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# **Production of electricity from coal-fired power plants and accompanying CO<sub>2</sub> emissions: comparison of EU-27 and US**

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**Summary:** Even in the third decade of the 21st century, large power plants are still responsible for more than half of the electricity production in Europe and US. They predominantly use fossil fuels in their work, which results in the emission of pollutants into the air, soil and water. In addition to the production of electric energy, fossil fuels, including coal, are used for industrial purposes. Although the use of coal, especially in the countries of the European Union, is in constant decline, there is space for additional reduction. Through this paper, the authors wanted to present the completely actual situation of emissions of CO<sub>2</sub> from thermal power plants in Europe and US, which have used coal for electricity production. Also, this paper provides data and analyses of electricity generation from coal. The CO<sub>2</sub> emission was analyzed in relation to the installed capacity, as well as compared to the energy produced and supplied to the system. The analysis of CO<sub>2</sub> emissions in past few decades and the projection and targets for next 30 years has been showed. The trends in emissions compared to 1990 are rather different for EU and US. In the countries of the EU-27, there is a noticeable trend of decreasing CO<sub>2</sub> emissions since 1990, while in the USA, during the 90s of the last century, CO<sub>2</sub> emissions grew intensively with a peak that maintained its values in the first decade of the 21st century. Only in the second decade of 21<sup>st</sup> century, emissions of coal-fired power plants in the USA have been continuously decreasing with the lowest value in 2020, which also coincides with the lowest emission value in the EU-27.

**Keywords:** CO<sub>2</sub>, emission, coal, thermal power plant, US, EU-27

## **1. Introduction**

Energy today is the carrier of socio-economic development of the social community, representing one of the most important needs of humanity. Management of energy development at the local, national, regional, and global level is one of the most important tasks at the state level. It should also be borne in mind that the demand for final energy at the beginning of the third decade of the 21st century has grown as much as 30 times since the industrial revolution, because of rapid technological progress and exceptional demographic transition [1]. Looking at long-term changes and projections of the possible development of various energy sectors is a vital activity for the sustainable development of states, regions, local governments, as well as economic and other organizations. The electricity sector, its production, as well as its consumption, represents one of the most important elements in the puzzle of satisfying various aspects of human needs and the development of civilization itself. However, this sector is also decorated with the satisfaction of existence and comfort in performing daily activities with an increasingly obvious pressure on the systematic reduction of the impact on the environment in the processes of production, transformation, and consumption of electricity.

Total global energy-related greenhouse gas emissions rise by about 1% to a record high of 41.3 Gt CO<sub>2</sub>eq. CO<sub>2</sub> emissions from energy-burning plants and the industrial sector accounted for 89% of greenhouse gas emissions in 2022. In particular, the global emission of carbon

dioxide (CO<sub>2</sub>) from the energy and industrial plants increased by about 1% or 321 Mt in 2022 to a new record value of 36.8 Gt [2]. This assessment is based on a detailed regional sectoral and energy analysis, including the most recent official national statistics publicly available data on energy use, economic indicators, and climatic features.

The pandemic impact and geopolitical moment in East Europe caused an increase in CO<sub>2</sub> emissions from combustion plants by about 1.3% or 423 Mt in 2022, while CO<sub>2</sub> emissions from the industrial sector decreased by 102 Mt. Emissions growth in 2022 was below global GDP growth (an increase of 3.2%), returning to a decades-long trend of decoupling emissions growth from economic growth that was interrupted in 2021 [2, 3]. Different trends are noticeable between regions and sectors. CO<sub>2</sub> emissions increased in North America and Asia (excluding the People's Republic of China), to a greater extent than emissions reductions in Europe and China. At the global level, CO<sub>2</sub> emissions from electricity generation and the transport sector increased by 261 Mt and 254 Mt, respectively, which is more than the reduction of emissions in the industrial sector and buildings [1, 2]. The largest absolute sectoral increase in emissions in 2022 was in the electricity and heat generation sector. Emissions in the electricity and heat generation sector increased by 1.8% (i.e., 261 Mt), reaching the highest level of 14.6 Gt. The shift from gas to coal in many regions was the main driver of this growth: CO<sub>2</sub> emissions from coal-fired power generation increased by 2.1%, led by increased Asian market and economic development. Global demand for electricity increased by 2.7% [4].

This paper analyzes production and emissions of CO<sub>2</sub> in sector of electricity in two big worlds region - EU-27 and US. The emission of CO<sub>2</sub> in EU-27 and US in last 30 years are anatomized through paper, also showing trends and targets of future development. Only in the last decade (since 2011) emissions of coal-fired power plants in the US have been continuously decreasing with the lowest value in 2020, which also coincides with the lowest emission value in the EU-27. Since 2012, total coal power generation has dropped by almost a third in the EU. The declining use of coal has caused mines to close down and power plants to be decommissioned in a number of regions across Europe. Paper also provides the projection and targets of CO<sub>2</sub> emissions for 2030, 2040 and 2050.

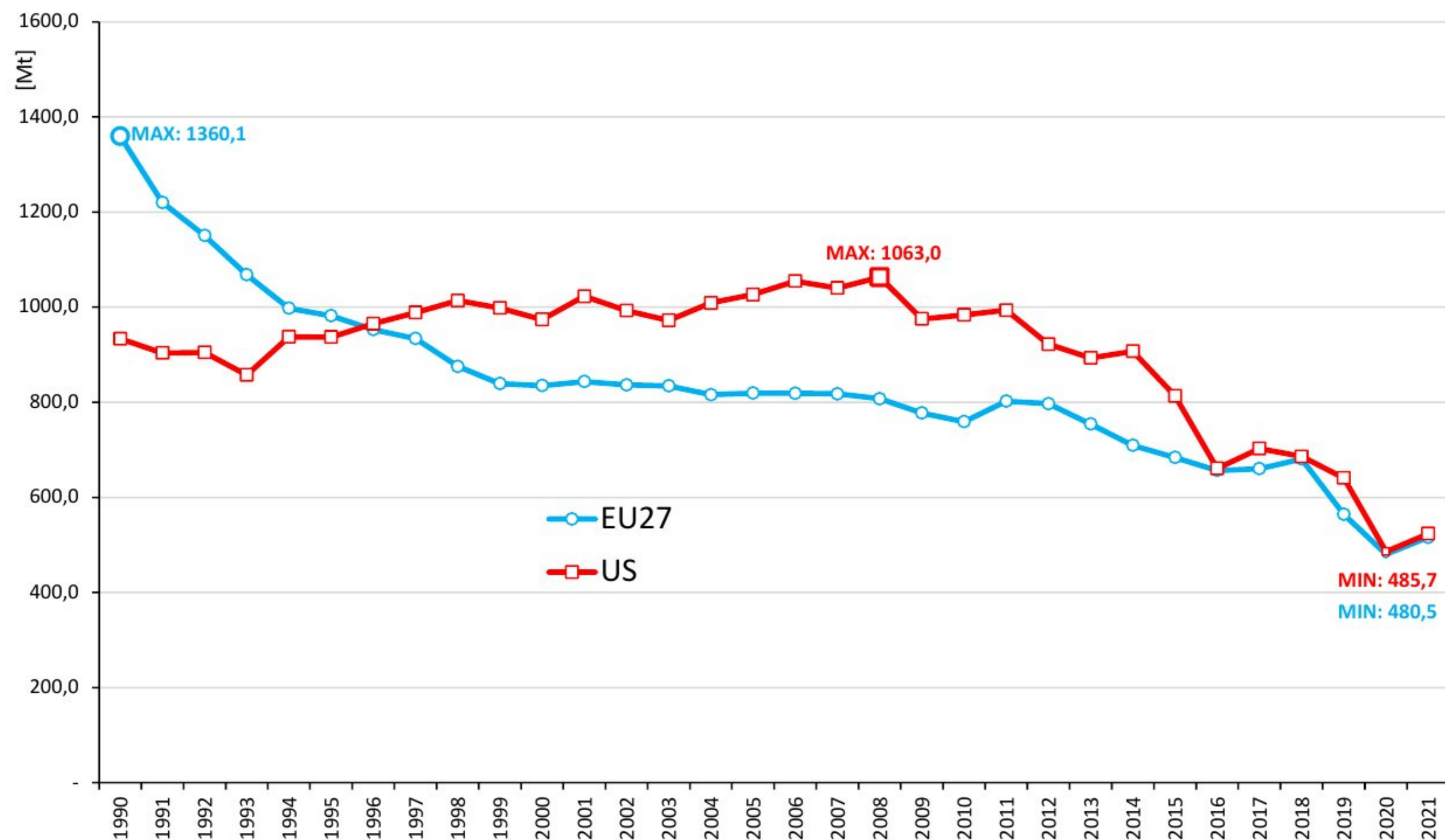
## **2. Production of electricity from coal-fired power plants**

The US has 12.595 electricity generation sources with an installed capacity of 1.202.471 MW, while the EU-27 has 26.649 electricity generation sources with an installed capacity of 649.819 MW. In the US, there are 18.3% of coal-fired power plants of the total installed capacity, and in the EU-27 there are 19.8% of coal-fired power plants of the total installed power [5]. The coal production in EU-27 and US in last three decade is shown in Figure 1.

About 495 million tons of coals were consumed in the US, that is around 11% of total US energy consumption. Since 1964, this is the lowest amount of US total annual energy consumption since at least 1949 [6, 7]. Although coal use was once common in the industrial, transportation, residential, and commercial sectors, today the main use of coal in the United States is to generate electricity. The majority of U.S. coal consumption since 1961 is to product electricity from coal-fired power plants. Table 1 shows coal consumption in US and share of total coal consumption [6]. Figure 2 shows coal consumption in the US in the last half of previous century and first two decades of this century, with specific statistical results for most characteristic years.

Coal consumption in US peaked in 2005, but the total annual coal consumption in tons peaked in 2007 with 948,2 million tons of coal consumed in electric power sector [7]. Coal

consumption declined since then, mainly because of a decline in the use of coal for electricity generation [7].



**Figure 1.** Coal production in EU-27 and US

At one time, coal had the greatest importance in the EU-27 countries as an energy source for obtaining electricity. In 1990, the share of coal in the production of electricity was 36,7%, while in 2021 this share was only 14,8% [4]. Nevertheless, even in the third decade of the 21st century, large power plants are still responsible for about 40% of the total electricity production in Europe. In their work, they predominantly use fossil fuels, which results in the emission of pollutants into the air, soil, and water. Sector of production and use of coal also provides jobs to around 230.000 people in mines and power plants across 31 regions and 11 EU countries [8].

**Table 1.** The US coal consumption in 2021 [6]

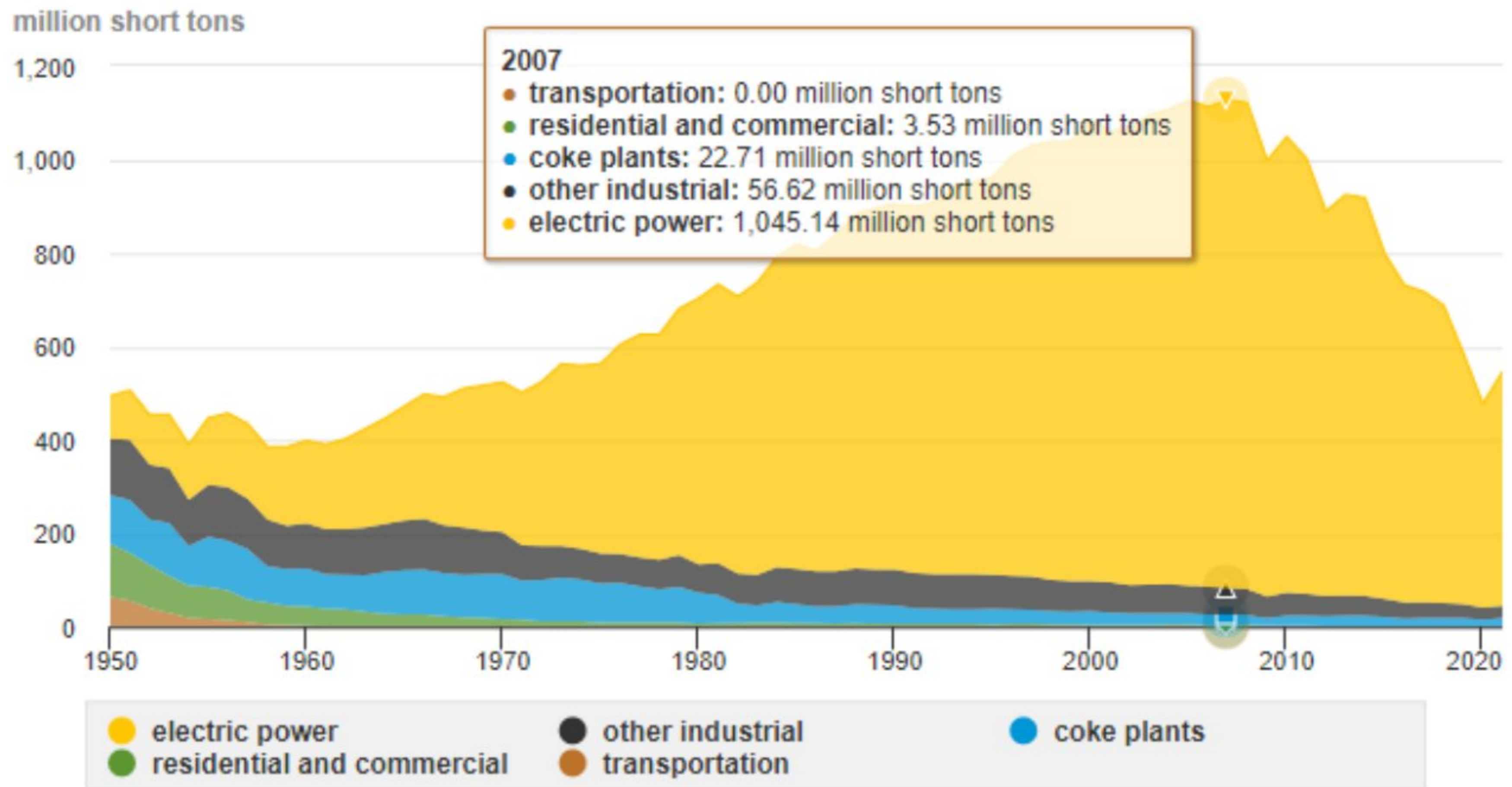
	Electric power	Industrial total	Commercial	Residential and transportation <sup>1</sup>
Coal consumption [million tons]	455	39,4	0,73	n.a.
Share of total coal consumption [%]	91,9	8	0,1	n.a.

Apart from electricity generation, fossil fuels, including coal, are also used for industrial purposes. About 3,000 different large industrial plants in the EU-27 countries are emitters of various pollutants from fossil fuels. In order to mitigate the impact on the environment, EU policy aims to reduce emissions from such plants, which gives results already in the first years of the change in the use of energy [1, 2, 4].

It is noticeable that there is an obvious connection between the level of development of a country or region and the amount of energy consumed in the country. Figure 3 shows the ratio of specific electricity production per capita in the EU-27 and the US. In the last 2 decades, the

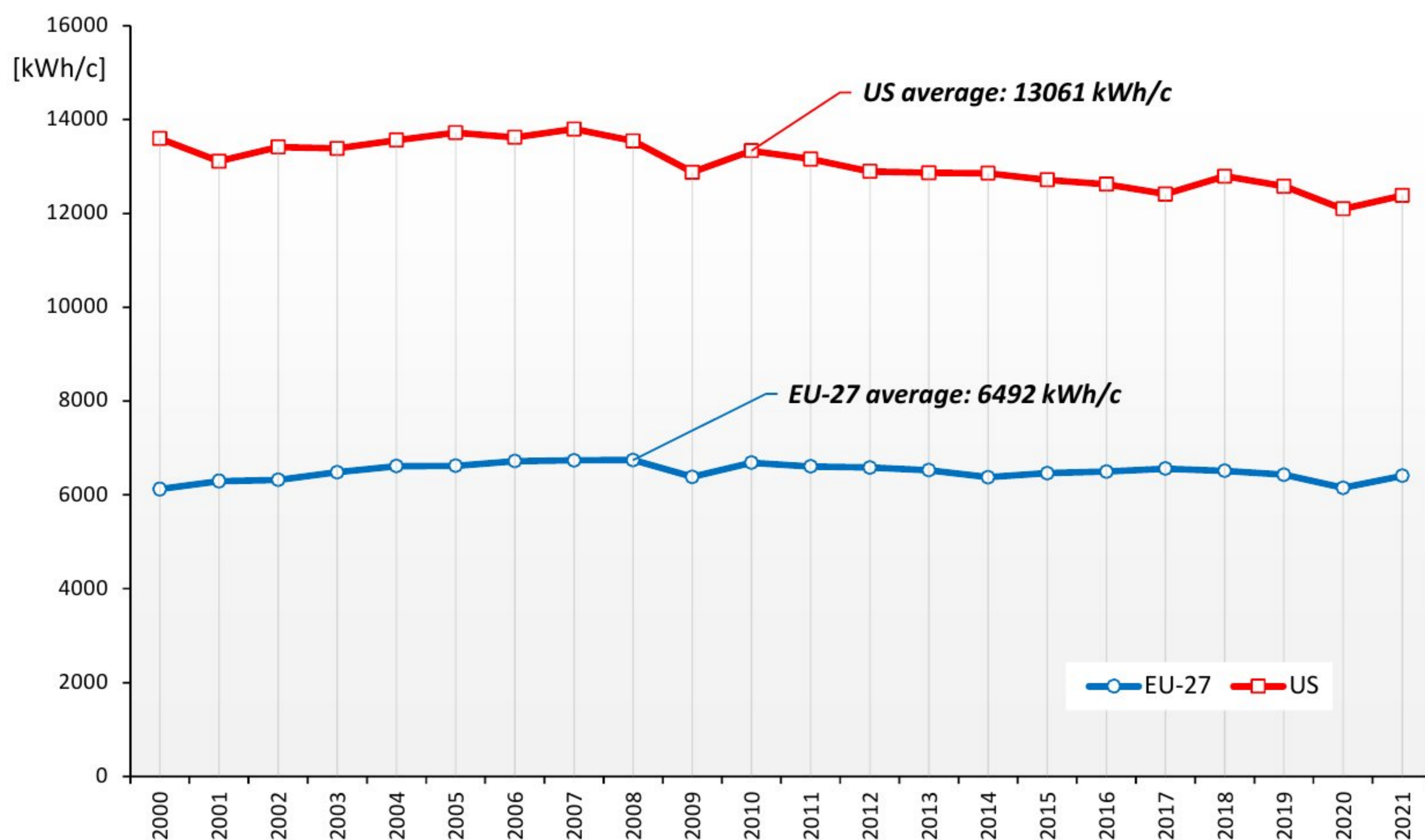
<sup>1</sup> Minor amounts of coal are still consumed in the residential and transportation sectors. However, EIA (U.S. Energy Information Administration) no longer tracks coal consumption in these sectors.

average electricity production in the EU-27 is 6492 kWh per capita, in the US 13061 kWh per capita, and in Serbia 5461 kWh per capita [6, 8, 9].



**Figure 2.** Coal consumption in US with 2007's peak [7]

The thermal energy capacities of the Republic of Serbia consist of six thermal power plants, with 17 active thermo-blocks, with a total installed capacity of 4400 MW, which exclusively use lignite and three thermal power plants-heating plants, with a capacity of 403 MW to produce electricity and 505 MW for the production of thermal energy, divided into 6 blocks, on liquid and gaseous fuels [9].



**Figure 2.** Ratio of specific electricity production in EU-27 и US

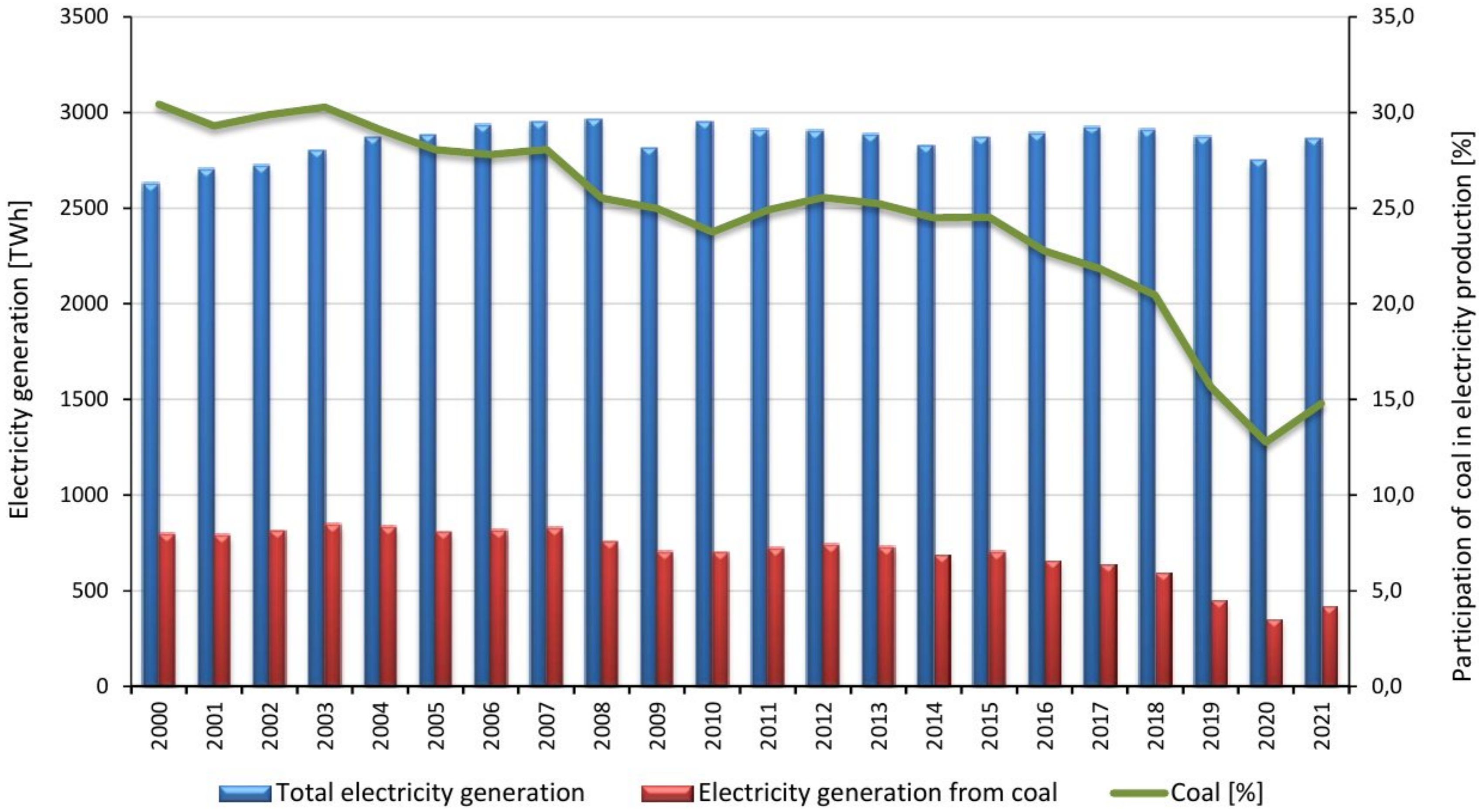
Nevertheless, based on the strategic orientations of development, as well as on the basis of the balance sheet data, it is noticeable that renewable energy sources take precedence. While coal

remains a primary fuel in the European energy mix, the transition to cleaner forms of energy and innovative technologies, such as carbon capture and storage, is imperative to meet the EU's commitment to reduce CO<sub>2</sub> emissions by at least 55% by 2030 and to become the world's first climate-neutral bloc by 2050 [10].

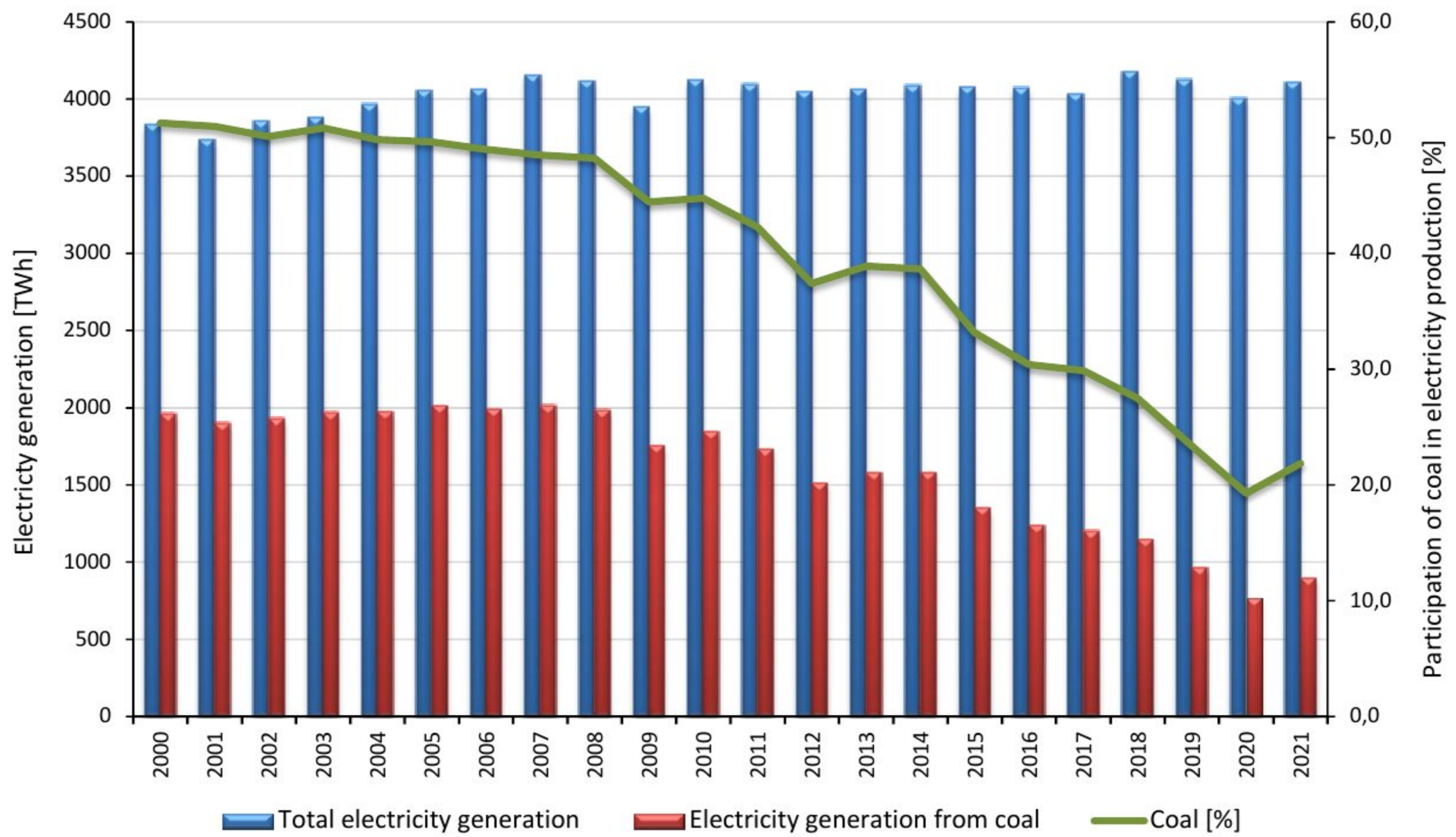
In the same period from 1990 to 2021, electricity production increased by 26%. Figure 4 shows the diagram of the total production of electricity in the countries of the European Union, as well as the generation of electricity from coal, as well as the share of coal in the energy mix of annual production. It remains an indisputable fact that the problems of climate change and CO<sub>2</sub> emissions have slowed down the expansion of the use of coal as an energy source [1, 4]. Since 2012, total coal power generation has dropped by almost a third in the EU. The declining use of coal has caused mines to close down and power plants to be decommissioned in a number of regions across Europe [8].

In developing countries, coal is often the only alternative when cleaner energy sources are inadequate to meet the growing demand for energy, i.e., impact on rising standards. Such is the case with Serbia. In 1990, the share of coal in the production of electricity was 72,6%, while in 2021 this share was 64.1%. In the same period from 1990 to 2021, electricity production decreased by 4% [11, 12].

Electricity production in USA follows the trend of the rest of the world, increasing year by year, while the share of coal in the same decreases. Figure 5 shows a diagram of the total generation of electricity, electricity generation from coal, as well as the share of coal in it in the USA from 2000. US electricity generation for 2021 are 4433,9 TWh, of which it is 1273 TWh (28,7%) from coal and coal products [6, 7].



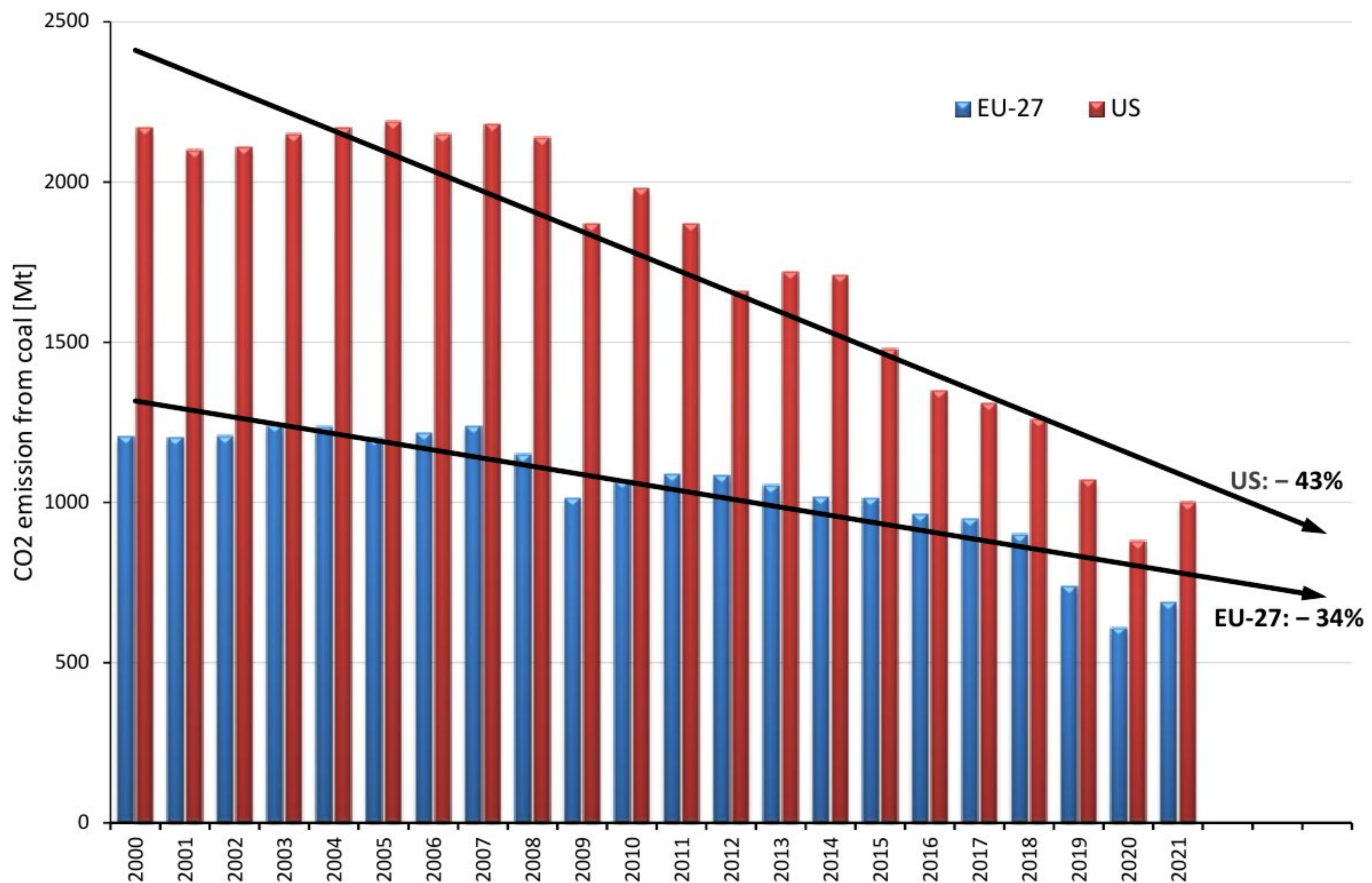
**Figure 4.** EU-27 electricity generation [8]



**Figure 5.** US electricity production [5, 6]

### 3. CO<sub>2</sub> emissions

EU-27 has 193 active coal-fired thermal power plants, with 480 thermal units. The total installed capacity of these power plants is 111.606 MW [11, 12]. USA has 230 active coal-fired thermal power plants, with total installed capacity of 219.067 MW [5]. Figure 6 presents CO<sub>2</sub> emissions trend from coal-fired power plants in the EU-27 and the US in this century.



**Figure 6.** CO<sub>2</sub> emissions decrease from coal-fired power plants in the EU-27 and the US [14]

The emissions decrease compared to 1990 in the countries of the European Union is 34%, while the average reduction in the US is 43% [13, 14].

CO<sub>2</sub> emissions in the 20 thermal power plants in Europe and US, which are the largest emitters, are shown in Table 2. The thermal power plants Nikola Tesla, Serbia, which are positioned in the 4th place in terms of absolute and specific emissions, have been singled out for the purpose of comparison [15].

**Table 2.** The largest emissions of CO<sub>2</sub> in the 20 largest thermal power plants in the EU-27 and the US in 2021 [13, 14, 15]

Power plant	Country	State/ Province	CO <sub>2</sub> emissions [Mt]	Coal / Fuel	Installed power [MW]	Ratio [tCO <sub>2</sub> /MW]	Generation [MWh]	Ratio [tCO <sub>2</sub> /GWh]
Belchatow	Poland	Województwo łódzkie	25540	Lignite	5097	5,01	27400	0,93
Neurath	Germany	North Rhine-Westphalia	22100	Lignite	3800	5,82	31300	0,71
James H Miller Jr	US	Alabama	20834	Subbituminous	2822	7,38	20529	1,01
Nikola Tesla <sup>2</sup>	Serbia	Belgrade	17464	Lignite	3036	5,75	17623	0,99
Niederaussem	Germany	North Rhine-Westphalia	16100	Lignite	3021	5,33	24500	0,66
Kozienice	Poland	Województwo mazowieckie	15900	Hard coal	3994	3,98	11000	<b>1,45</b>
Labadie	US	Missouri	15636	Subbituminous	2389	6,54	16608	0,94
Boxberg	Germany	Saxony	15500	Lignite	2582	6,00	18000	0,86
Janschwalde	Germany	Brandenburg	15200	Lignite	3210	4,74	20000	0,76
Weisweiler	Germany	Nordrhein-Westfalen	14500	Lignite	1595	<b>9,09</b>	13400	1,08
Monroe	US	Michigan	14263	Subbituminous/ Bituminous	3293	4,33	14722	0,97
W A Parish	US	Texas	13795	Subbituminous	4008	3,44	14817	0,93
Martin Lake	US	Texas	13413	Lignite/ Subbituminous	2380	5,64	13180	1,02
Gen J M Gavin	US	Ohio	13386	Bituminous/ Subbituminous	2600	5,15	13807	0,97
Oak Grove	US	Texas	12516	Lignite	1795	6,97	12334	1,01
Prairie State Generating Station	US	Illionis	12330	Bituminous	1766	6,98	12686	0,97
Schwarze Pumpe	Germany	Brandenburg	11800	Lignite	1600	7,38	10000	1,18
John E Amos	US	WV	11425	Bituminous	2933	3,90	12011	0,95
Lippendorf	Germany	Saxony	11100	Lignite	1868	5,94	11000	1,01
Sam Seymour	US	TX	10901	Subbituminous	1690	6,45	10281	1,06

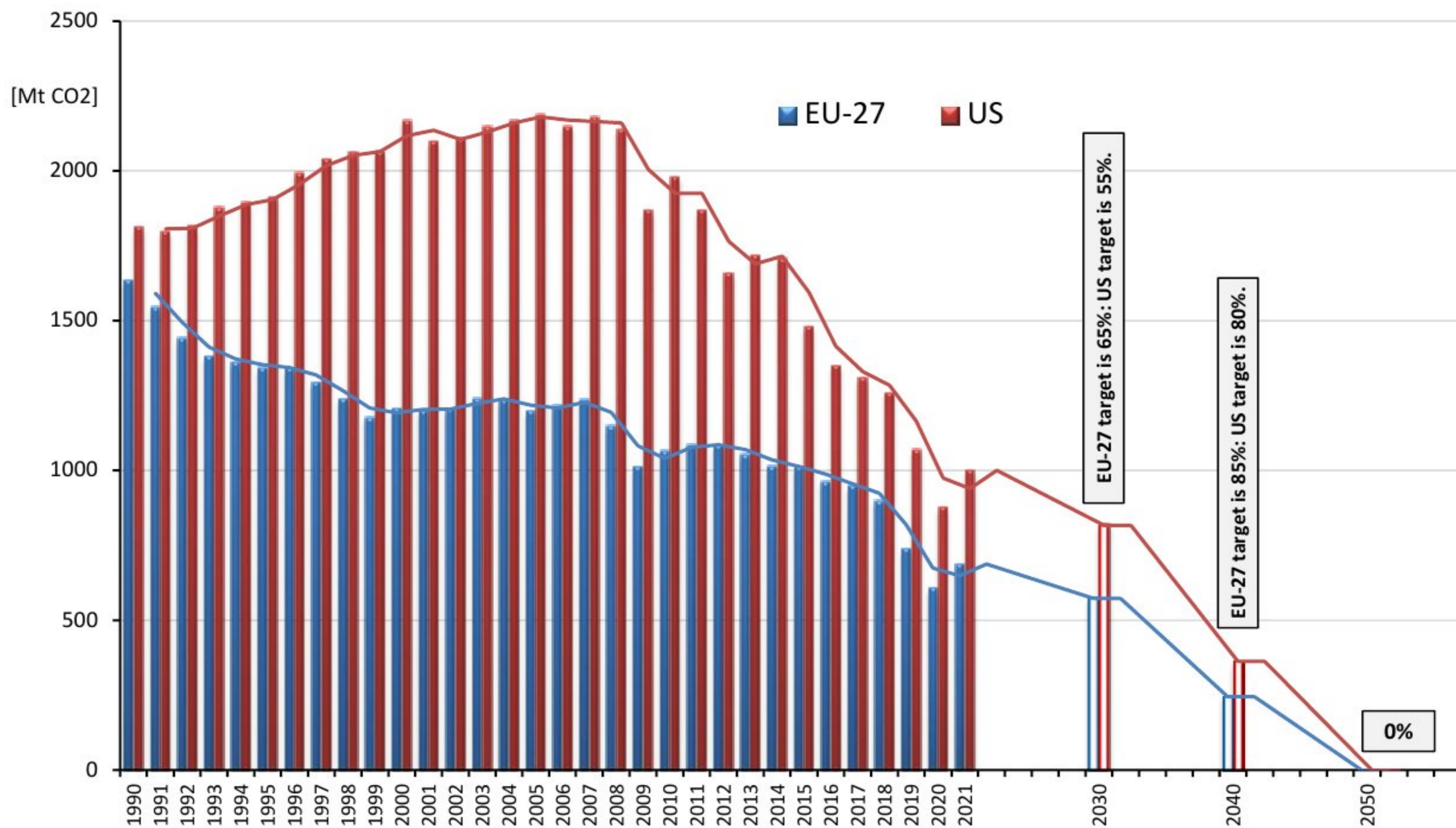
The total CO<sub>2</sub> emission in the EU-27 and the US is given in Table 3, while the comparative CO<sub>2</sub> emission in the largest power plants in Europe and US for the period 2010-2021, with projections till 2050, are shown in Figure 7.

<sup>2</sup> The Nikola Tesla power plant is in Serbia, which is not a member of the EU-27, but is one of the largest emitters of CO<sub>2</sub> in Europe



**Table 3.** CO<sub>2</sub> emissions from coal-fired power plants in 2021 [11]

	Million tons CO <sub>2</sub>	Ratio to the area of the territory [tCO <sub>2</sub> /km <sup>2</sup> ]	Ratio to the number of inhabitants [tCO <sub>2</sub> /st]	Ratio to electricity production [kgCO <sub>2</sub> /MWh]	Ratio to electricity production from coal [kgCO <sub>2</sub> /MWh]	Ratio to electricity consumption [kgCO <sub>2</sub> /MWh]	Ratio to GDP per capita [tCO <sub>2</sub> /US\$]
US	1000	109	3,01	240	1114	251	14235
EU-27	688	162	1.54	248	1622	264	18470



**Figure 7.** Comparative CO<sub>2</sub> emissions of coal-fired power plants in the EU-27 and power plants in the US for the period 1990-2021 with projection

The projection and targets for 2030, 2040 and 2050 has been showed at Figure 7. At the same time, the decline in emissions compared to 1990 was also marked at the same figure. In the countries of the EU-27, there is a noticeable trend of decreasing CO<sub>2</sub> emissions since 1990, while in the USA, during the 90s of the last century, CO<sub>2</sub> emissions grew intensively with a peak that maintained its values in the first decade of the 21<sup>st</sup> century. Only in the last decade (since 2011) emissions of coal-fired power plants in the US have been continuously decreasing with the lowest value in 2020, which also coincides with the lowest emission value in the EU -27. Figure also shows targets for EU-27 and US for 2030, 2040, and 2050.

#### 4. Directions of development and conclusion

Based on current market trends, coal consumption can be predicted to stay at current level through next few years, as declines in established, western markets are offset by continued strong demand in emerging, fast-growing Asian economies. This means that coal will probably be the largest single source of carbon dioxide emissions in the global energy system until the end of this decade. It is noticeable that, driven by the challenges of the pandemic and conflict in Eastern Europe, the strong policy of reducing the use of coal in Europe and slightly less intensive politics of reduction in US have become frozen only at the moment. EU-27 countries continue to see their energy future through energy-imagined minimal use of fossil fuels, reducing their import independence, by increasing security of supply and energy security in general.

Global coal consumption increased by over 6% in 2021, to levels slightly above 2019, but also above the highest consumption recorded in 2014. In addition to consumption, coal prices increased extremely in 2021, so prices in Europe (\$121/tons) and Asia (\$145/ton) reached their peak since 2008 [16].

Demand for coal is primarily dictated by the needs of industry and the power generation sector in China and India, which accounted for over 70% of coal demand growth in 2021. Notably, both EU-27 countries and US showed an increase in coal consumption in 2021 after nearly 10 years of consecutive decline [16].

If it is necessary to replace the production of electricity that would be deprived by the planned shutdown of coal-fired power plants in next decades, for example, the following measures would have to be implemented. For EU-27, 50% of the electricity currently provided by TPP Neurath, Germany needs to be produced annually from renewable sources to make up the difference by 2050 (that is about 2000 MW of installed power for 8000 h of operation per year). For US, annually, it is necessary to produce 1,5 times the amount of electricity produced by TPP James H. Miller, Alabama from renewable sources in order to make up the difference by the year 2050 (that is about 4000 MW of installed power for 8000 hours of operation per year).

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