www.dergipark.gov.tr
ISSN:2148-3736

El-Cezerî Journal of Science and Engineering
Vol: 10, No: 3, 2023 (554-570)
DOI: 10.31202/ecjse.1271128

ECJSE

Research Paper

A Study on The Projection of Coal Fired Power Plants

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Received:26.03.2023 **Accepted:**19.08.2023

Abstract: In this study, Turkey and the main countries with high capacity of Coal Fired Thermal Power Plants (CTPPs) installation capacity in the world were examined. Related parameters such as installed power values, energy production values and capacity factors in these countries are also discussed. These parameters in the countries that stand out in coal-based electrical energy production have been evaluated over the years and projection studies have been carried out. By making these projection studies, predictions about the future of CTPPs can be tried easily to be made. Analysis results are indicated and interpreted with figures and tables. In addition, capacity utilization rates, which is an important parameter in terms of efficient operation and age of coal-based thermal power plants, were also examined firstly. According to these results of the analysis, the country with the highest capacity ratio was determined as Japan with a value of around 90%. Today, with the emergence of the energy crisis, depending on the re-emergence of coal, energy production planning and projection studies gain strategic importance for every country. Country-based projection studies for CTPPs are insufficient and limited in the literature. With this projection study, predictions were made for the development of CTPPs on the basis of countries and around the world and contributed to the studies in the literature in this field.

Keywords: Coal-fired thermal power plant, energy, fossil fuel, electricity generation, projection, capacity utilization.

1. Introduction

Although the tendency towards low-carbon technologies and renewable energy systems has increased day by day in the world, it is seen that the global energy demand will be met mainly by fossil fuels in the near and medium term. Generally, most of the increase in energy demand comes from non-OECD countries, especially China and India [1]. The need to consume electricity as soon as it is produced obliges market actors to maintain the supply-demand balance. In the S decades, the issue of supply-demand, balancing has been emphasized [2]. Coal is the only way to maintain the energy supply-demand balance in a world where there is an energy crisis. Even European Union (EU) countries, which are planning to exit from coal, have started to turn to coal. It is seen that China has increased its coal imports from Russia in parallel with its production speed. The International Energy Agency (IEA) in 2020 predicted that EU consumption could increase by an estimated 7%, leading to a 14% increase in 2021 [1]. The report of National Bureau of Statistics says that China extracted 2.19 billion tons of coal between January and June at 2021, it means that an increase of 11% year-by-year [3]. According to the IEA report, the contraction in global gas supply, which has caused record prices worldwide, will also help to revive coal demand.

How to cite this article
N.Ersoy, N. Bingöl, İ. Ekmekçi "A Study on The Projection of Coal Fired Power Plants," ", *El-Cezerî Journal of Science and Engineering*, Vol: 10, No: 3, 2023, pp. 554-570.
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Nearly 55% of the world's coal has been used by developing countries and this share is expected to increase to 65% after 15 years. It is also stated that by 2050, coal will meet more than 34% of the world's electricity production [4].

It is seen that CTPPs will play an important role in meeting the future electricity needs. Roy et al., in their projection for CTPPs in Vietnam; The share of electricity generation by CTPPs is projected to increase from 49.3% in 2020 to 53.2% in 2030 [5]. However, it is predicted that the amount of coal consumed will increase from 63 million tons in 2020 to 129 million tons in 2030 [5]. However, the amount of coal consumed is projected to double by 2030 [5]. In Vietnam, the government has stressed the importance of adapting carbon capture technology to existing CTPPs as well as increasing renewable energy sources to comply with the COP21 agreement and reduce CO_2 [5].

Du et al. found that India surpasses China in air pollution with per capita CO_2 emissions. In South Asia and East Asia, it has been stated that air pollution is caused by CTPPs, and the lack of preventive regulatory control causes significant emissions and degrades the air quality and the environment [6]. Kichonge et al. have applied different energy system models in terms of Tanzania's electricity demand and different energy supply options in a generation. In the projection study, it was emphasized that it is important for each country to produce the electricity of the future by using its own energy resources [7]. In this study, nominal electrical power developments of CTPPs in Türkiye and the major countries in the world and in the first place, in electricity generation from coal and electrical energy production from these plants between 2000 and 2020 were analyzed. Projections were made for 2030 and 2050 according to the current situation. In addition, the capacity utilization rates, which is an important parameter related to the working efficiency and age of CTPPs were examined. In the literature, there are very limited research and projection studies based on countries in terms of CTPPs. Accordingly, this study is a study in which the capacity utilization rates of CTPPs are analyzed as well as a comprehensive projection study in the literature. With this projection study, predictions were made for the development of CTPPs on a country basis and around the world. A contribution has been made to the literature by considering the capacity utilization rates of these power plants.

2. Progress of Coal Fired Thermal Power Plants

2.1. Electricity Production Shares of CTPPs in the World

When the fossil fuel primary energy consumption of major countries in the world in 2020 is reviewed, OECD (Organization for Economic Cooperation and Development) countries come first in oil and natural gas consumption, and China in coal consumption. World fossil fuel consumption is 79.3% in 2020. Considering the world's primary energy sources, coal is in second place after oil [8]. Today, when we look at the situation in the world due to the energy crisis, coal consumption has started to increase.

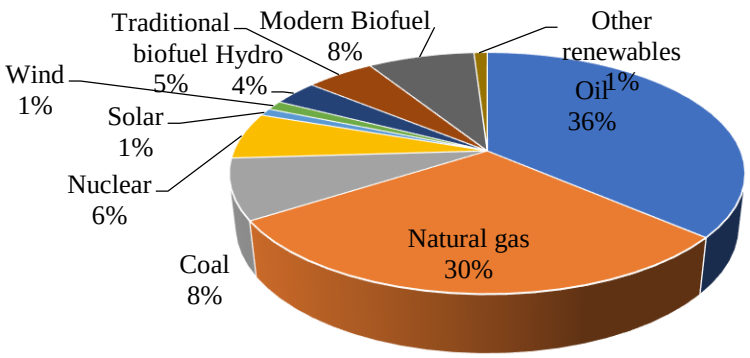

Figure 1. Primary energy consumption of the world in 2020

According to the IEA report in 2021, the rapid economic recovery shows that global coal-fired electricity production reaches a record level this year and total coal demand reaches its all-time high potential by 2022. According to the report, it is stated that the amount of electricity produced from CTPPs increased by 9% this year after the increase in fossil fuel demand [3]. It is seen that the increase in coal demand will reach an all-time high in 2022, depending on economic growth and weather conditions. Global coal demand is expected to remain at this level for 2 years. According to OECD, Türkiye has one of the fastest-growing economies due to its young population and rapidly growing economy [9]. Therefore, Türkiye demands an increase in its energy supply. In parallel with the pace of industrialization in Türkiye, an annual average increase of 6% is observed in energy demand. Although Türkiye is the fastest-growing country after China in energy demand and use, it is highly dependent on foreign energy in terms of its past policies. Since energy resources are limited in Türkiye, energy efficiency is important. Türkiye's share in fossil resources is 88.3%, while its import share is 70.2%. The share of coal in the energy sector is 27.6% [10].

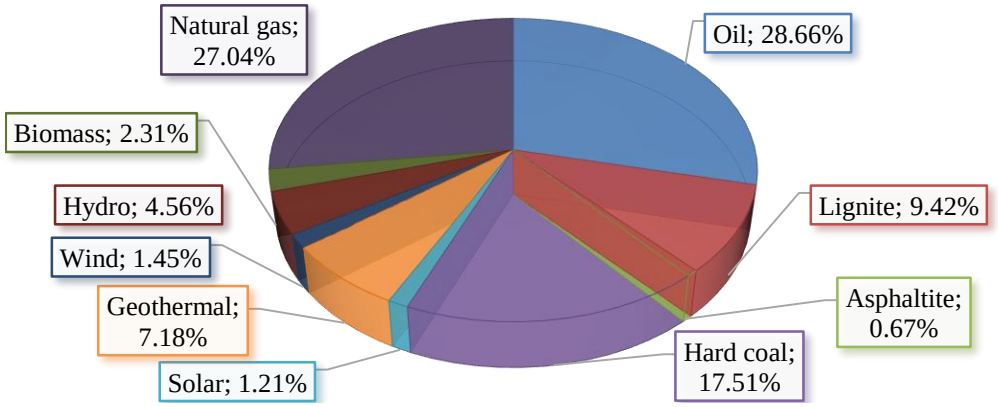

Figure 2. Distribution of Türkiye's primary energy supply in 2020

When the shares of countries in electricity production are examined, it is seen that China uses coal at very high rates. China, the world's second-largest economy, produces 74.7% of its electricity from coal. Germany, which has a large share with 40 billion tons of the total 200 billion tons of lignite reserves in the world, produces 44.6% of its electricity from coal. In Türkiye, this rate is around 25.8% with imported coal. The share of coal used in electricity generation from 2000 to 2020 in total coal consumption has increased by 11% in China and Japan, and around 22% in Türkiye. The share of coal used in electricity generation from 2000 to 2020 in the total coal consumption of India and the USA remained constant. With the shutdown of CTPPs, Germany reduced the share of coal used in electricity generation by 5% from 2000 to 2020. Today, due to the energy crisis, it is predicted that the share of coal used in electricity production in total coal consumption will increase again, with Germany returning to CTPPs. Russia, a regional power, decreased the share of coal used in electricity generation by 12% from 2000 to 2020 [8]. Coal-based electricity production, on the other hand, decreased by 4% in 2020 due to the effect of Covid-19, and a record 9% increase is observed in 2021 with the recovery after Covid-19. Due to the natural gas crisis during the Ukraine-Russia war, it is expected to return to CTPPs again.

About 38% of the electricity in the world and about 33% of the electricity in Türkiye is currently produced by CTPPs. While Türkiye is increasing its renewable energy resources, it has to improve and use its existing old CTPPs.

According to TEİAŞ (Turkish Electricity Transmission Corporation) data, Türkiye's installed electricity capacity was 100GW (March 2022). According to TEİAŞ data, it is seen that solar power plants (GES) take the first place in the order of the number of electricity-generating power plants, and

coal power plants (imported, domestic) take the third place in installed power [11]. Reducing foreign dependency on energy is important in Türkiye as it is in the world.

3. Progress of Electricity Production from CTPPs in the World and Developed Countries

A comprehensive projection study for the years 2030 and 2050 has been made with the help of the development data of the installed power values of CTPPs between 2000-2020 in Türkiye and the major countries with high CTPP installed capacity and in the first place in electricity production in the world. Fig. 3 shows the analysis results of this study. The total capacity of CTPPs put into operation in the world increased in 2020 for the first time since 2015. In 2021, the capacity of CTPPs decreased by 13%. In the post-Covid-19 period in the world, in 2021, a coal-fired thermal power plant with a capacity of 45 GW was put into operation, 26.8 GW was deactivated. There was a net growth of 18.2 GW in the global CTPP fleet [12]. When the projection is made according to the status, it is predicted that the world's CTPPs will increase rapidly in 2030 and 2050.

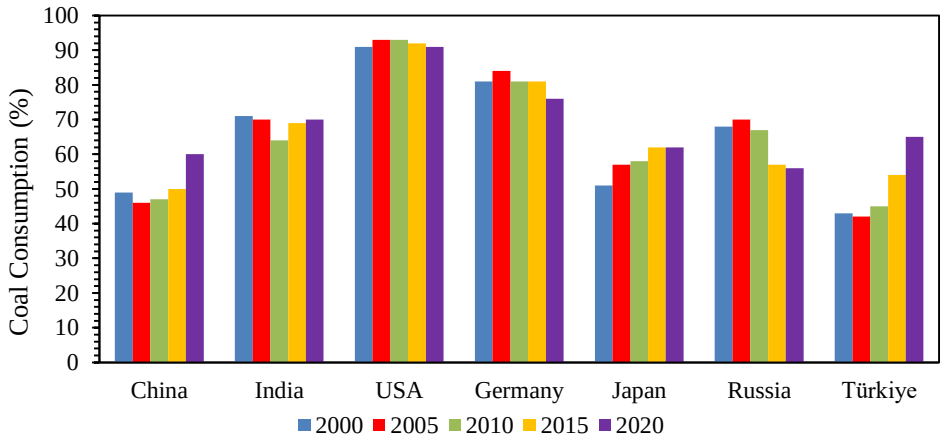

Figure 3. Production Shares of electricity generation from coal in total coal consumption of different countries

More than half (56%) of the newly commissioned 45 GW power plants were in China. Excluding China, the global coal fleet continued to shrink for the fourth consecutive year. In the USA, which has the world's largest economy, CTPPs with a capacity of 16.1 GW in 2019 and 11.6 GW in 2020 were closed, while this amount was estimated between 6.4 GW and 9 GW in 2021. In 2021, 27 EU countries closed a record level of CTPPs. Germany (5.8 GW) became the first country in the EU to shut down CTPPs. As seen in Fig. 4 in the world, it is seen that the power developments of CTPPs installed over the years have increased continuously. As can be seen in Fig. 4, the USA is the first place in 2000. After 2011, the USA started to reduce its installed power by following a policy of closing its CTPPs. When projections are made according to the current situation, it is predicted that the USA will decrease its CTPP installed power in 2030 and 2050. According to the projections, it is seen that the USA is behind India. Today, China has the second-largest installed capacity. Over the years, China has rapidly increased its installed power by accelerating. When projections are made according to the current status, it is predicted that China will rank first in the world in 2030 and 2050 in its CTPP capacity.

As seen in Fig.4, India is expected to increase the installed capacity of the CTPP in 2000 rapidly, especially after 2011, and when projections are made according to the current status, it is predicted that India will rank second after China. As it can be seen in Fig. 4, Japan has increased its CTPP installed power in an accelerated way today. When the projection is made according to the current status, it is predicted that Japan will increase its CTPP installed power rapidly in 2030 and 2050. With Germany shutting down its CTPPs since 2016 when projections are made according to the current situation, it is predicted that even if the CTPP increases its installed capacity in 2030 and 2050, it will

lag behind Japan. When projections are made according to the current status, it is predicted that Russia will lag behind Japan and Germany even if it increases its CTPP installed capacity in 2030 and 2050. When projections are made according to the current situation, it is predicted that Türkiye will follow Russia with its accelerated increase in the installed capacity of CTPPs in 2030 and 2050. As seen in Fig. 4, the EU gradually reduced 2019 the installed capacity of CTPPs in 2000. When the projection is made according to the current status, it is foreseen that the EU will decrease the installed power of coal power plants in 2030 and 2050. China, which owns half of the CTPPs all over the world, continued to rank first by increasing its capacity to 1064 GW in 2022. India increased its capacity from 228 GW to 232 GW in 2022 from third place to second place. As the USA moved up to a or the second place with a capacity of 246 GW. As the USA started to partially shut down coal power plants, it shrank in its global capacity in 2022, falling to third place, following India.

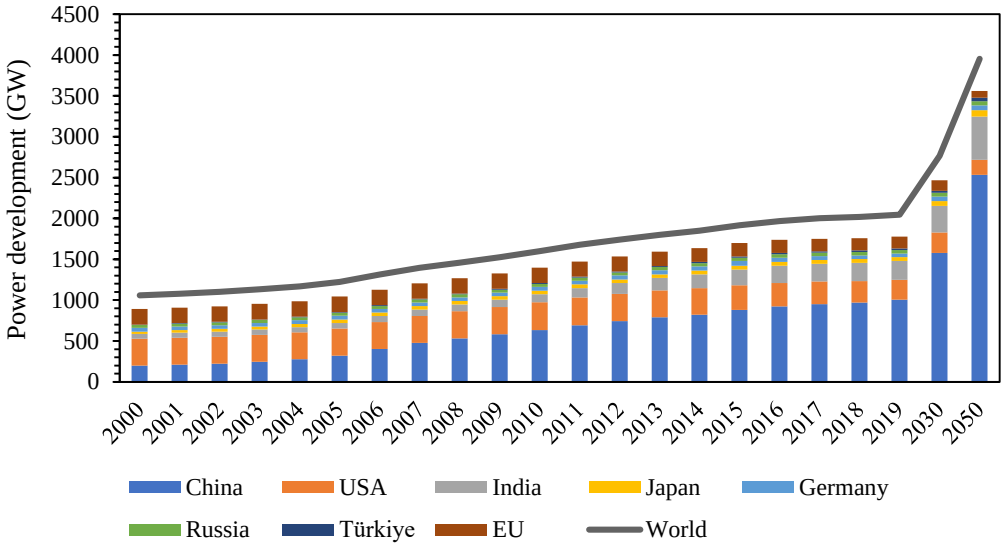

Figure 4. Power perspectives and projections of CTPPs in the world

The total capacity of newly installed CTPPs in the world between 2000 and 2022 reached 1455 GW. China, which had 85% of the world's CTPPs since 2016, installs an average of 34 GW of new CTPPs every year. Global installed power dropped significantly by 17.2 GW in 2020, excluding China.

Table 1. Power perspectives and projections of CTPPs in the world

Years	China	USA	India	Japan	Germany	Russia	Türkiye	EU	World
2000	199	327	61	28	44	36	6	189	1057
2005	321	330	70	42	45	37	7	191	1223
2010	635	338	99	44	45	38	11	188	1599
2015	881	302	192	47	56	41	15	167	1917
2019	1004	246	228	49	44	43	19	143	2045
2025	1336	267	277	56	51	45	23	142	2472
2030	1576	251	327	61	52	47	26	130	2768
2035	1815	235	376	65	54	48	30	118	3064
2040	2055	218	426	69	55	50	34	107	3361
2045	2294	202	476	74	57	52	37	95	3657
2050	2534	186	526	78	58	54	41	83	3953

Power Capacity Progress and Projections of CTPPs all over the world has been shown clearly at Fig.6. When we made projection for the world with a 4th order polynomial regression using the data between 2000-2019, the following equation has been obtained with a correlation coefficient of 99.93%:

$$y = 0{,}0072x^4 - 58{,}377x^3 + 176707x^2 - 2E{+}08x + 1E{+}11;\ R^2 = 0{,}9993 \quad (1)$$

Table 2. The value of the power development rates of the countries that stand out in the use of CTPPs in the world by years (%)

Years	China	USA	India	Japan	Germany	Russia	Türkiye	EU	Others
2000	18.8	30.9	5.8	2.6	2.6	3.4	0.6	18.0	15.0
2005	26.2	27.0	5.7	3.4	2.5	3.0	0.6	16.0	14.0
2010	39.7	21.1	6.2	2.8	1.9	2.4	0.7	12.0	12.0
2015	46.0	15.8	10.0	2.5	1.9	2.1	0.8	9.0	11.0
2019	49.1	12.0	11.1	2.4	2.0	2.1	0.9	7.0	14.0
2030	56.9	9.1	11.8	2.2	1.7	1.7	0.9	5.0	10.0
2050	64.1	4.7	13.3	2.0	1.5	1.4	1.0	2.0	11.0

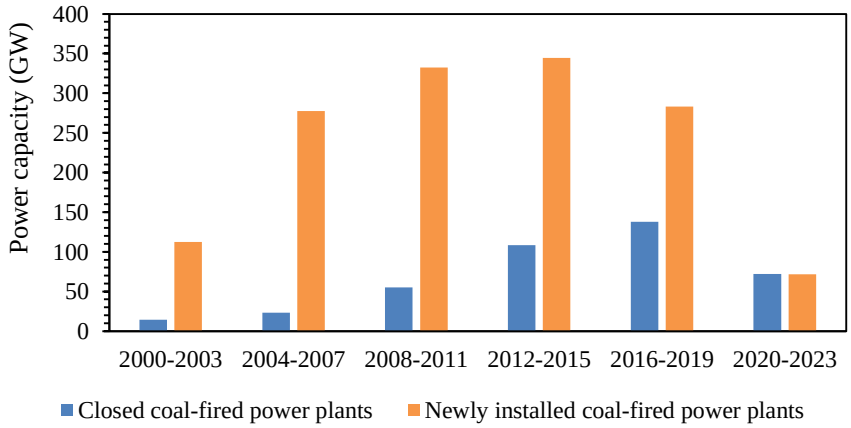

Figure 5. Nominal power values of CTPPs that have been closed and newly installed in the world

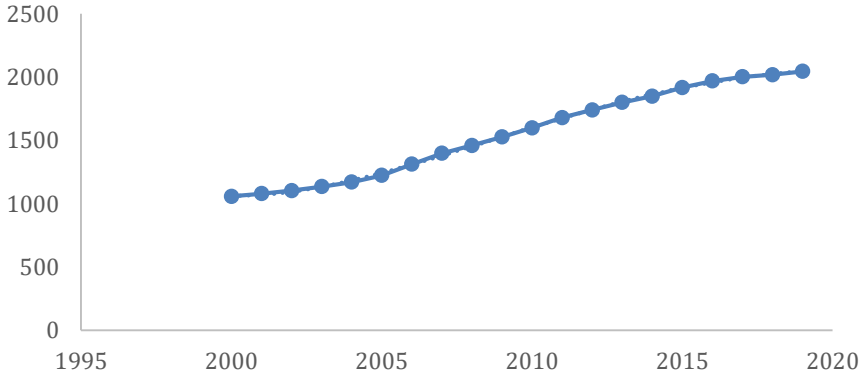

Figure 6. Power Capacity Progress and Projections of CTPPs all over the world

When China has been analyzed based on CTPPs, the largest installed power is in Shandong. More than half of the 68.3 GW installed power newly commissioned in the world is located in China. With

the exception of China, the global coal plant fleet contracted one after the other in 2018 and 2019, as other countries cut off more of their newly commissioned coal plant capacity.

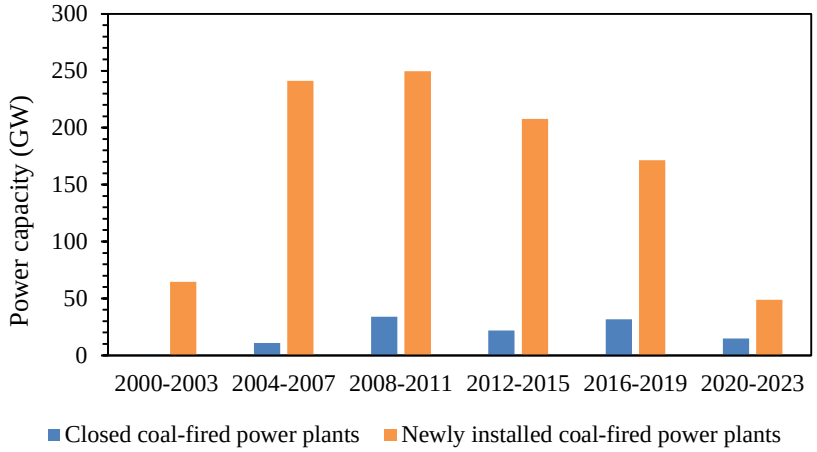

Figure 7. Nominal power values of CTPPs closed and newly installed in China over the years

Power Capacity Progress and Projections of CTPPs for China has been shown clearly at Fig.8. When we made projection for the world with a 3rd order polynomial regression using the data between 2000-2019, the following equation has been obtained with a correlation coefficient of 99.74%:

$$y = -0{,}1866x^3 + 1125x^2 - 2E{+}06x + 2E{+}09;\ R^2 = 0{,}9974 \quad (2)$$

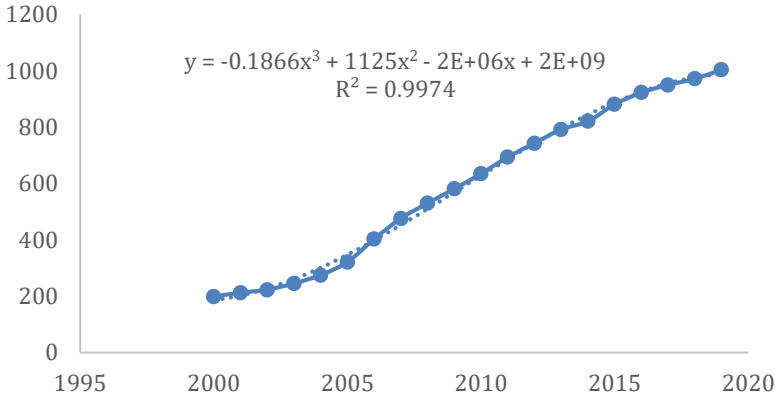

Figure 8. Power Capacity Progress and Projections of CTPPs for China

Newly installed CTPP power in India reached a record number between 2012 and 2015. When the newly installed and closed CTPPs in India since 2000 are examined, it is seen that the power plants that have been closed are so few that they are negligible next to the newly installed CTPPs. The installed capacity of CTPPs in India has reached 231 GW. India has the third largest coal power plant in the world with 11% capacity. When India is analyzed based on CTPPs, the highest installed power is in the cities of Maharashtra and Chhattisgarh.

Power Capacity Progress and Projections of CTPPs for India has been shown clearly at Fig.10. When we made projection for the world with a 4th order polynomial regression using the data between 2000-2019, the following equation has been obtained with a correlation coefficient of 99.83%:

$$y=-0{,}0091x^4+73{,}157x^3-220401x^2+E{+}08x-1E{+}11;\ R^2 = 0{,}9983 \quad (3)$$

The installed capacity of the CTPP, which was closed between 2000-2003 in the USA, and the newly installed CTPP are almost equal to each other. The power of the CTPP, which was closed between 2004-2007 in the USA, has begun to exceed the power of the newly installed CTPP. The USA has

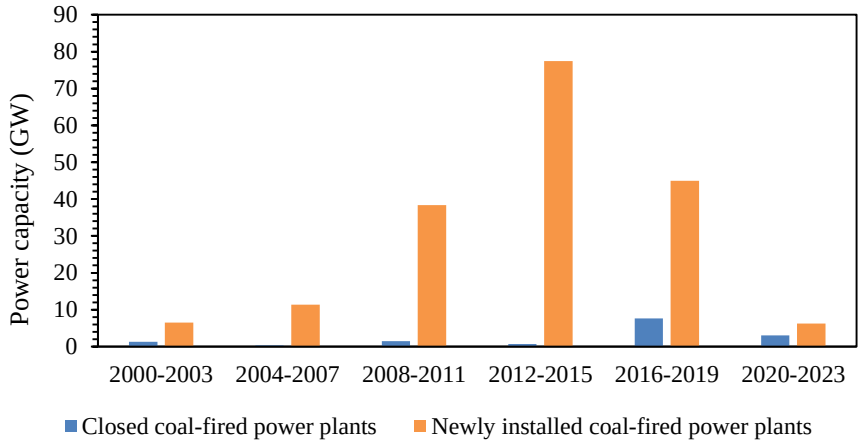

Figure 9. Nominal power values of CTPPs closed and newly installed in India

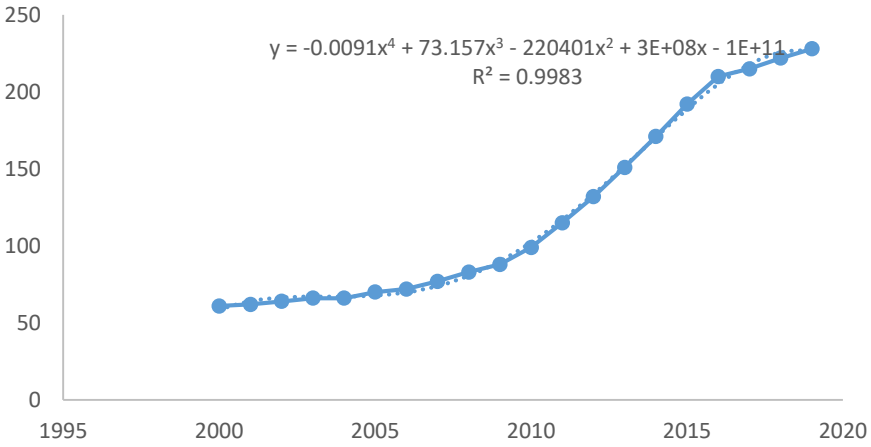

Figure 10. Power Capacity Progress and Projections of CTPPs for India

the second largest CTPPs in the world. When the USA is analyzed on the basis of CTPPs, the highest installed power is in the state of Texas. Since 2016, there has been no newly established CTPP in the USA. The USA ranks first in the number of CTPPs closed between 2016-2019. The USA has not built any new coal power plants since 2016.

Power Capacity Progress and Projections of CTPPs for USA has been shown clearly at Fig.12. When we made projection for the world with a 3rd order polynomial regression using the data between 2000-2019, the following equation has been obtained with a correlation coefficient of 98%:

$$y = -0{,}0446x^3 + 268{,}57x^2 - 538553x + 4E{+}08;\ R^2 = 0{,}98 \quad (4)$$

As of 2022, China is the first in the world with a number of CTPPs. In terms of the number of CTPPs, India ranks second, followed by the USA. The number of CTPPs in China is more than four times the number of CTPPs in India, its closest competitor.

When the closed and newly installed CTPPs in Japan, the world's fourth largest economy, are analyzed from 2000 to the present, Fig. 14 shows that the new CTPPs increased their power maximum between 2000-2003. It is seen that the power of the closed CTPP in Japan is negligible

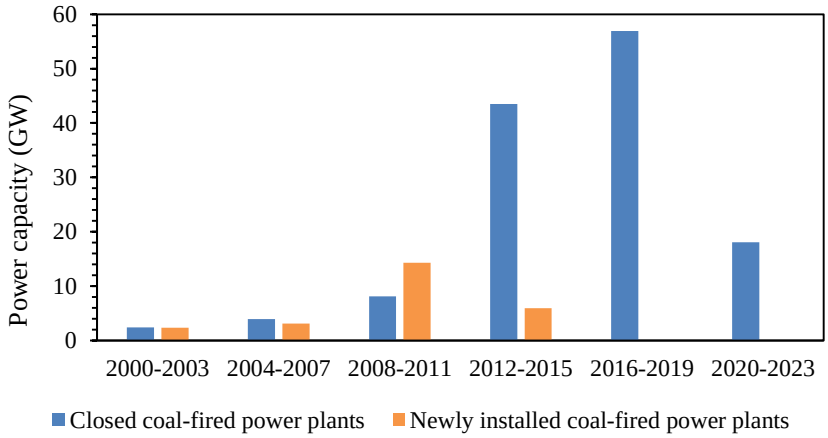

Figure 11. Nominal power values of CTPPs that have been closed and newly installed in the USA

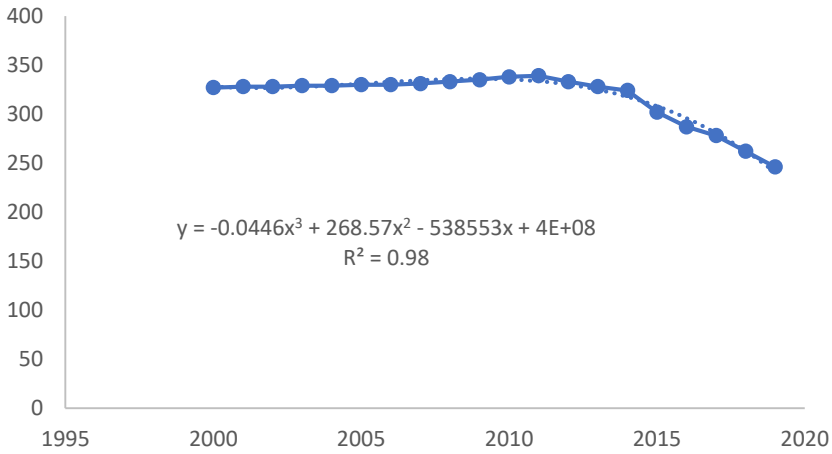

Figure 12. Power Capacity Progress and Projections of CTPPs of USA

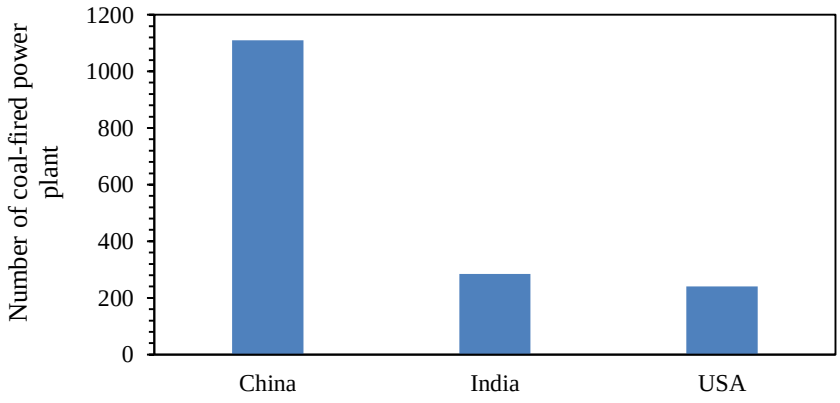

Figure 13. Number of coal - fired power plants in the world analysis of the top three countries compared to the installed power of the newly installed CTPP.

Power Capacity Progress and Projections of CTPPs for Japan has been shown clearly at Fig.15.

When we made projection for the world with a 3rd order polynomial regression using the data between 2000-2019, the following equation has been obtained with a correlation coefficient of 98.42%:

$$y=0{,}0069x^3-41{,}73x^2+83981x-6E+07;\ R^2 = 0{,}9842 \quad (5)$$

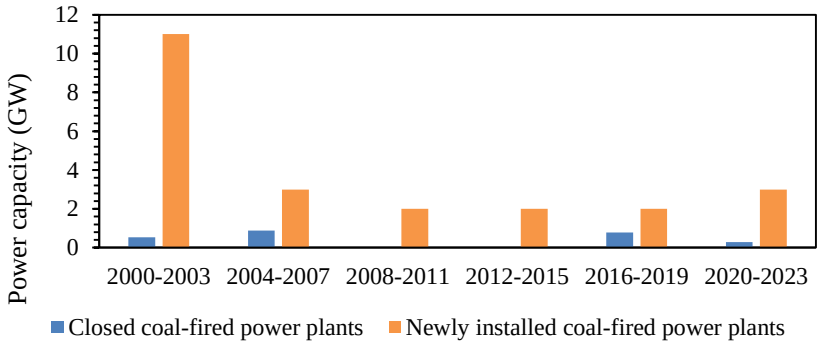

Figure 14. Nominal power values of CTPPs closed and newly installed in Japan

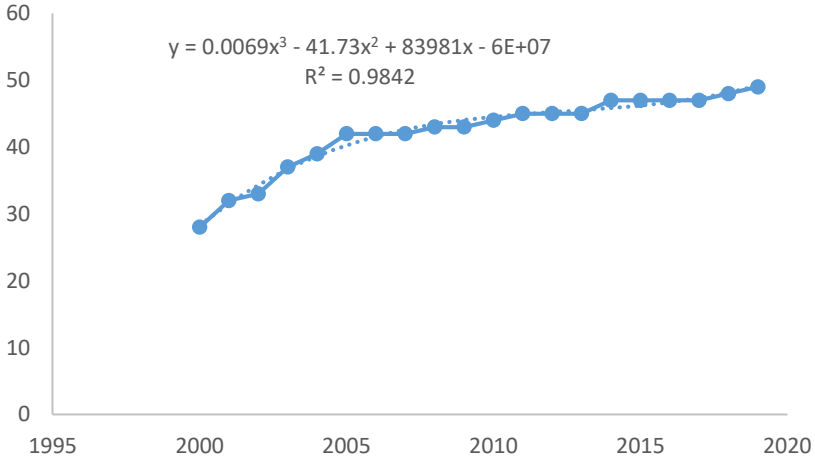

Figure 15. Power Capacity Progress and Projections of CTPPs for Japan

When the newly installed CTPPs in Germany, which have been closed since 2000 until today, are examined in Fig.16, it is observed that the newly installed CTPPs exceeded the power plants that were closed between 2012 and 2015. It is seen that Germany has a tendency to close its CTPPs.

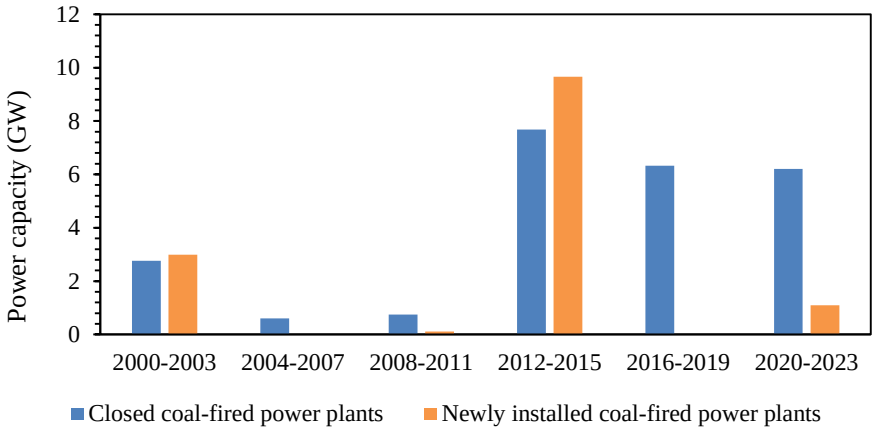

Figure 16. Nominal power values of CTPPs closed and newly established in Germany

Power Capacity Progress and Projections of CTPPs for Germany has been shown clearly at Fig.17.

When we made projection for the world with a 6th order polynomial regression using the data between 2000-2019, the following equation has been obtained with a correlation coefficient of 88.62%:

$$y=8E\text{-}05x^6\text{-}0{,}9171x^5+4606{,}9x^4\text{-}1E+07x^3+2E+10x^2\text{-}1E+13x+5E+15;\ R^2 = 0{,}8862 \quad (6)$$

When the newly installed CTPPs in Russia, which have been closed since 2000 until today, are examined in Fig.18, it is observed that the newly installed CTPPs exceeded the power plants that were closed between 2000 and 2016. The CTPPs in Russia, which were shut down in 2016, exceed the power of the newly installed CTPPs.

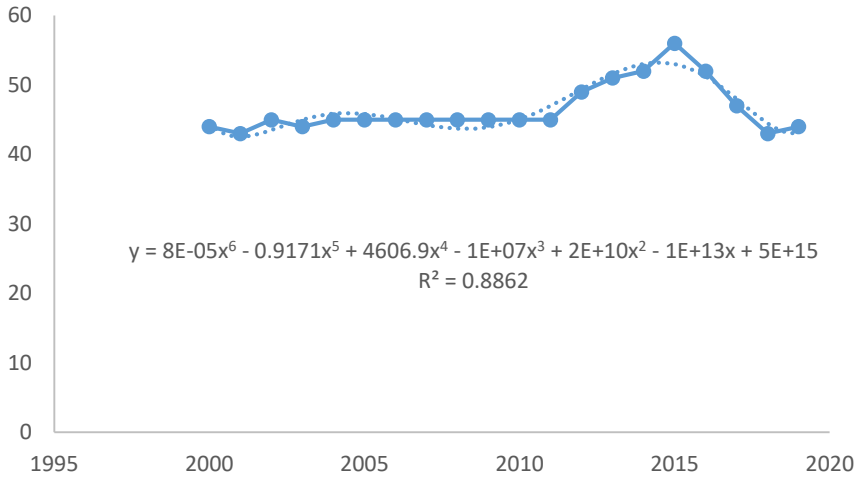

Figure 17. Power Capacity Progress and Projections of CTPPs for Germany

Power Capacity Progress and Projections of CTPPs for Russia has been shown clearly at Fig.19. When we made projection for the world with a 4th order polynomial regression using the data between 2000-2019, the following equation has been obtained with a correlation coefficient of 96.96%:

$$y=-0{,}0004x^4+2{,}9081x^3\text{-}8768x^2+1E+07x\text{-}6E+09;\ R^2 = 0{,}9696 \quad (7)$$

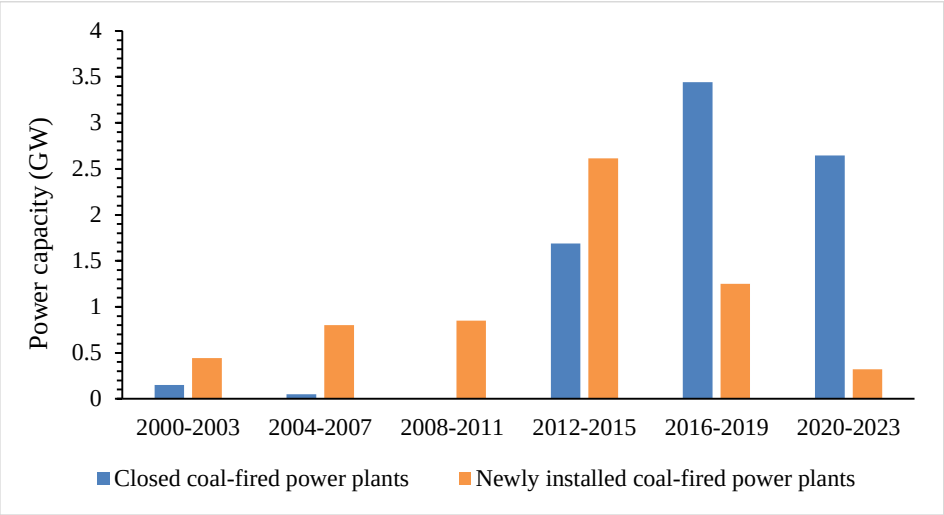

Figure 18. Nominal power values of CTPPs closed and newly installed in Russia

Türkiye has tended to close its CTPPs since 2000. Since 2020, Türkiye has succeeded in surpassing the power of the newly installed CTPP, which was shut down. Power Capacity Progress and Projections of CTPPs for Türkiye has been shown clearly at Fig.21. When we made projection for the world with a 6th order polynomial regression using the data between 2000-2019, the following equation has been obtained with a correlation coefficient of 98.72%:

$$y = -1E\text{-}05x^6 + 0{,}1279x^5 - 641{,}89x^4 + 2E{+}06x^3 - 3E{+}09x^2 + 2E{+}12x - 7E{+}14;\ R^2 = 0{,}9872 \quad (8)$$

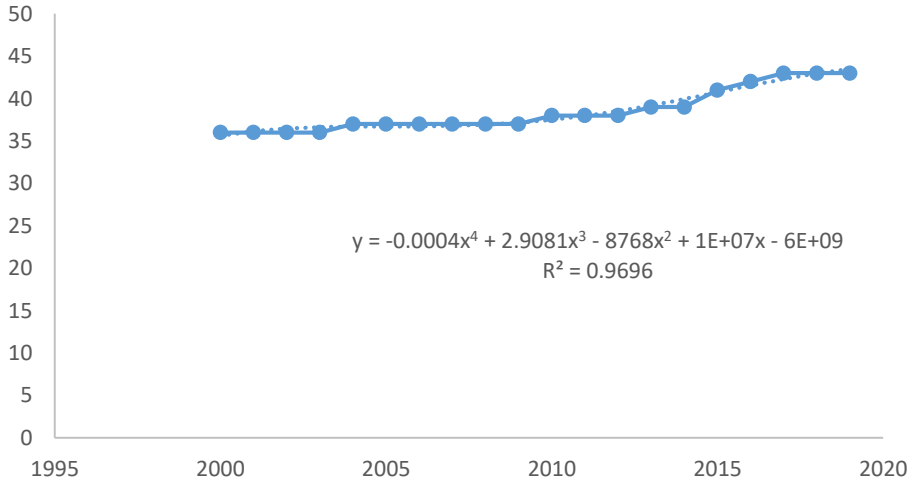

Figure 19. Power Capacity Progress and Projections of CTPPs for Russia

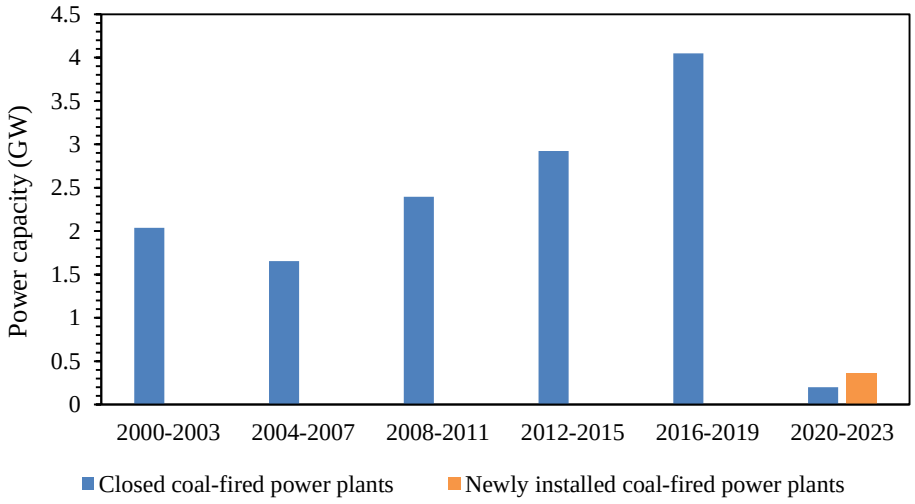

Figure 20. Nominal power values of CTPPs that have been closed and newly installed in Türkiye

4. Electricity Production from CTPPs in the World

According to the IEA's World Energy Outlook Report, global electricity generation is projected to reach 38.7 billion MWh in 2040.

According to the IEA's 2019 World Energy Outlook Report, global electricity demand, which was 23 billion MWh last year, is expected to increase to 34.5 billion MWh by 2040. It is predicted that most of the global electricity demand will originate from the countries in the Asia-Pacific Region, whose growth momentum is increasing rapidly with 18 billion MWh, and produced from CTPPs in the world between 2000 and 2021, global coal-fired production has increased with the effect of increasing gas prices in the USA and Europe and the economic status in China. In 2020, electricity produced in CTPPs decreased compared to 2019 due to the Covid-19 pandemic, low gas prices, and mild winters in important regions.

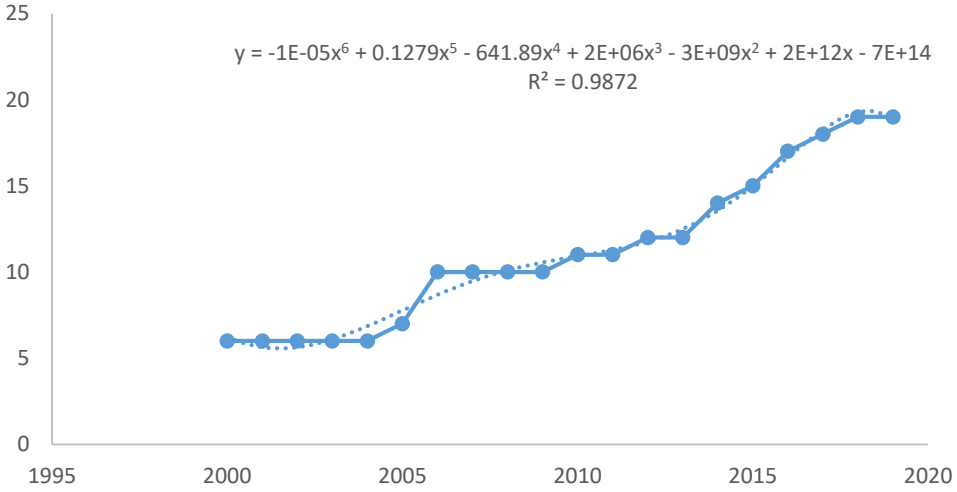

Figure 21. Power Capacity Progress and Projections of CTPPs for Türkiye

When the amount of electricity generation from CTPPs in the world and in certain countries is examined according to Fig. 22, it is seen that China, India, Japan, and Türkiye have increased their production over time. Fig. 22 shows that the USA, the EU, Germany, and Russia have reduced their electrical energy production in parallel with the closure of their CTPPs. It is observed that electricity

energy production from CTPPs has increased worldwide. When the projection is made according to the current situation in the world, it is predicted that the electricity produced from CTPPs will increase in parallel with the increasing installed power. When the projection is made according to the current status, it is predicted that China, which has become a CTPP investor, will increase its electricity production from coal in 2030 and 2050 in parallel with its increasing installed power. It is observed that the electricity production in CTPPs increases in parallel with the increase in capacity. India is the world's largest coal producer, consumer, and importer after China. CTPPs account for 76% of the electricity produced in India in 2017. Gas has not played a significant role in India's energy mix. India currently imports about half of its gas, which accounts for six percent of its electricity generation, largely from Qatar, the USA, Australia, and Russia. Today, due to the international war, the EU supplies natural gas through India. This situation not only contributes to the Indian economy but also increases its importance in the supply chain. When projections are made according to the current situation, it is predicted that India will become the second country after China, with the production of electricity from CTPPs in 2030 and 2050.

Coal production in the USA peaked in 2007 before falling 38% in a decade, and shale gas took its place as the largest electricity source in the USA for the first time in 2016. With the effect of the EU green deal and the global climate crisis, the USA has reduced its oil-fired production by two-thirds in 15 years. The USA is the largest producer and consumer of both oil and natural gas. Gas-fired thermal power plants are in first place in electricity generation in the USA in 2020. Much of the electricity produced by burning coal in the past has been replaced by gas and, to a lesser extent, renewable energy sources, which have replaced it as the largest source of power. When the projection is made according to the current situation, it is predicted that the USA will reduce its electricity production from CTPPs in 2030 and completely exit coal by 2050 and will be stopped.

Electricity generation from CTPPs in Japan was 27% in 2010 and 34% in 2017. Coal continued to be the dominant fuel for electricity generation in 2021, increasing its share from 35.1% to 36% in 2020. If Japan continues its current policy, it is expected to gradually increase coal power generation in 2030 and 2050. In the event that the current policies of the major countries in the world are not fulfilled, it is predicted that CTPPs, especially in China and India, will continue to produce electricity in 2050, excluding the USA, EU, OECD countries, and Germany. The EU is dependent on Russian natural gas. When projections are made according to the current situation, it is predicted that the EU will continue to produce electricity from CTPPs by gradually reducing its capacity in 2030 and 2050. When the projection is made according to the current status, it is predicted that Türkiye will increase its electricity production capacity in 2030 and generate more electricity from coal in 2050 than Russia. When projections are made according to the current situation, it is predicted that Russia will increase its electricity generation from coal in 2030 and decrease its electricity generation from CTPPs in 2050.

Europe's war with Russia and Ukraine, along with the rise in natural gas prices, has led power plants to turn to coal, which pollutes the air more. Emissions Trading System (ETS), which was established with the aim of reducing carbon dioxide gas released into the air in the EU, collected a certain fee per ton of emissions released into the air from electricity generation plants and industrial factories. Due to the additional cost of carbon emissions, natural gas conversion plants have been more advantageous than CTPPs for more than 2 years. However, with the rise in prices, this case changed in July 2021. Energy experts state that hard coal and lignite will continue to be advantageous over natural gas in the upcoming period.

4.1. Capacity Utilization Rate of CTPPs in the World

The capacity utilization rate (CUR) values of CTPPs are the ratio of the electrical energy that the thermal power plant can obtain if it operates at full capacity for 8760 hours in a year and the electrical

energy obtained under real operating conditions. The CUR value is highly dependent on the age of the power plant, its modernization, and low maintenance hours, and it is a different value from the thermal efficiency or similar efficiency of the thermal power plant. The CUR value is an important factor to be considered in energy planning. Accordingly, in this study, CUR values in CTPPs in the world and in Türkiye were examined.

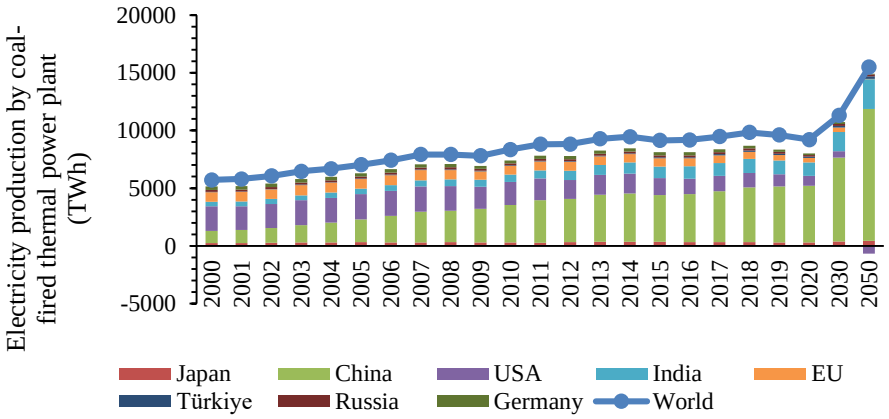

Figure 22. Electricity production projection of CTPPs in the world

As seen in Fig.23, according to the data from 2000-2019, CTPPs have decreased their capacity utilization rates as CTPPs in all countries wear out. Currently, China and India continue to increase their CTPP capacity. The USA reducing its usage capacity by closing its CTPPs. Japan stands out with its highest capacity utilization rate in 2000. As seen in Fig. 16, capacity utilization rates are above 70%, excluding the EU, Russia, and China, according to 2000 data. According to 2019 data, only Japan has a capacity utilization rate of over 70%. It is known in the literature that Japan's CTPPs are efficient. The efficiency of newly established CTPPs in Japan is high, and the efficiency decreases as the power plants age. Japan is closing its old CTPPs and operating the efficient power plants it has built with new technologies.

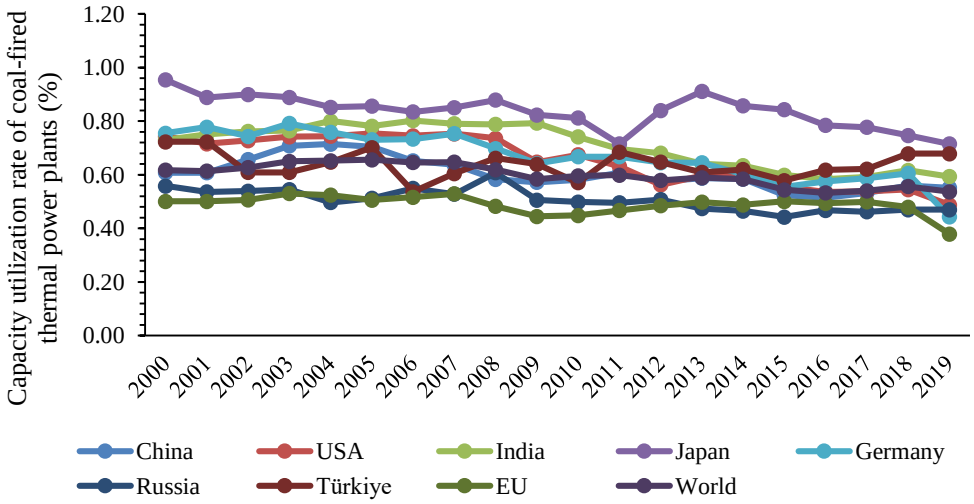

Figure 23. The realized capacity utilization rate of CTPPs in the world and in some developed countries by years

5. Conclusions

A detailed analysis is made with the help of the installed power values, electrical energy production values, high CTPP installation capacity and ranked first in the world in electricity generation and Türkiye's CTPPs in these countries between the years 2000-2020. The power development rates of the countries that stand out in the use of CTPPs by years in the world are given in Table 2. In Figure 5 the capacity development projections of the countries that stand out in the use of CTPPs in the world, as well as the EU and Türkiye are made. In Figures 7,9,11,14.16.18.20, the world and major countries, the nominal power values of CTPPs that have been closed and newly established over the years were calculated. In figures 6,8,10,12,15,17,19,21 power capacity progress and projections of CTPPs are calculated. Fig. 22 the projection study of the electricity production of CTPPs in the world and in some countries over the years has been done.

The capacity utilization rate (CUR) values of CTPPs are an important factor to be considered in energy planning. Accordingly, in this study, CUR values in CTPPs in the world and in Türkiye were examined. Fig. 23 shows the analysis results of the change in the actual capacity utilization rate of CTPPs in the world and in certain countries over the years.

The center of gravity of energy demand is shifting to the East. In this context, while the demand in OECD countries is decreasing relatively, energy demand is increasing in Asia, especially in China and India, in parallel with the rapidly increasing living standards.

The war between Russia and Ukraine seriously affects the EU, which is dependent on foreign energy, especially in energy. The EU and especially Germany have started to use CTPPs in electricity production to reduce the energy crisis they are experiencing. Developed and developing countries constantly change their policies due to economic stagnation, energy crisis, and lack of access to energy in a fair way, and the scenario of exiting coal is not considered possible for a long time. In this study, it emphasizes the importance of planning and shows the case that will be reached if the current energy policies continue. From the perspective of Türkiye, the purchase guarantee and capacity mechanism payments for domestic coal power plants continued in their current form.

China is the world's largest coal consumer, using more than half of all coal globally. After China, India comes in this area. The United States, Russia, Japan and South Africa are the largest consumers, along with India, accounting for a quarter of global coal use. Coal power plant closures in the United States are accelerating, and coal generation capacity is expected to fall by 45% after a decade, from 2020 levels. Increasing construction of wind and solar power plants is the most important driving factor in this area. It reduces the use of coal in other regions, especially in Europe. Metallurgical coal, a much smaller market than thermal coal, is still widely used in steelmaking. Close monitoring of the energy environment associated with fossil fuels and evaluation of trends and risks by making projections are of great importance in terms of global warming.

Since CTPPs are old, they must be shut down or made usable by reducing CO_2 emissions with new technologies. Carbon capture units are not common practice in CTPPs. To make power plants more sensitive to the environment; technology, economy, environment, social effects, and other factors should be planned in an integrated way.

It has been seen that it is important to establish additional flue gas desulfurization (FGD) plants in order to reduce sulfur oxide (SO_2) and nitrogen oxide (NO_x) pollutant emissions in CTPPs, which cause the most climate crisis among fossil fuel thermal power plants. Clean coal technologies should be applied to significantly reduce CO_2 emissions of global warming, climate change, and greenhouse gases.

Authors' Contributions

NE Create concepts; data supply; data analysis; creating graphical analysis; integration; creation of the original draft; writing and editing reviews. NB edited the article and contributed to the language. IE Formal analysis; methodology; writing - original draft; writing-review & editing. All three authors read and approved the final version of the article.

Competing Interests

The authors declare that they have no competing interests.

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