ARAŞTIRMA MAKALESİ/RESEARCH ARTICLE

Resource Diversification in Turkey's Electricity generation

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Abstract

Natural gas, fuel oil, coal, lignite, geothermal, wind, solar, hydraulics, etc. are used in electricity generation, which is one of the most important inputs of industrial production. Being dependent on one or several sources of electricity generation is an important risk factor for the industry and economy of the country. A problem in the supply of one of these resources or an increase in prices may adversely affect the entire country's industry and therefore the economy. In this research, we measured the concentration of the resources Turkey uses in electricity generation between the years 2000-2020. We used the Herfindahl-Hirschman and concentration indices. The resource concentration in Turkey's electricity production started to decrease towards the end of the period. Reducing the use of natural gas and more use of geothermal, solar, and wind resources have been effective in this result. While Turkey produced 49.8% of its electricity production using natural gas in 2008, this rate decreased to 23.1% in 2020. While Turkey provided 95.6% of its electricity production from four sources in 2002, this rate decreased to 81.3% in 2020. These rates show that Turkey has increased diversification in electricity generation, but this diversification is still not sufficient.

Keywords: Electricity Generation, Concentration, Diversification Energy Resources, Herfindahl-Hirschman

JEL codes: K3, O13, P18

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1. INTRODUCTION

Electricity infrastructure and the security of supply is a critical issue for a country's economy. It is impossible for a country that has not been able to provide electricity supply security to develop its industry and achieve economic development. Electricity is provided using different sources such as natural gas, fuel oil, coal, lignite, geothermal, wind, solar and hydraulic. The excessive increase in natural gas prices with the Russia-Ukraine war in 2022 is pushing the industry of European countries that focus on natural gas and electricity production (Halser & Paraschiv, 2022, p.1-2). In short, an external problem experienced in one of the sources used in electricity generation causes the country's economy and industry to experience difficult times. For this reason, it is a strategic necessity to use different sources as much as possible and not be too dependent on one or more sources of electricity production.

Turkey is a developing country that aims to export around $250 billion in 2022. The items that come to the fore in exports are automotive, iron and steel, machinery and boilers. Therefore, electricity supply security is an issue of strategic importance for Turkey as well (Yılmaz, 2012, p.34). Diversifying the resources used in and increasing the share of renewable resources in electricity generation is of strategic importance for the country's industry and economy (Obadi & Korcek, 2020, p.276-277; Rosa et.al. 2022, p.2). The use of resources such as coal, oil, and natural gas in electricity generation results in foreign dependence of countries that do not have these resources. After the Russian-Ukrainian war, the importance of diversifying the sources used in electricity production was better understood (Halser & Paraschiv, 2022, p.1-2; Lambert et.al. 2022, p.1-2). Situations such as war, conflict, etc. that may occur in countries that own mines such as oil, natural gas, coal, etc. are risky for countries that provide most of their electricity production with these mines.

Several studies have focused on the importance of diversification and increasing the use of renewable sources in electricity generation in Turkey and in the world (Yılmaz, 2012; Altun

& İşleyen, 2018; Erdoğan et.al. 2018; Kaya et.al. 2018; Bağcı, 2019; Konak, 2019; Odeh & Watts, 2019, İnançlı & Akı, 2020, Obadi & Korcek, 2020, Birol, 2021, Kamacı & Akça, 2021, Halser & Paraschiv, 2022; Lambert et.al. 2022; Rosa et.al. 2022). Rubio-Varas & Munoz-Delgado (2018), used Herfindahl-Hirschman index while calculating the energy mix concentration index (EMCI) in selected countries (United Kingdom, France, Germany, and the Netherlands, Italy, Portugal, Spain, and Sweden). Şensoy (2019) calculated the market shares and concentration of companies in the Turkish electricity market using the Herfindahl-Hirschman index. There are also studies that use the Herfindahl-Hirschman index to measure LNG, natural gas, etc. import diversification (Vivoda, 2019; Dilek & Konak, 2022). Our study will contribute to the literature by measuring the concentration of resources used in electricity generation in Turkey with the concept of Herfindahl-Hirschman and concentration index.

In this study, it has been investigated whether the resources used in electricity generation in Turkey are sufficiently diversified. For this purpose, first, a conceptual framework has been drawn about electricity supply security. In the next stage, the development of the concentration of resources used by Turkey in electricity generation over the years was examined by using the Herfindahl-Hirschman and concentration indices.

2. ENERGY AND SOURCES

Energy is the basic input of economic activities. In addition to meeting individual needs such as communication, transportation, and heating, it is also of great importance for the production activities of the industries. It is not possible for any industry to produce without energy. In the literature, there are studies that detect causality both from growth to electricity production and from electricity production to growth (Uzun et.al. 2013, p.331; Erdoğan et.al. 2018, p.235-236; Moftah & Dilek, 2021; Altınay & Karagöl, 2005). Population growth and industrialization also increase the demand for energy. Energy is examined in the literature in two different forms (primary and secondary) according to its convertibility. The form of energy that has

not undergone any change or transformation is known as primary energy. Primary energy sources are oil, coal, natural gas, nuclear, hydraulic, biomass, wave-tide, solar and wind.

Electrical energy can be produced from different primary sources such as fossil fuels, renewable energy sources and nuclear. Non-renewable energy sources are divided into core and fossil sources (Kaya et.al. 2018, p.220). In the 21st century, renewable sources have started to gain importance in electrical energy production. However, the weight of non-renewable resources in electricity generation still continues. There are three main reasons for the importance of renewable resources. First; it is the concern that fossil fuels and nuclear power plants harm the environment (Altun & İşleyen, 2018, p.1578-1579). Latter; Developed countries find it strategically dangerous to depend on countries which produce fossil fuels. This concern increased after the Russia-Ukraine war. The availability of renewable energy sources in every country eliminates foreign dependency for countries. The third is the risk to be faced in the event that fossil fuels gradually decrease and run out. It is stated that the world's oil and natural gas reserves can only meet the world's needs for 50 years (Kaya et.al. 2018, p.221-222). For these reasons, energy generation using renewable energy sources is gradually increasing. However, the use of renewable resources in electricity generation has not reached a satisfactory level yet and it is difficult to replace fossil fuels in the short term (Birol, 2021, p.453). Electricity generation from hydraulic, wind, geothermal, biomass and solar energy has become possible with current production techniques. In the literature, there are studies on the necessity of accessing renewable energy sources (Karagöl & Kanaz, 2017).

Nuclear energy is a type of energy obtained as a result of the fusion of the nucleus of an atom such as uranium, that is, its separation into various parts. Developed countries turned to nuclear energy as a result of the oil crisis in the 1970s. However, nuclear energy is criticized because of nuclear waste and the possibility of polluting the environment. After the accident at the Chernobyl nuclear power plant in Ukraine, the popularity of nuclear energy decreased (Birol, 2021, p.453).

The use of renewable energy sources in electricity generation reduces the risks that may be encountered in energy supply security, but it is not sufficient on its own. It is not possible to terminate the use of fossil fuels in electricity generation in the short term. Therefore, it is also important to diversify the resources used in electricity production and to supply these resources from different countries. In the short term, different sources should be used as equally as possible in electricity production. Thus, the import of these resources should be made from different countries as much as possible.

3. TURKEY AND ELECTRIC GENERATION SOURCES

Most of Turkey's natural gas dependency is due to the use of natural gas in electricity generation (Konak, 2019, p.197-198). Since Turkey has limited oil and natural gas resources, it imports these resources from countries such as Russia, Azerbaijan and Iran, and therefore faces the problem of current account deficit. (Bağcı, 2019, p.102; İnançlı & Akı, 2020, p.554). There are studies stating that Turkey should turn to electricity generation from renewable sources in order to reduce its dependence on foreign energy and to solve the current account deficit problem (Konak, 2019, p.198).

While generating electricity, Turkey uses hard coal, Asphaltite, imported coal, lignite, Fuel-oil, Diesel, LPG, NAFTA, Natural Gas, hydraulics, wind, geothermal and solar. Although developed countries obtain a significant part of their electrical energy from nuclear energy, Turkey does not yet produce electricity from nuclear energy. However, the Akkuyu nuclear power plant is under construction.

Hydraulic energy is the energy obtained from streams. The flow rate and amount of the stream and the fall of water from high points cause a high amount of energy production. Energy can be obtained by the pressure differences (wind) arising from the warming and cooling air on the earth and the rays emanating from the sun's core. With the rise of the heat in the earth's core towards the earth, geothermal energy is another source used in electricity production (Bağcı,

2019, p.107-108). There are several advantages of obtaining electrical energy from renewable sources. They prevent the country from being dependent on foreign sources, they do not harm the environment, and there is no risk of extinction.

Turkey imports some of the coal it uses in electricity generation and produces some of it itself. The most important coal basin in Turkey is Zonguldak and its surroundings. The countries in which Turkey imports coals are Russia, Colombia, the USA, Australia, and South Africa. It is observed that the share of imported coal in Turkey's electricity production has increased in the last 5 years. One of the most used resources in Turkey's electricity generation is lignite. Turkey is rich in lignite reserves, but the heating value of lignites in Turkey is low. Turkey's largest lignite reserves are located in the Afşin-Elbistan basin. Asphaltite, a petroleum-based fuel, has a low share in electricity generation in Turkey. Turkey's most important asphaltite deposits are in the Southeastern Anatolia region (Yılmaz, 2012, p.38-39).

Natural gas is the most used resource in electricity generation in Turkey. However, Turkey can produce only a small portion of natural gas. Turkey imports most of the natural gas it needs from Russia, Iran, and Azerbaijan. This increases Turkey's foreign dependency. The place where Turkey has limited natural gas reserves is Thrace. In 2020, natural gas reserves were found on the shores of the Black Sea and studies for the extraction of this natural gas were started.

4. METHOD

The Herfindahl-Hirschman index is widely used to measure market concentration. Concentration; It is the situation where the total sales, production etc. in the market is made by a small part of the companies in the market (Dilek, 2017, p.51-53). Concentration shows that the market is similar to a monopoly or oligopoly market. Condensation measurement is also used to determine whether there is diversification in different areas. Dilek & Konak (2022) determined whether North African countries diversify in their imports by using Herfindahl-Hirschman indices and concentration

ratios (Dilek & Konak, 2022, p.4-5). Countries that meet their imports from a small number of countries are in fact taking a significant risk, because in cases of conflict, turmoil, etc. that may occur in the source country, imports may not be realized.

The mathematical formula of the N firm concentration ratio and the Herfindahl-Hirshman index (HHI$_N$) and CR$_N$ is as follows (Dilek, 2017, p.55-57; Dilek & Konak, 2016, p.160).

$$CR_N = \frac{\sum_{i=1}^{N} A_i}{A_T}$$

$$HHI_N = \sum_{i=1}^{N} P_i^2$$

determines how many firms the concentration will be calculated for and is usually chosen as 4 or 8. We chose 4 in our study because Turkey uses 12 sources (Hard coal+ Asphaltite, imported coal, lignite, fuel-oil, diesel oil, LPG, Naphta, natural gas, renewable wastes, hydro, geothermal+ wind, solar) in electricity generation. While Ai gives the production of the ith element, At gives the total production. Pi gives the percentage of the element i. Interpretations according to CR$_N$ values are made as follows (Polat, 2007, p.100).

If 0<CR$_N$<0,30 Low concentration

0,31<CR$_N$<0,50 moderate level

0,51<CR$_N$<0,70 high concentration

CR$_N$>0,70 Ultimately high concentration

Interpretations according to HHI$_N$ values are made as follows (Dilek, 2017, p.57).

If HHI$_N$<1000 low concentration

1001<HHI$_N$<1800 moderate level

1801<HHI$_N$<10000 High concentration

HHI$_N$=10000 Full concentration (monopoly)

Data are obtained from Turkish Electricity Transmission Corporation.

5. FINDINGS

The resources used in electricity generation in Turkey are given in Table 1. There are 12 sources (Hard coal+Asphaltite, Imported coal, Lignite, Fuel-oil, Diesel oil, Naphta, Natural Gas,

Renewable + Wastes, Hydro, Geotermal + Wind, Solar) which are used in electricity generation. As can be seen from Table 1, the sources used extensively in Turkey's electricity generation are natural gas, hydro, lignite and imported coal. There is a great increase in electricity production from solar, geothermal and wind after 2014. Europe's largest solar power plant was established in Konya Karapınar (Güngör, 2022). It is observed that the use of imported coal in electricity generation has increased after 2010. While electricity production was 124,921 Gwh in 2000, this figure increased to 306,703 Gwh in 2020, that is, an increase of 145%.

In the 2000-2020 period, the most used resource in electricity generation is natural gas. In the period after 2010, hydro took second place except for 2018. Lignite and imported coal are other important resources used in electricity generation. It is seen that imported coal surpasses lignite after 2015. The Herfindahl-Hirschman index and concentration ratios for four sources are given on the right side of Table 2. The HHI value started to decrease after reaching its maximum value in 2007. HHI, which was between 1800 and 10000 during the 2000-2019 period, decreased below 1800 in 2020. In other words, high concentration was observed until 2019, and moderate concentration was observed in 2020. The concentration ratio reached its

Table 1. Electricity Production Turkey

YEARS	HARD COAL + ASPHAL-TITE	IMPORTED COAL	LIGNITE	FUEL-OIL	DIESEL OIL	LPG	NAPH-THA	NATURAL GAS	RENEW. + WASTES WASTE HEAT	HYDRO	GEOTER-MAL + WIND	SOLAR	GENERAL TOTAL
2000	3,175.9	643.1	34,367.3	7,459.1	980.6	324.0	547.1	46,216.9	220.2	30,878.5	108.9		124,921.6
2001	2,705.7	1,340.3	34,371.5	8,816.6	904.0	162.1	483.5	49,549.2	229.9	24,009.9	152.0		122,724.7
2002	2,646.1	1,447.0	28,056.0	9,505.0	270.9	34.8	933.1	52,496.5	173.7	33,683.8	152.6		129,399.5
2003	2,693.6	5,969.4	23,589.9	8,152.7	4.4	2.9	1,036.2	63,536.0	115.9	35,329.5	150.0		140,580.5
2004	2,478.0	9,520.1	22,449.5	6,689.9	7.3	33.4	939.7	62,241.8	104.0	46,083.7	150.9		150,698.3
2005	2,965.1	10,281.1	29,946.3	5,120.7	2.5	33.7	325.6	73,444.9	122.4	39,560.5	153.4		161,956.2
2006	3,073.6	11,143.0	32,432.9	4,232.4	57.7	0.1	50.2	80,691.2	154.0	44,244.2	220.5		176,299.8
2007	3,289.6	11,846.6	38,294.7	6,469.6	13.3	0.0	43.9	95,024.8	213.7	35,850.8	511.1		191,558.1
2008	3,290.8	12,566.7	41,858.1	7,208.6	266.3	0.0	43.6	98,685.3	219.9	33,269.8	1,008.9		198,418.0
2009	3,782.4	12,813.2	39,089.5	4,439.8	345.8	0.4	17.6	96,094.7	340.1	35,958.4	1,931.1		194,812.9
2010	4,572.6	14,531.7	35,942.1	2,143.8	4.3	0.0	31.9	98,143.7	457.5	51,795.5	3,584.6		211,207.7
2011	4,529.6	22,817.9	38,870.4	900.5	3.1	0.0	0.0	104,047.6	469.2	52,338.6	5,418.2		229,395.1
2012	4,113.7	29,210.5	34,688.9	981.3	657.4	0.0	0.0	104,499.2	720.7	57,865.0	6,760.1		239,496.8
2013	4,070.3	29,453.7	30,262.0	1,192.5	546.3	0.0	0.0	105,116.3	1,171.2	59,420.5	8,921.0		240,154.0
2014	4,561.3	35,086.0	36,615.4	1,662.9	482.4	0.0	0.0	120,576.0	1,432.6	40,644.7	10,884.1	17.4	251,962.8
2015	4,843.9	39,986.0	31,335.7	980.4	1,243.6	0.0	0.0	99,218.7	1,758.2	67,145.8	15,077.0	194.1	261,783.3
2016	5,985.3	47,717.9	38,569.9	969.1	957.2	0.0	0.0	89,227.1	2,371.6	67,230.9	20,335.6	1,043.1	274,407.7
2017	5,663.8	51,118.1	40,694.4	520.6	679.3	0.0	0.0	110,490.0	2,972.3	58,218.5	24,031.3	2,889.3	297,277.5
2018	5,173.1	62,988.5	45,087.0	328.9	0.2	0.0	0.0	92,482.8	3,622.9	59,938.4	27,380.2	7,799.8	304,801.9
2019	5,627.2	60,394.7	46,872.2	335.1	0.9	0.0	0.0	57,288.2	4,624.2	88,822.8	30,682.5	9,249.8	303,897.6
2020	5,368.1	62,505.6	37,938.4	322.1	0.5	0.0	0.0	70,931.3	5,736.6	78,094.4	34,855.9	10,950.2	306,703.1

Source: https://www.teias.gov.tr/Turkey-elektrik-uretim-iletim-istatistikleri (Date:03.09.2022).

maximum value in 2002. It has also decreased continuously since 2011 and took its minimum value in 2020. Even in 2020, the concentration ratio is above 0.70, that is, ultimately a high concentration ratio for sources in electricity generation.

Graphs of HHI and concentration ratios for four sources are given as Graph 1 and Graph 2. The downward trend in both of them in recent years is clearly seen in the graphs.

6.CONCLUSION

Ensuring energy supply security is an issue of strategic importance for countries that want to achieve their economic growth targets. In order to ensure the development of the industrial sector, countries have to produce uninterrupted and stable electrical energy. Turkey, which is included in the class of high-middle-income countries in the 21st century, needs to increase the production of electricity in order to get out of the middle-income trap (Kesgingöz & Dilek, 2016). Diversifying the resources used in electricity generation will also minimize the risks that may arise in the supply of these resources. In our study, the diversification of resources used in Turkey's electricity generation was examined with the help of the Herfindahl-Hirschman index and concentration ratios.

**Table 2**. The First Four Sources In Electricity Generation and Their Shares

YEARS	First	P	%	Second	P	%	Third	P	%	Fourth	P	%	Total	C	HHI
2000	N. Gas	46,216.9	36.997	Lignite	34,367.3	27.511	Hydro	30,878.5	24.718	Fuel Oil	7,459.1	5.971	**124,921.6**	95.2	2772.3
2001	N. Gas	49,549.2	40.374	Lignite	34,371.5	28.007	Hydro	24,009.9	19.564	Fuel Oil	8,816.6	7.184	**122,724.7**	95.1	2848.8
2002	N. Gas	52,496.5	40.569	Hydro	33,683.8	26.031	Lignite	28,056.0	21.682	Fuel Oil	9,505.0	7.345	**129,399.5**	95.6	2847.5
2003	N. Gas	63,536.0	45.195	Hydro	35,329.5	25.131	Lignite	23,589.9	16.780	Fuel Oil	8,152.7	5.799	**140,580.5**	92.9	2989.4
2004	N. Gas	62,241.8	41.302	Hydro	46,083.7	30.580	Lignite	22,449.5	14.897	Imported Coal	9,520.1	6.317	**150,698.3**	93.1	2902.8
2005	N. Gas	73,444.9	45.349	Hydro	39,560.5	24.427	Lignite	29,946.3	18.490	Imported Coal	10,281.1	6.348	**161,956.2**	94.6	3035.4
2006	N. Gas	80,691.2	45.769	Hydro	44,244.2	25.096	Lignite	32,432.9	18.396	Imported Coal	11,143.0	6.320	**176,299.8**	95.6	3103.0
2007	N. Gas	95,024.8	49.606	Lignite	38,294.7	19.991	Hydro	35,850.8	18.715	Imported Coal	11,846.6	6.184	**191,558.1**	94.5	3248.9
2008	N. Gas	98,685.3	49.736	Lignite	41,858.1	21.096	Hydro	33,269.8	16.768	Imported Coal	12,566.7	6.333	**198,418.0**	93.9	3240.0
2009	N. Gas	96,094.7	49.327	Lignite	39,089.5	20.065	Hydro	35,958.4	18.458	Imported Coal	12,813.2	6.577	**194,812.9**	94.4	3219.7
2010	N. Gas	98,143.7	46.468	Hydro	51,795.5	24.523	Lignite	35,942.1	17.017	Imported Coal	14,531.7	6.880	**211,207.7**	94.9	3097.6
2011	N. Gas	104,047.6	45.357	Hydro	52,338.6	22.816	Lignite	38,870.4	16.945	Imported Coal	22,817.9	9.947	**229,395.1**	95.1	2963.9
2012	N. Gas	104,499.2	43.633	Hydro	57,865.0	24.161	Lignite	34,688.9	14.484	Imported Coal	29,210.5	12.197	**239,496.8**	94.5	2846.1
2013	N. Gas	105,116.3	43.770	Hydro	59,420.5	24.743	Lignite	30,262.0	12.601	Imported Coal	29,453.7	12.265	**240,154.0**	93.4	2837.3
2014	N. Gas	120,576.0	47.855	Hydro	40,644.7	16.131	Lignite	36,615.4	14.532	Imported Coal	35,086.0	13.925	**251,962.8**	92.4	2955.4
2015	N. Gas	99,218.7	37.901	Hydro	67,145.8	25.649	Imported Coal	39,986.0	15.274	Lignite	31,335.7	11.970	**261,783.3**	90.8	2471.0
2016	N. Gas	89,227.1	32.516	Hydro	67,230.9	24.500	Imported Coal	47,717.9	17.389	Lignite	38,569.9	14.056	**274,407.7**	88.5	2157.5
2017	N. Gas	110,490.0	37.167	Hydro	58,218.5	19.584	Imported Coal	51,118.1	17.195	Lignite	40,694.4	13.689	**297,277.5**	87.6	2248.0
2018	N. Gas	92,482.8	30.342	Imported Coal	62,988.5	20.665	Hydro	59,938.4	19.665	Lignite	45,087.0	14.792	**304,801.9**	85.5	1953.2
2019	N. Gas	57,288.2	18.851	Hydro	88,822.8	29.228	Imported Coal	60,394.7	19.873	Lignite	46,872.2	15.424	**303,897.6**	83.4	1842.5
2020	N. Gas	70,931.3	23.127	Hydro	78,094.4	25.463	Imported Coal	62,505.6	20.380	Lignite	37,938.4	12.370	**306,703.1**	81.3	1751.5

Turkey has succeeded in increasing its electricity production continuously since 2000. However, natural gas is the most commonly used resource in electricity generation. Since Turkey's natural gas production is not sufficient, it is imported from abroad. Among the imported countries, Russia, Iran, and Azerbaijan are leading. The Russia-Ukraine war that broke out in 2022 shows that natural gas supply security is an important problem not only for Turkey but also for the whole of Europe. The rate of natural gas used by Turkey in electricity generation has decreased continuously, but it has been revealed that this is not enough and should be further reduced (Birol, 2021; Konak, 2019).

It is observed that the Herfindahl-Hirschman index started to decline steadily after 2007. In 2020, the Herfindahl-Hirschman index fell below 1800. In other words, there has decrease from high-level to medium-level concentration. The concentration rate also started to decrease after 2011 and decreased to 81.3 in 2020. However, the concentration ratio is still above 0.70 and indicates an ultimately high concentration. These results show that Turkey has increased resource diversification in electricity generation. This is undoubtedly a success, but not enough, as the concentration ratio is still above 0.70. Resources such as natural gas and imported coal are still used extensively in electricity generation. After 2013, there has been a noticeable increase in electricity generation from geothermal, wind, and solar energy, but still, electricity generation from renewable sources has not been included in

Graph 1. HHI Indıces
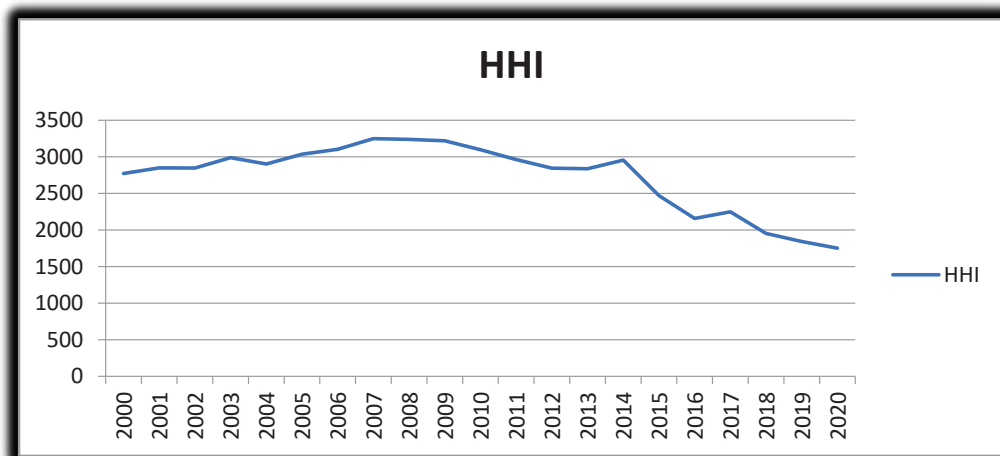
Graph 2. Concentration Ratios
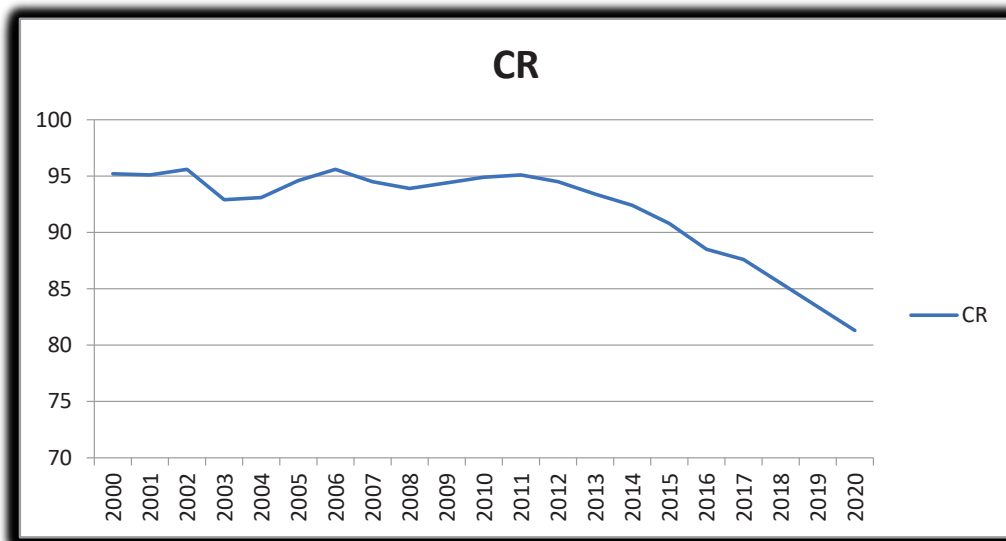
the top four sources. These results are consistent with the results of studies in the literature (Yılmaz, 2012; Uzun, 2013; Altun & İşleyen, 2018; Kaya et.al. 2018; Bağcı, 2019; Konak, 2019; İnançlı & Akı, 2020; Kamacı & Akça, 2021).

Our study is limited to the diversity of resources in Turkey's electricity generation between the years 2000-2020. However, Turkey continues to invest in renewable energy (geothermal, wind, solar) resources. If new researchers conduct research on the resource diversity in Turkey's electricity production in the next period, different results may emerge. In addition, new research in this area will reveal whether Turkey reduces the risks it may face in electricity generation. After the Russia-Ukraine war, it is seen that the risks that may be encountered in natural gas supply have increased.

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