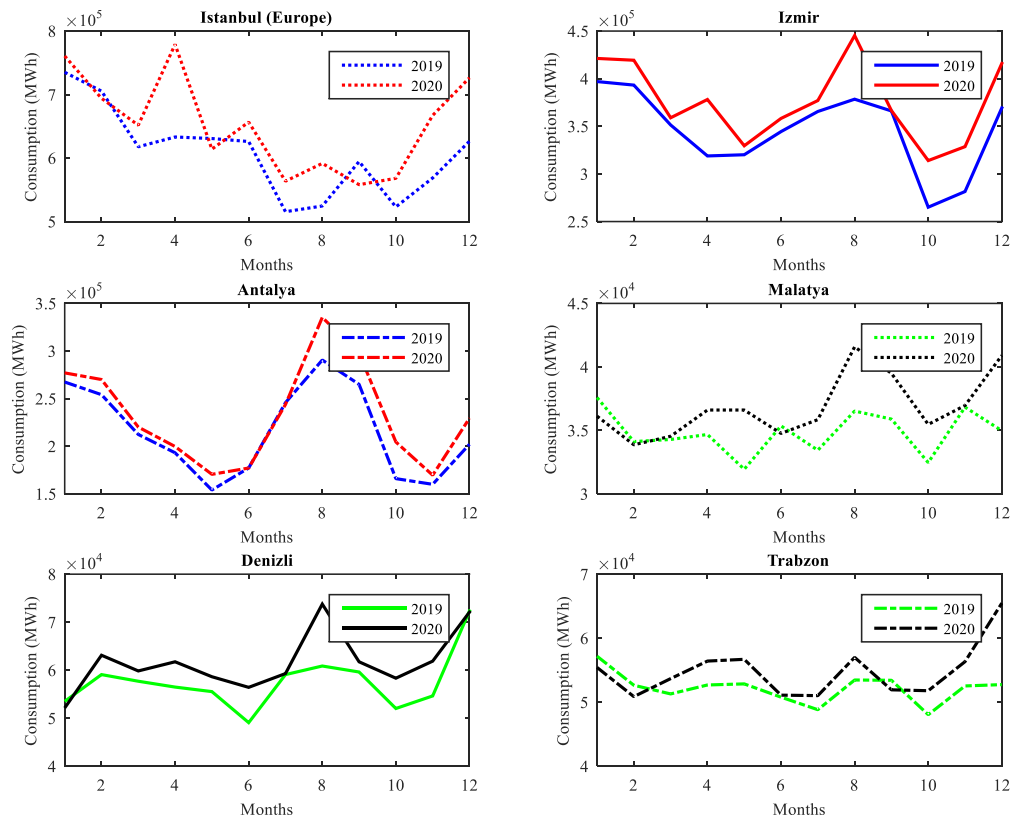

Figure 2. Residential electricity consumption
a) İstanbul (Europe) b) İzmir c) Antalya d) Malatya e) Denizli f) Trabzon

As can be seen from Figure 2, distance education that applied for nine days of March and all days of April increased residential electricity consumption. Increases in May and June can also be seen from the graph.

Although distance education, flexible working and no restrictions in July and August, there has been an increase in residential electricity consumption. It is thought that this is due to the excessive time spent at homes because of closed schools. With the initiation of distance education and flexible working in the public in September, an increase was seen in residential electricity consumption again.

With the start of distance education and flexible working in the public sector in September, again, an increase in residential electricity consumption was observed. The average increase rates of residential electricity consumption in 2020 compared to 2019 were respectively 7.54% (530 161 MWh) for Istanbul (Europe), 9.1% for Izmir (361875 MWh), 8.1% for Antalya (207075 MWh), 6.02% for Malatya (24658 MWh), 7.33% (49065 MWh) for Denizli and 5.05% (31257 MWh) for Trabzon. The increase rates in January and February are respectively 3.48% and - 1.61% for Istanbul, 6.12% and 6.62% for İzmir, 3.58% and 6.26% for Antalya, -3.90% and -0.74% for Malatya, -2.56% and 6.82% for Denizli and -3.07% and - 3.37%.for Trabzon. As can be seen, the increase rates in January and February for all provinces in 2020 are below the average value of that province. This indicates that in the remaining 10 months, residential electricity consumption has increased due to the impact of COVID-19.

3.2 Industrial Electricity Consumptions

Industrial consumers use electrical energy to produce a product by processing raw materials in many areas such as manufacturing, construction, agriculture and mining [34].
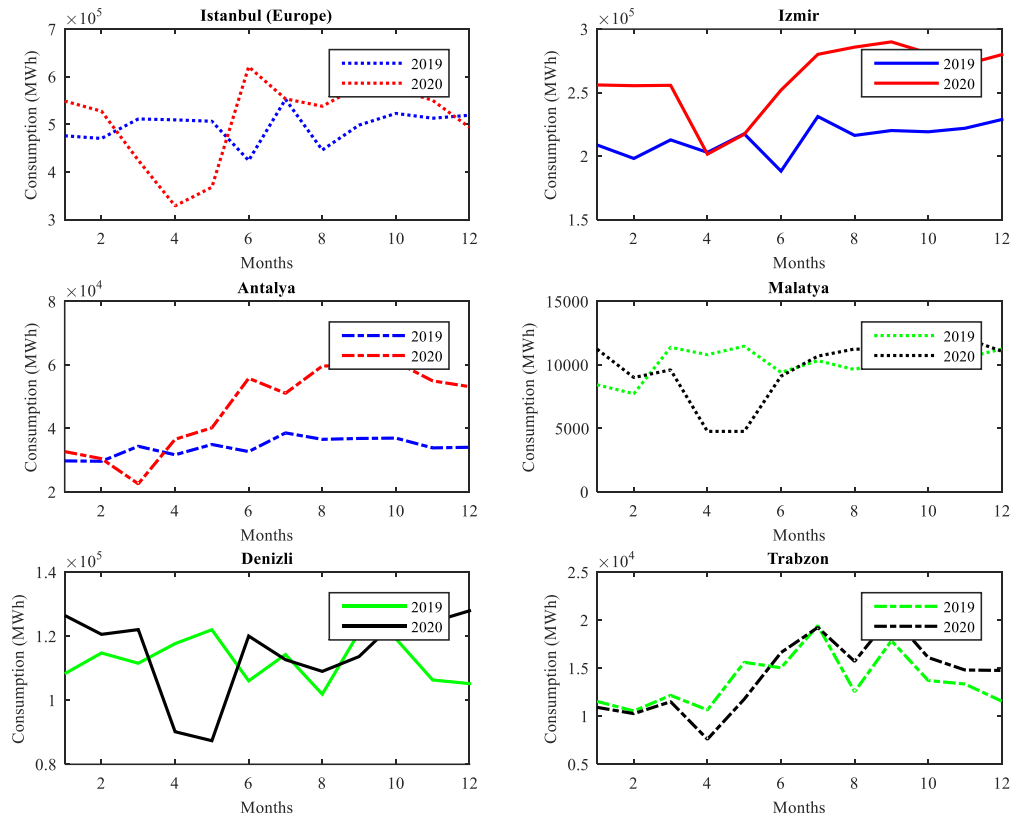

Figure 3. Industrial electricity consumption
a) İstanbul (Europe) b) İzmir c) Antalya d) Malatya e) Denizli f) Trabzon

The industrial electricity consumption values of six different provinces are given in Figure 3. In 2020, the industrial electricity consumption in 2019 for the six provinces studied is as follows: 3.62% (158516 MWh)

increase in Istanbul (Europe), 21.92% (561070 MWh) increase in İzmir, 35.04% (147962 MWh) increase in Antalya, 2.75% (5632 MWh) decrease in Malatya, % 2.94 (30661 MWh) increase in Denizli and 3.24% (5786 MWh) increase for Trabzon.

3.3 Business Electricity Consumptions

Business premises are places where business activity takes place. This group has a different tariff than residential and industrial electricity tariffs in Turkey [28].
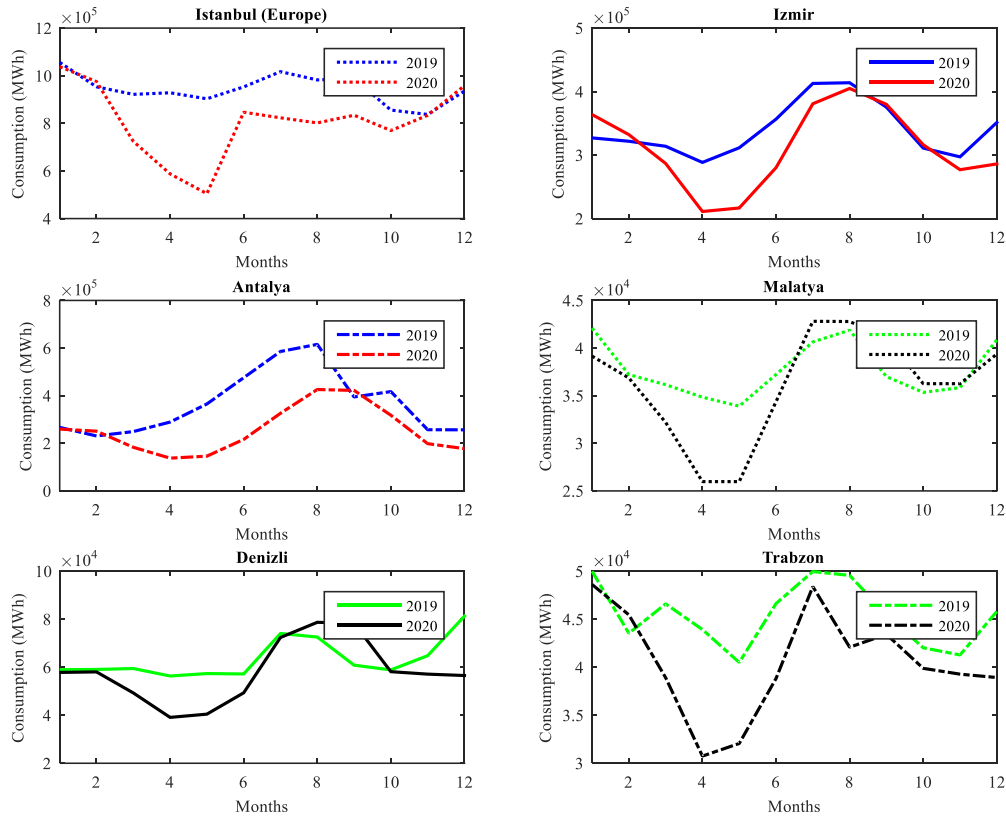

Figure 4. Business Electricity Consumption
a) İstanbul (Europe) b) İzmir c) Antalya d) Malatya e) Denizli f) Trabzon

In Figure 4, it is possible to say that the biggest impact of the COVID-19 outbreake on Turkey's electricity consumption is in business. Business electricity consumption values for 2020 were low in the six provinces studied. In January and February, when there was no outbreake in all six provinces, it is seen that the consumption was almost the same as the 2019 values, but there were decreases in the following months. The average decrease rates of business electricity consumption in 2020 compared to 2019 were respectively 14.50% (1635121 MWh) for Istanbul (Europe), 8.77% (345 275 MWh) for İzmir, 27.75% (1341521 MWh) for Antalya, 4.73% (19896 MWh) for Malatya, 8.60% (65559 MWh) for Denizli and 10.84% (58683 MWh) for Trabzon.

3.4 Total Electricity Consumptions

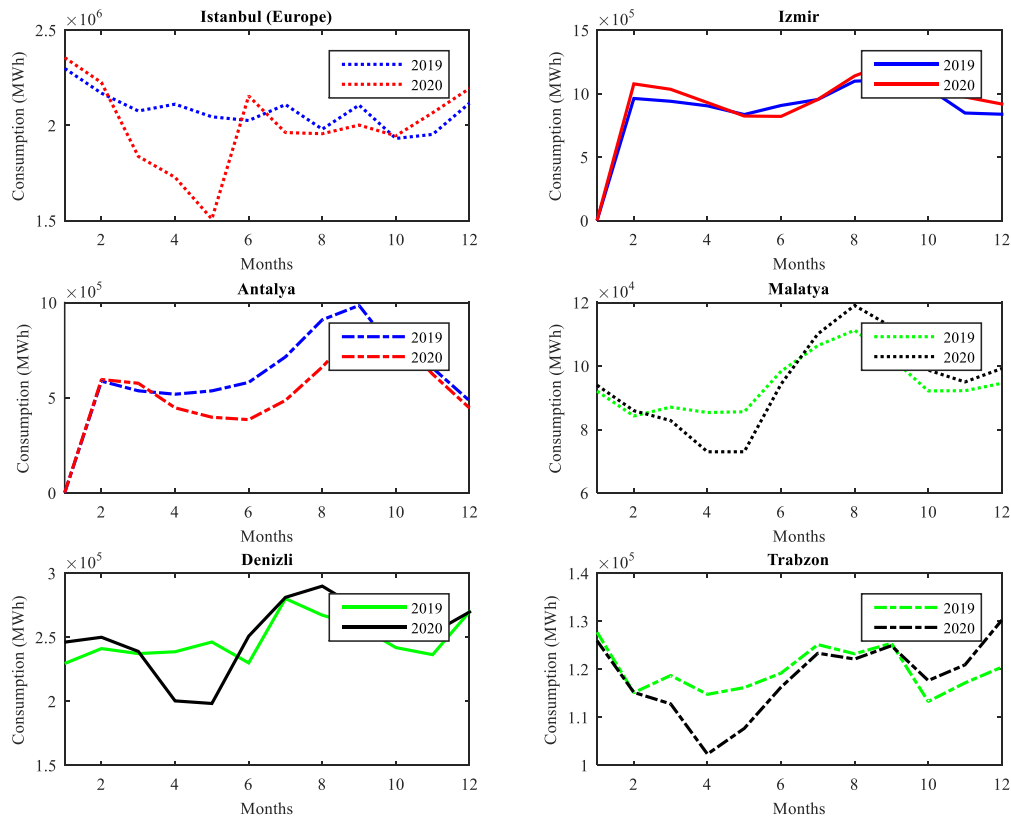In Figure 5, the total electricity consumption values of the six provinces studied are given.

Figure 5. Total Electricity Consumption
a) İstanbul (Europe) b) İzmir c) Antalya d) Malatya e) Denizli f) Trabzon

In the city of Istanbul (Europe), electricity consumption is 24928841.35 MWh in 2019, while this value is 23940480.02 MWh in 2020. A decrease of 3.95% (988361.33 MWh) occurred. In January and February, when the COVID-19 outbreake is not seen, there is an increase of 2.5%. The months in which total electricity consumption decreased were March with 11.48%, April with 18.19%, May with 26.22%, July with 6.96%, August with 1.19%, and September with 4.97%. Due to the outbreake, it is seen that the biggest decrease in electricity use is in the business sector for Istanbul (Europe).

While 10448965.86 MWh of electricity consumption is realized in the province of Izmir in 2019, this value is realized as 11051796.76 MWh in 2020. There was an increase of 5.77% (602830.90 MWh). The reason for this increase is thought to stem from industrial electricity consumption. In 2020, the rate of industrial electricity usage increased by 21.92% compared to 2019. The biggest decrease in total electricity consumption is realized in May with 9.47%.

While 7253153.45 MWh of electricity consumption is realized in Antalya in 2019, this value is realized as 6323616.99 MWh in 2020. A decrease of 12.82% (929536.46 MWh) occur. Except for the months of January and February when the outbreake is not seen, an increase of 12.22% is observed only in September. In the remaining nine months, there is a decrease in total consumption compared to 2019. The biggest decrease is 33.66% in April.

While 1132106.74 MWh electricity consumption is realized in the city of Malatya in 2019, this value is realized as 1137624.17 MWh in 2020. An increase of 0.07% (5517.43 MWh) is observed. In Malatya, industrial and business electricity consumption decreased by 2.75% and 4.73%, respectively, in 2020 compared to 2019, while residential electricity consumption increased by 6.02%. The biggest decrease is 14.48% in April. While 2978398.18 MWh electricity consumption is realized in Denizli in 2019, this value is realized as 3003 846.76 MWh in 2020. An increase of 0.86% (25448.58 MWh) is observed. In Denizli, industry (2.94%) and residential (7.33%) electricity consumption increased, while business (8.60%) electricity consumption decreased compared to 2019. The biggest decrease is 19.49% in May. While 1436659.38 MWh electricity consumption is realized in the province of Trabzon in 2019, this value is realized as 1419696.25 MWh in 2020. There is a decrease of 1.20% (16963.13 MWh). In 2020, electricity consumption rates for residential (5.05%) and industrial (3.24%) increased, while electricity consumption rate decreased to business (10.84%). It is observed that the decrease in total electricity consumption is due to business.

3.5 Residential Consumer Number

In this section, the changes in the number of residential consumers are examined in order to interpret the changes in residential electricity consumption from 2019 to 2020 more accurately.
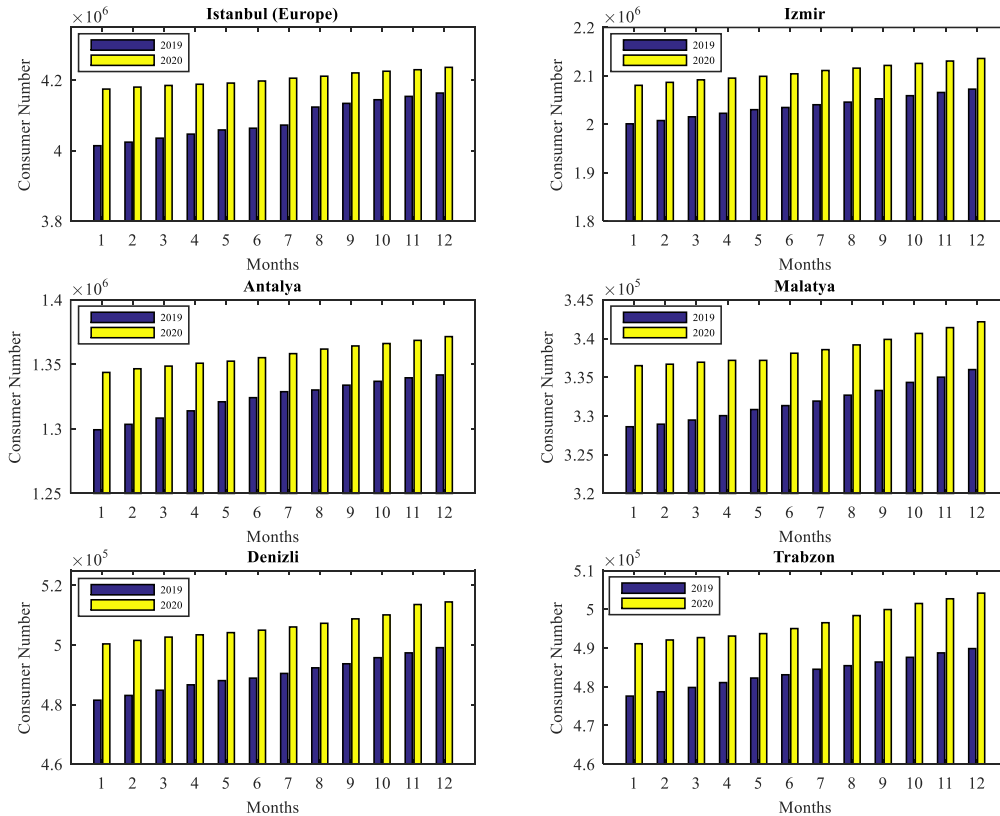

Figure 6. Residential Consumer Number
a) İstanbul (Europe) b) İzmir c) Antalya d) Malatya e) Denizli f) Trabzon

When Figure 6 is examined, it is seen that the number of residential consumers is constantly increasing in the six provinces where the study is conducted. The number of residential consumers in Istanbul (Europe) increased from 4014125 to 4163743 in 2019. In 2020, it reached 4174978 in January, and rose to 4236699 at the end of the year. While in Izmir province increase from 2000858 to 2072566 in 2019, it increases from

2080481 to 2135939 in 2020. While these values are 1299332 in January 2019 in Antalya, it become 1371484 in December 2020. It increases from 328612 to 342163 in Malatya province, from 481490 to 514478 in Denizli and finally from 477590 to 504182 in Trabzon.

3.6 Industrial Consumer Number

In this section, the change in the number of industrial consumers by years has been examined. Changes in the number of consumers enable a more accurate analysis of the change in electricity consumption in the industrial sector.
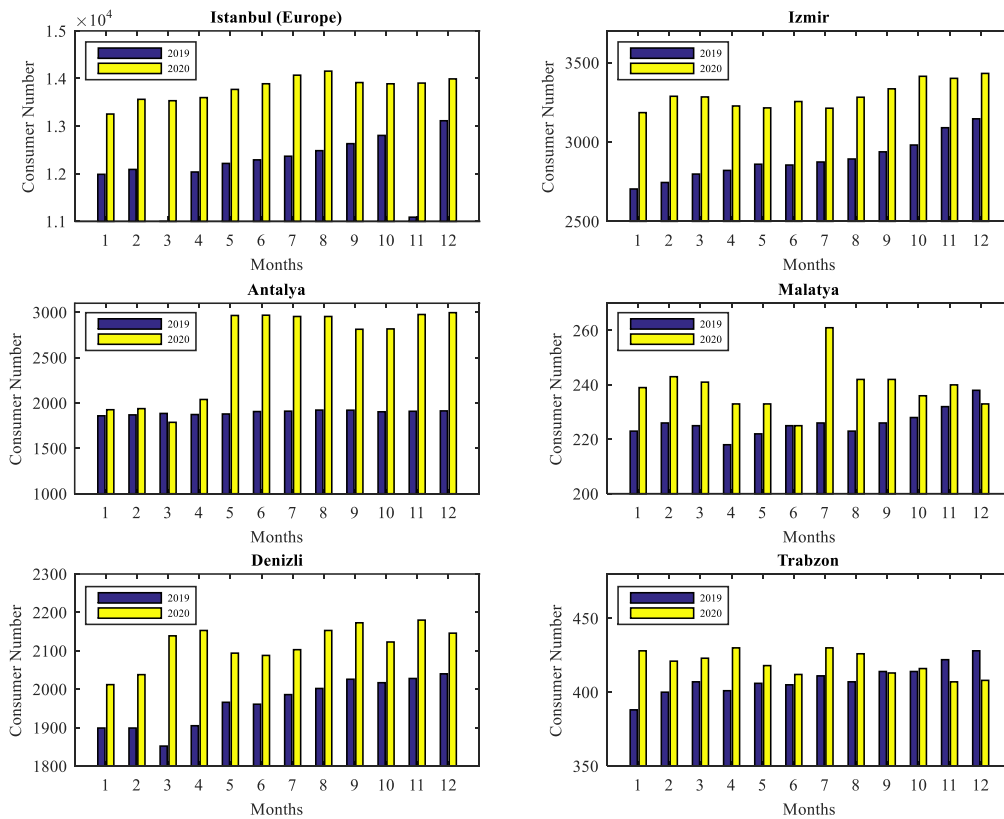

Figure 7. Industrial Consumer Number
a) İstanbul (Europe) b) İzmir c) Antalya d) Malatya e) Denizli f) Trabzon

When Figure 7 is analyzed, it is seen that the number of industrial consumers generally increased in the six provinces where the study is conducted. The decreases occurred in Antalya in March, in Malatya in December and in Trabzon in September, November and December. While the number of industrial consumers increase from 11988 to 13113 in 2019 in Istanbul (Europe), it reaches 13992 from 13254 in 2020. While in İzmir province increase from 2704 to 3146 in 2019, it increases from 3185 to 3432 in 2020. These values increase from 1859 in January 2019 in Antalya to 2996 in December 2020. It increases from 223 to 233 in Malatya, from 1899 to 2146 in Denizli and from 388 to 408 in Trabzon. The highest increase in Istanbul (Europe) is in March with 37.07%. The highest increase in İzmir province is realized in February with 19.78%. While a decrease of 5.20% is experienced in the province of Antalya, the highest increase is realized with 56.61% in December. While the province of Malatya decrease 2.10% in December, the highest increase is seen in July with 15.49%. While the lowest increase in Denizli is in December with 5.20%, the highest increase is in March with 15.50%. Finally, the biggest increase in Trabzon province is realized in January with 10.31%.

3.7 Business Consumer Number

In this section, the changes in the number of business consumers in six provinces for the years 2019 and 2020 are analyzed.
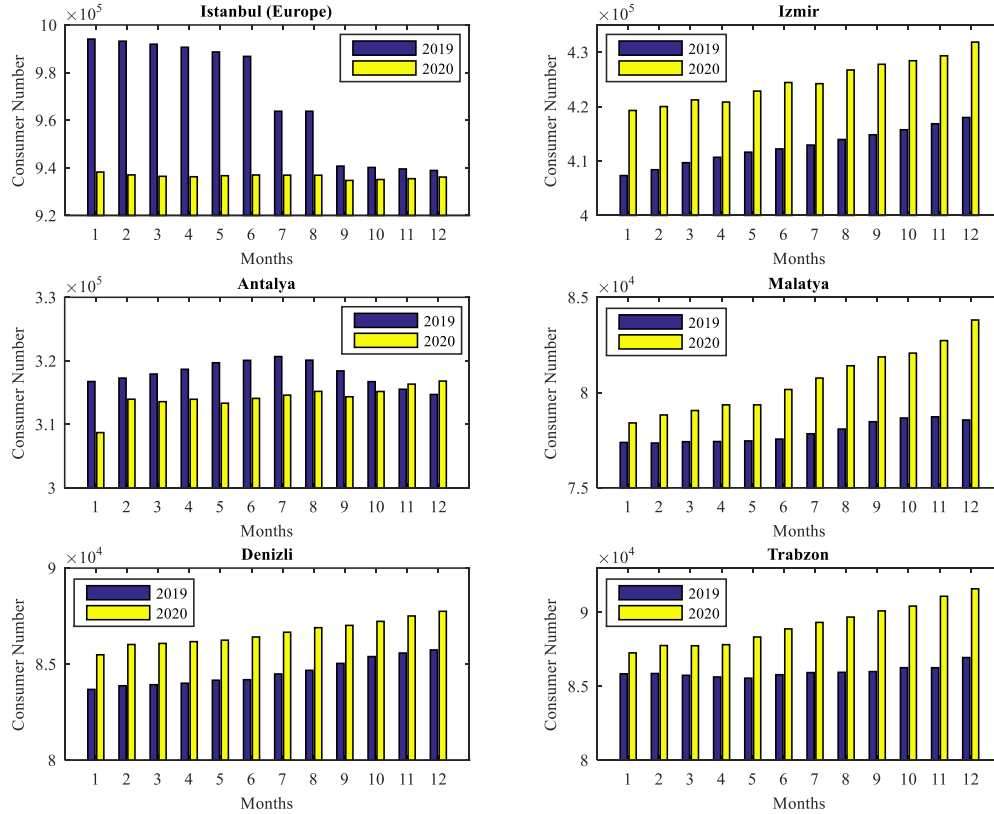

Figure 8. Business Consumer Number
a) İstanbul (Europe) b) İzmir c) Antalya d) Malatya e) Denizli f) Trabzon

When Figure 8 is analyzed, it is seen that the number of business consumers generally increased in four provinces excluding Istanbul and Antalya. A decrease is observed in all months in the province of Istanbul. The average decrease in these twelve months is 3.35%. In the first ten months of Antalya, the number of business consumers decrease. These decreases vary between 0.49% and 2.54%. While the number of business consumers in Istanbul (Europe) decrease from 994066 to 938899 in 2019, it decreases from 938207 to 936113 in 2020. There is a decrease in both years. While in İzmir province increase from 407332 to 417999 in 2019, it increases from 419291 to 431849 in 2020. While these values are 316738 in January 2019 in the province of Antalya, it become 316806 in December 2020. It increases from 77380 to 83807 in Malatya province, from 83682 to 87748 in Denizli and finally from 85839 to 91595 in Trabzon.

3.8 Consumption Variation Rates

With the consumption variation study, the aim is to reveal the real consumption variation. It would be misleading to evaluate only the energy consumption values on a yearly basis and to comment on the decrease or increase. Because electricity consumption values can also vary with the number of consumers. In this respect, equation 1 has been obtained to make the correct analysis.

$$Variation_{month} \ (\%) = \frac{\left[\left(\frac{TEC_{2020-month}}{CN_{2020-month}}\right) - \left(\frac{TEC_{2019-month}}{CN_{2019-month}}\right)\right] \times 100}{\left(\frac{TEC_{2019-month}}{CN_{2019-month}}\right)} \qquad (1)$$

$Variation_{month}$ (%), Percentage variation for the relevant month between 2020 and 2029
$TEC_{2020-month}$, Total energy consumption for the relevant month for 2020, (MWh)
$CN_{2020-month}$, Consumer number for the relevant month in 2020
$TEC_{2019-month}$, Total energy consumption for the relevant month for 2019 (MWh)
$CN_{2019-month}$, Consumer number for the relevant month in 2019

4. RESULTS AND DISCUSSIONS

4.1 Residential Consumption Variation Rates

Table 1 is obtained by using the residential consumption data in equation 1.

Table 1. Residential consumption variation values

Months	Residential					
	Variations (%)					
	Istanbul (Europe)	Izmir	Antalya	Malatya	Denizli	Trabzon
January	-0.51	2.06	0.15	-6.15	-6.24	-5.74
February	-5.29	2.60	2.86	-3.02	2.89	-6.00
March	1.72	-1.58	0.55	-1.50	0.03	1.93
April	18.88	14.47	0.59	3.32	5.68	4.47
May	-5.75	-0.44	8.12	12.44	2.21	4.77
June	1.54	0.58	-2.31	-3.64	11.30	-1.80
July	5.86	-0.32	-2.94	5.09	-2.74	1.97
August	10.45	13.75	12.71	11.67	17.62	3.84
September	-8.05	-3.15	9.80	7.90	0.50	-5.42
October	6.53	14.74	20.55	7.24	8.97	4.80
November	15.24	13.18	3.73	-1.54	9.68	4.24
December	13.95	9.30	11.09	14.84	-3.30	20.60

Residential consumption variation rate in the province of Istanbul (Europe) is negative for three months. In other words, electricity consumption has decreased in these months compared to 2019. The highest decrease in electricity consumption is in May with 5.75%. In the months when the increase is observed, the biggest increase is realized in April with 18.88%. While the month in which electricity consumption fell the most in İzmir city is March with 1.58%, the highest increase in consumption is in October and April with 14.74% and 14.47%, respectively.

In Antalya province, electricity consumption decreases only in June and July, while an increase is observed in other months. The biggest increase is in October with 20.55%. In the province of Malatya, there is a five-month decrease and a seven-month increase. The biggest decrease is in January, when the COVID-19 outbreake isn't yet seen in Turkey, with 6.15%. The biggest increase is realized in December with 14.84%.

The province of Denizli has only decreased for three months. An increase is observed in the remaining nine months, the highest increase is in August with 17.62%. In the province of Trabzon, the biggest decrease is in January with 5.74% and the biggest increase is in December with 20.60%.

4.2 Industrial Consumption Variation Rates

Table 2 is obtained using industrial consumption data in equation 1.

Table 2. Industrial consumption variation values

Months	Industrial Variations (%)					
	Istanbul	Izmir	Antalya	Malatya	Denizli	Trabzon
January	4.30	4.11	6.04	24.32	10.26	-14.22
February	0.00	7.63	-0.93	8.40	-2.09	-7.46
March	-39.42	2.39	-30.78	-21.23	-5.25	-8.99
April	-42.87	-13.17	5.99	-58.72	-32.21	-33.47
May	-35.54	-11.19	-27.11	-60.41	-32.78	-26.73
June	29.57	17.45	9.52	-3.14	6.32	8.67
July	-11.94	8.38	-14.44	-10.42	-6.90	-5.38
August	6.37	16.48	6.13	7.61	-0.52	19.58
September	5.59	16.04	11.06	-0.90	-12.58	15.01
October	1.24	12.00	11.39	7.05	-0.66	16.83
November	-14.41	11.38	4.10	10.91	8.92	15.02
December	-10.90	12.14	-0.36	0.58	15.61	33.94

When the industrial consumption variations values in Table 2 are examined, the variation in the province of Istanbul (Europe) has been negative for three months since March, when the COVID-19 outbreake first appeared. In other words, electricity consumption has decreased in these months compared to 2019.

The month in which electricity consumption fall the most was April with 42.87%. In the months when the increase is observed, the biggest increase is in June with 29.57%. In Izmir, the month in which electricity consumption fall the most was April with 13.17%, while the highest increase in consumption is June with 17.45%. The biggest decrease in electricity consumption in Antalya is realized in May with 27.11%. In the province of Malatya, it has been observed that electricity consumption has decreased for four months, especially since March, when the COVID-19 outbreake and restrictions begin.

The biggest consumption decrease is realized in May with 60.41%. In Denizli province, the biggest electricity consumption decreases are seen in April and May with 32.21% and 32.78%. In the province of Trabzon, the biggest decreases were in April and May with 33.47% and 26.73%, respectively.

As it will be noted, in all provinces, following the onset of the COVID-19 outbreake and the start of the restrictions, it is seen that the consumption of industrial electricity decreased in the following months due to the removal of the restrictions.

4.3 Business Consumption Variation Rates

Table 3 is obtained using business consumption data in equation 1.

Table 3. Business consumption variation values

Months	Business Variations (%)					
	Istanbul	Izmir	Antalya	Malatya	Denizli	Trabzon
January	4.11	8.07	-0.14	-8.21	-4.01	-4.34
February	8.44	0.39	9.83	-2.82	-4.18	2.16
March	-16.76	-11.13	-25.42	-12.79	-19.16	-18.39
April	-33.03	-28.56	-51.68	-27.26	-32.34	-31.75
May	-41.01	-32.29	-59.21	-25.19	-31.18	-23.34
June	-6.43	-23.68	-53.63	-10.66	-15.94	-19.64
July	-16.75	-10.21	-43.25	1.51	-4.69	-6.82
August	-16.03	-5.10	-29.73	-1.99	5.68	-18.63
September	-15.11	-1.90	8.34	6.44	25.73	-8.89
October	-9.54	-1.33	-23.46	-1.67	-3.33	-9.47
November	-0.01	-9.52	-22.99	-3.75	-13.80	-9.90
December	2.72	-21.19	-31.27	-9.66	-32.03	-19.33

When the business consumption variations values in Table 3 are analyzed, it is seen that business electricity consumption decrease in Istanbul (Europe) in all months except January, February and December. The highest decrease is in May with 41.01%. There is a decrease in all months except January and February in the city of Izmir. The biggest decrease is seen in May with 32.29%. In the province of Antalya, there is a decrease in business electricity consumption in 10 out of 12 months. The biggest decrease is in May with 59.21%. In the province of Malatya, the biggest decrease is realized in April with 27.26%. The biggest decrease in business electricity consumption in Denizli province take place in April with 32.34%. In the province of Trabzon, decreases are observed in eleven months. The biggest decrease is in April with 31.75%. If it is noticed, it is seen that the biggest decreases in business electricity consumption generally occur in April and May. The graphical representation of the values in Table 1, Table 2 and Table 3 is as in Figure 9.

4.4 Box-plot Graphs

A boxplot chart is used to show the visual distribution of numerical data and variability. It is a type of chart frequently used in data analysis. It provides a visual summary of the distribution of the data set and the signs of variability [35].
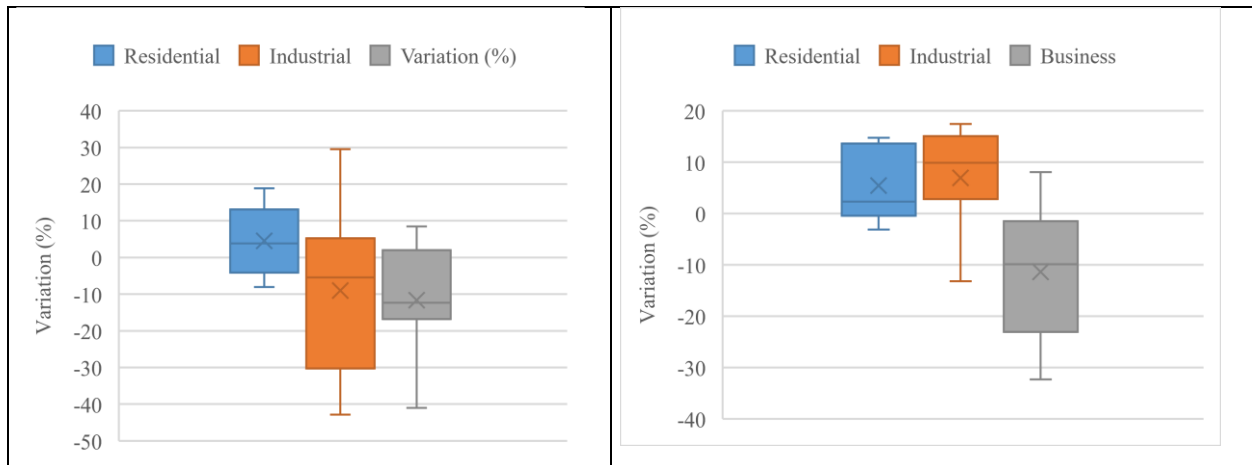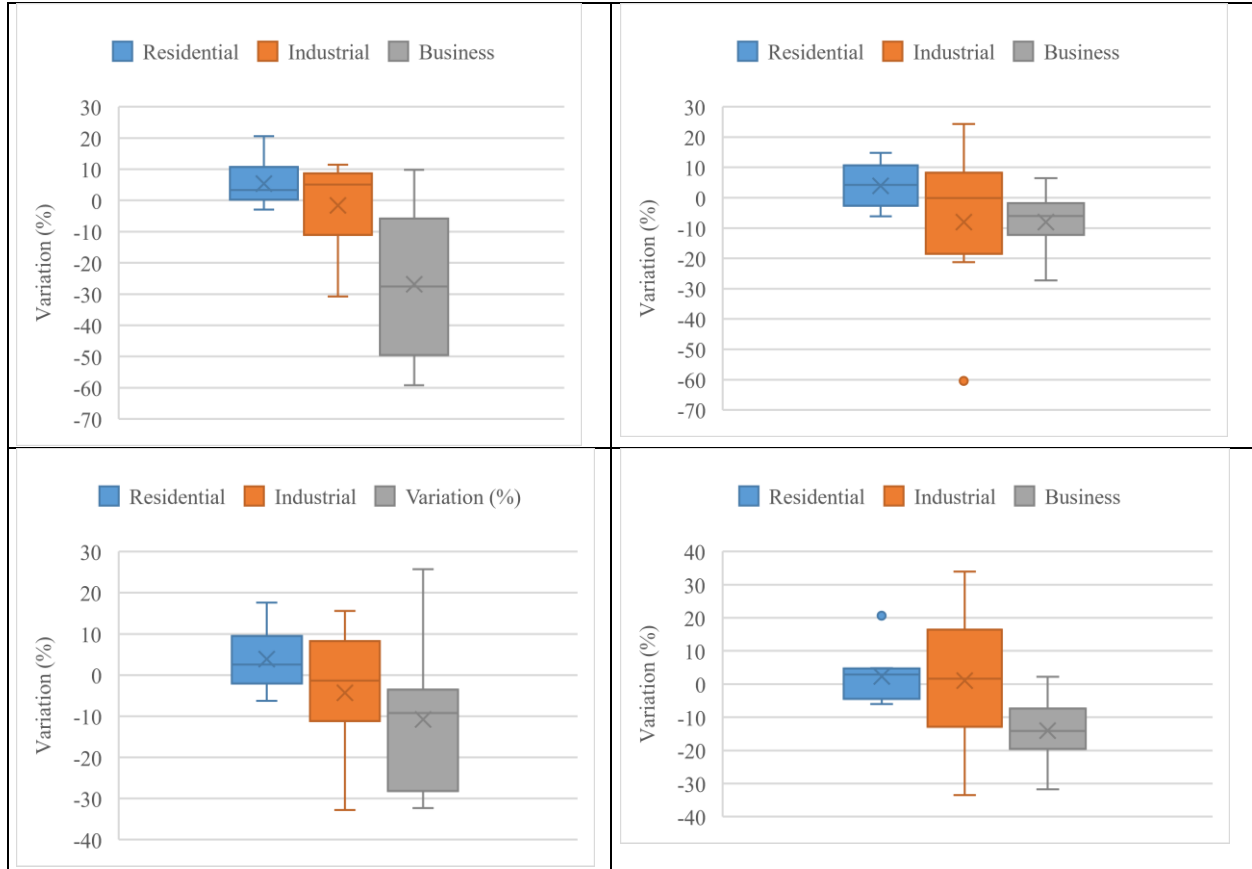
Figure 9. Variation (%) Values (%) from 2019 to 2020 (Boxplot)
a) İstanbul (Europe) b) İzmir c) Antalya d) Malatya e) Denizli f) Trabzon

When the boxplot graphs in Figure 9 are examined, it is calculated that the median value for the number of residential buildings in Istanbul is 3.79% and the mean value is 4.55%. In the industrial graph, the median value is - 5.45%, the mean value is -9.0%, in the business graph the median value is -12.33%, while the mean value is -11.62%. It has been calculated that the median value for the number of residential buildings in Izmir is 2.33% and the mean value is 5.43%. The median value is 9.88% in the industrial graph, the mean value was 6.97%, in the business graph the median value is -9.87%, while the mean value was -11.37%. It is calculated that the median value in the residential graph in Antalya province is 3.30% and the mean value was 5.41%. The median value is 5.05% in the industrial graph, the mean value is -1.62%, while the median value is -27.58% in the business graph, while the mean value is -26.88%. It is calculated that the median value in the residential graph in Malatya province is 4.21% and the mean value is 3.89%. The median value is -0.16% in the industrial graph, the mean value is -8.0%, while the median value is -5.98% in the business graph, while the mean value is -8.00%.

It is calculated that the median value in the residential graph in Denizli province is 2.55% and the mean value is 3.88%. The median value is -1.38% in the industrial graph, the mean value was -4.32%, while the median value is -9.25% in the business graph, while the mean value is -10.77%. It is calculated that the median value in the residential graph in Trabzon province is 2.91% and the mean value is 2.31%. The median value is 1.65% in the industrial graph, the mean value is 1.07%, in the business graph the median value is -14.14%, while the mean value is -14.03%.

4.5 Daily per Capita Electricity Consumption Analysis

In this section, the analysis of daily per capita electricity consumption in total electricity consumption in Turkey in 2020 compared to 2019 has been made.

Table 4. Annual electricity energy consumption in Turkey [29]

Years	Total Consumption (MWh)
2019	290446923.91
2020	291017232.10

The total electricity consumption values in 2019 and 2020 are given in Table 4. For the daily electricity consumption per capita calculation, the total electricity consumption value, the number of days for that year and the population data of that year should be included in the calculation. These values are shown in Table 5. The population data used in the study were obtained from TSI [31].

Table 5. Days and population numbers for 2019 and 2020 in Turkey

Years	Number of days	Population
2014	365	77695904
2015	365	78741053
2016	366	79814871
2017	365	80810525
2018	365	82003882
2019	365	83154997
2020	366	83614362

Accordingly, equation 2 is obtained for the total daily electricity consumption calculation.

$$PPC_{daily}\ (Wh) = \frac{TC\ (Wh)}{TD \times TP} \tag{2}$$

PPC_{daily}, daily per capita electricity consumption (Wh)
TC, total electricity consumption for that year (Wh)
TD, the total number of days for that year
TP, total population for that year

According to the calculation made according to this equation, daily electricity consumption values per person are as in Table 6.

Table 6. Variation values for per capita electricity consumption for 2019 and 2020

Years	Per capita electricity consumption (Wh)	Variation (%)
2019	9569.42	- 0.63
2020	9509.48	

The variation of - 0.63% corresponds to 60.29 Wh per capita electricity consumption. In other words, daily electricity consumption per capita in 2020 has decreased by 60.29 Wh compared to 2019.

4.6 Daily per Capita Electricity Generation Analysis

In this section, the variation analysis of the total electricity generation daily per capita in Turkey in 2020 compared to 2019 has been made.

Table 7. Per capita electricity generation by years [30]

Years	Total Generation (TWh)
2014	247.84
2015	258.42
2016	269.29
2017	289.86
2018	291.17
2019	289.82
2020	290.23

Table 7 shows the total electricity generation values between 2014-2020. For the calculation of daily electricity consumption per capita, total generation, the number of days for that year and the population data of that year should be taken into account. Considering the data in Table 5 and Table 7, the daily total electricity generation calculation is obtained with equation 3.

$$PPG_{daily}\ (Wh) = \frac{TG\ (Wh)}{TD \times TP} \tag{3}$$

PPG_{daily}, daily per capita electricity generation (Wh)
TG, total electricity generation for that year (Wh)
TD, the total number of days for that year
TP, total population for that year

Accordingly, the variations in the daily per capita electricity generation amount obtained over the years have been as in figure 10. This graph includes the values until 2019. Because it is aimed to compare the actual amount generated in 2020 with the estimated amount. In order to calculate the estimated value for 2020, curve fitting method is used.
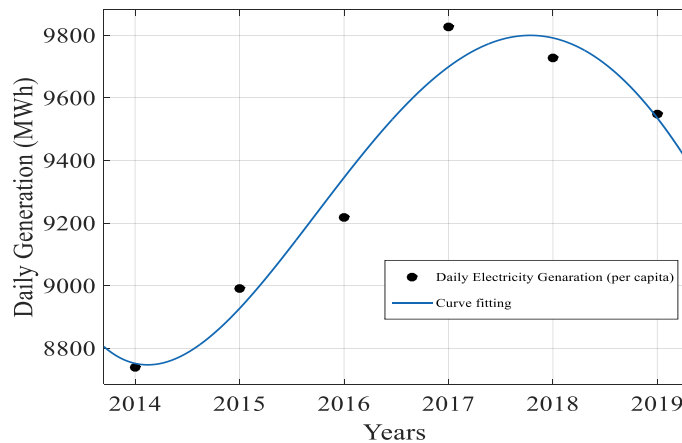

Figure 10. Total electricity generation of Turkey

With the study done in Matlab [36] environment, the polynomial equation in equation 4 has been obtained for the curve fitting for total electricity generation.

$$Generation\ (Wh) = 4.605x^4 - 97.291x^3 + 590.05x^2 - 982.78x + 9237.6 \qquad (4)$$

The x values in this equation represent values assigned to years. *1* for 2014, *2* for 2015, *3* for 2016, *4* for 2017, *5* for 2018, *6* for 2019 and *7* for 2020. R^2 value of equation 4 is obtained as 0.9559. Accordingly, while the real electricity generation value per capita in 2020 was 9483.67 Wh, it is estimated as 8956.38 Wh according to the polynomial curve equation obtained here. In other words, it is estimated that the daily electricity generation per capita generated in Turkey in 2020, when the COVID-19 outbreake is experienced, is above the expected. This estimated rate of increase is around 5.89%.

Table 8 is obtained as a result of the calculations made to determine the variation of electricity consumption and generation values per capita by years and the ratio of generation to consumption by years.

Table 8. Per capita consumption and generation and variation amounts for 2019 and 2020

Years	Consumption (Wh)	Generation (Wh)	Insufficiency of generation for consumption (%)
2019	9569.42	9548.61	- 0.22
2020	9509.48	9483.67	- 0.27
Variation (%)	- 0.63	- 0.68	

As can be seen from Table 8, the per capita consumption in 2020 has decreased by 0.63% (59.94 Wh) compared to 2019. When the generation per capita is compared, per capita generation in 2020 decreased by 0.68% (64.94 Wh) compared to 2019. At the point where per capita generation coverage per capita consumption, it is seen that the generation in 2019 could not coverage the consumption and this ratio is 0.22% (20.81 Wh). In 2020, as in 2019, per capita generation could not coverage per capita consumption. The failure rate is 0.27% (25.81 Wh), higher than in 2019.

When the studies in the literature are examined, studies had been conducted to analyze the variations in electricity consumption and generation during the COVID-19 outbreak both in Turkey and worldwide. In this study, unlike other studies, the variations in both total and residential, industrial and business sectors were analyzed, and real variation rates were obtained by taking into account not only the variations in the data but also the consumer, population and number of days. By using the generation data of previous years, the generation variation due to the outbreake was estimated by comparing the estimated generation for 2020 with the actual generation amount with the curve fitting method. In the studies mentioned in the section of the literature review and carried out using different methods, TEPAV (2021) had reached the conclusion that the electricity consumption in Turkey between 30-31 March 2020 decreased by 12% compared to the previous year. Also,

In the study conducted by Firik et al. (2021), it was concluded that electricity consumption decreased on weekdays compared to the previous year, when evaluated according to the consumer group, the most serious decrease was experienced in the industrial and business group, and residential consumption increased. According to the data obtained in this study, it was calculated that per capita electricity consumption decreased by 0.63% compared to the previous year. When the consumer group was evaluated, it was concluded that the decrease in electricity consumption is in the industrial and business sectors and the increase is in the residential sector. It is thought that this presented study will contribute to the literature with the technical analyzes and evaluations it contains and will be beneficial to the readers.

5. CONCLUSIONS

In this study, variations in residential, industrial, business and total electrical energy consumption and electricity generation in Turkey due to the COVID-19 global outbreake had been comprehensively analyzed. Consumption analysis was carried out for six provinces. Variation rates were obtained by dividing annual consumption data for each sector by the number of days and the total number of consumers. In addition, daily electricity consumption values per capita for each year were also obtained. According to the values obtained, it was clearly seen that the biggest decreases in the residential, industrial and business sectors were in the business area. Daily electricity consumption per capita decreased 0.63% (60.29 Wh) in 2020 compared to 2019. Per capita electrical energy generation values in Turkey in 2019 and 2020 were also calculated. Using the generation data for the years 2014-2019 and applying curve fitting method, the daily electricity generation value per person for 2020 had been estimated. By comparing this estimated value with the actual value, the effect on electricity generation in 2020, when COVID-19 was effective, was revealed. When the per capita generation amounts were compared, it had been determined that the per capita generation in 2020 decreased by 0.68% (64.94 Wh) compared to 2019. Finally, the ratio of per capita electricity generation values obtained for both 2019 and 2020 to coverage the electricity consumption in the same years was obtained. According to the values obtained, it was seen that the generation could not coverage the consumption by 0.22% (20.81 Wh) in 2019 and 0.27% (25.81 Wh) in 2020. In studies conducted in other countries, Delgado et al. [12] reported the decrease in total electricity load in Brazil as 19%, Santiago et al. [5] reported the decrease in electricity consumption in Spain as 13.49% and Abu-Rayash et al. [13] reported the decrease in electricity consumption in Ontario as 14%. In this study, the calculated change values in total electricity consumption were calculated as 3.95% decrease for Istanbul (Europe), 5.77% increase for Izmir, 12.82% decrease for Antalya, 5.77% increase for Malatya, 0.86% increase for Denizli and 1.20% decrease for Trabzon. In the provinces where the increase occurred, there was an increase in electricity consumption due to the interruption of industrial activities and the people spending time at home. This study determined the variations in electricity consumption and generation caused by the outbreak, and it is thought that it will guide government officials in terms of what kind of outbreaks can be taken in case of similar restrictions that may occur in the future.

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