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EVALUATION OF COAL USE IN THE ENERGY SECTOR

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Abstract

In many countries, coal plays a primary role in ensuring energy supply security. As a competitive fuel, it directly affects the economic value in the production of steel, cement, and, most importantly, in the generation of electricity and heat. A diverse energy mix with controlled use of coal can be part of a strategy that reduces risk and supports sustainable economic growth. Conventional energy generation in thermal power plants, including nuclear, coal, lignite, and gas-fired plants, requires sustainability and will remain necessary in the future.

Today, new renewable energy sources, primarily wind turbines and solar photovoltaic systems, are gaining importance, but they still require reliable backup from conventional sources. Space is increasingly being created for the integration of renewable energy sources, given the flexibility and reliability of coal and lignite-based power generation. A key prerequisite for future electricity production in Europe lies in utilizing a broad spectrum of energy sources to minimize supply risks, maximize reliability, and achieve further progress in environmental and climate protection.

Keywords*: coal, energy, stability, supply*

1 INTRODUCTION

Coal has been a key energy source worldwide for decades, particularly in thermal power plants for electricity generation. Although it remains important in many countries, its role is diminishing due to climate change, environmental standards, and the transition to renewable energy sources. Coal has been used because of its high energy value, reliability of supply, as well as availability and low cost-especially in countries with large reserves (e.g., China, India, the USA, and Russia). In some developing countries, coal still accounts for more than 50% of total electricity generation [1].

The European energy sector faces significant challenges in ensuring the reliability of energy supply and investing in new energy infrastructure. Conventional thermal energy production, including nuclear, coal, lignite, and gas power plants, will still be necessary in the coming period. A key condition for energy supply stability in Europe is competitiveness.

Energy at affordable and transparent prices helps maintain the overall competitiveness of European industry. Risk management in energy supply has been an integral part of the Energy Union strategy since 2015. [1]. Two essential elements of a

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secure energy system are the diversity of energy sources and energy technologies. An energy mix consisting of domestic and imported energy sources-including hard coal and lignite-helps control supply risks.

The use of high-efficiency, low-emission technologies, including coal upgrading, advanced combustion technologies, pollution control measures, and the application of carbon capture and storage (CCS) technologies, can improve the sustainability of coal use [1].

2 GLOBAL ENERGY TRENDS

Electricity is no longer produced solely from conventional hydropower, coal, gas, and nuclear energy. New renewable energy sources, primarily wind turbines and solar photovoltaic systems, are becoming increasingly important, but they still require reliable backup from conventional sources-at least until large-scale energy storage options become available. Analyzing the flexibility and reliability of coal-based electricity generation reveals significant potential for maximizing the use of renewable energy sources.

The key to future electricity production in Europe lies in a wide variety of energy sources. Supply risks are minimized, ensuring maximum reliability by utilizing available electricity generation sources and achieving further progress in environmental and climate protection towards net-zero emissions by 2050.

Globally, the number of coal-fired power plants has been declining during the period from 2014 to 2024, as shown in Figure 1 [2]. Many governments are increasing efforts to reduce funding for new high-emission fuel sources. Coal, as the most polluting fossil fuel, remains a major energy source, especially in rapidly growing economies.

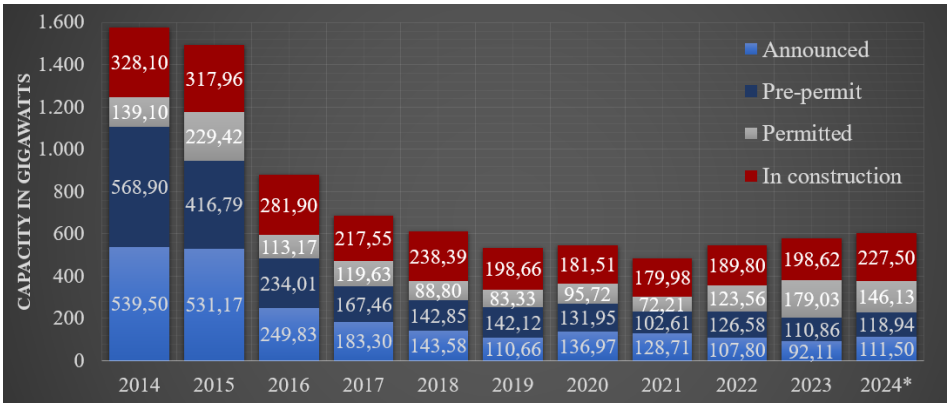

Figure 1 *Capacity of coal-fired power plants from 2014 to 2024 [2]*

The total global primary energy supply in 2022 amounted to 20,609 million tons of coal equivalent (Mtce), of which 26.7% came from coal, which is of particular importance for electricity generation, as shown in Figure 2 [2].

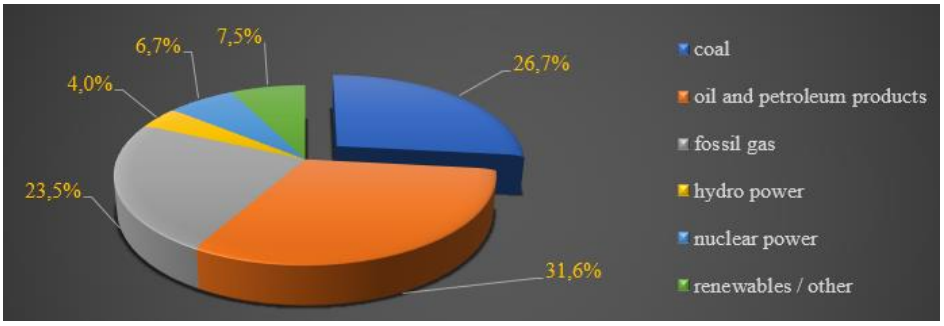

Figure 2 *Total world primary energy supply by fuel type, 2022 [3]*

Over one third, or 35.4%, of global electricity production and 17.1% of electricity production in the EU in 2022 were based on coal, as shown in Figure 3 [3].

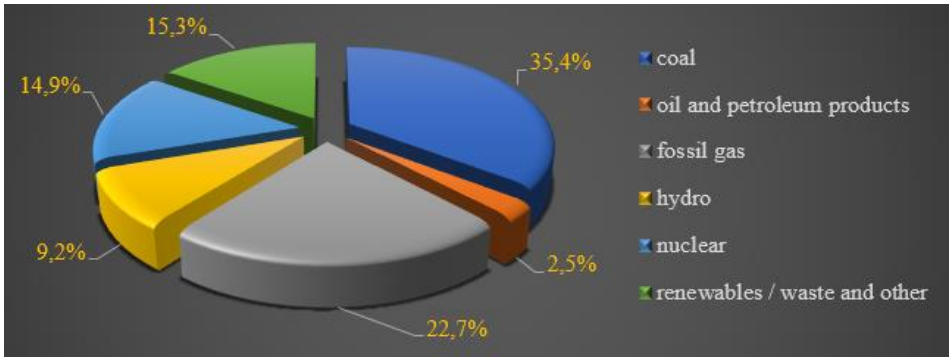

Figure 3 *World electricity production by fuel type, 2022 [3]*

Global coal consumption strongly recovered after a sharp decline at the peak of the pandemic [4, 5]. It is projected to reach a record 8.77 billion tons in 2024. However, demand is expected to remain close to this level until 2027. In China, which consumes 30% more coal than the rest of the world combined, coal consumption is expected to stabilize due to the massive expansion of renewable energy sources alongside strong growth in electricity demand [5].

In most developed economies, coal demand has already peaked and is expected to continue declining until 2027. Meanwhile, coal demand continues to grow in some developing economies where electricity demand is rapidly increasing alongside economic and population growth, such as India, Indonesia, and Vietnam. In developing economies, growth is mainly driven by coal demand from the power sector, although industrial use is also increasing, as shown in Figure 4 [6].

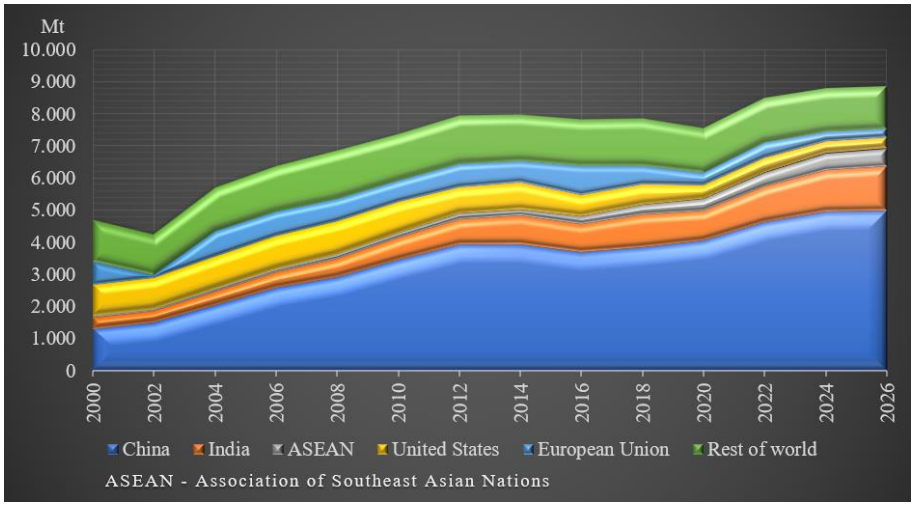

Figure 4 *Global coal consumption 2000 – 2026 [6]*

The International Energy Agency (IEA) report shows that global energy demand grew by 2.2% last year - lower than GDP growth of 3.2%, but significantly faster than the average annual demand growth of 1.3% between 2013 and 2023. Developed and developing countries accounted for over 80% of the global energy demand increase in 2024. The sharp rise in global electricity consumption was driven by record-high global temperatures, which increased cooling demand in many countries, as well as growing industrial consumption, transport electrification, and the expansion of data centers and artificial intelligence [6].

The growing supply of low-emission sources covered most of the increase in global electricity demand in 2024. As a result, 80% of the global electricity production growth in 2024 was provided by renewables and nuclear power, which together accounted for 40% of total production. Additionally, to meet rising electricity demand, natural gas saw the largest increase in demand among fossil fuels in 2024 [6].

Meanwhile, oil demand grew more slowly, causing the oil share in total energy demand to fall below 30%. Electric vehicle sales increased by over 25% last year, with electric models making up 20% of all cars sold worldwide. This significantly contributed to the decline in oil demand in road transport, while consumption of oil for aviation and petrochemicals increased [6].

3 ENERGY SECTOR INPUTS IN SERBIA

In the Central Balkan region, Serbia is favorably positioned for services and trade. The Morava Valley is the easiest land route from Europe to Turkey and beyond. Regarding energy, Serbia relies on lignite and small amounts of imported coal. Energy production in the country is largely based on lignite, accounting for 64.07%, as shown in Table 1 and Table 2. However, in the process of EU accession, the Republic of Serbia will be obliged to achieve an appropriate share of renewable energy sources in primary energy consumption [7].

On the other hand, existing low productivity, both in the mining sector and in electricity production in coal-fired thermal power plants, seriously calls into question the viability of maintaining existing capacities as well as the justification for building new ones [8]. To raise Serbia's development level to a

higher stage, energy development must be faster and more market-oriented than it is today [9].

Compliance with economic parameters is inevitable, without diminishing the importance of environmental protection.

Table 1 *Primary energy production (%) [3]*

Description / Year	2018	2019	2020	2021	2022	Average
Coal	65,37	66,22	65,11	61,58	62,05	64,07
Hydroelectric power	9,69	8,51	7,16	9,51	7,72	8,52
Solar photovoltaic power	0,01	0,01	0,01	0,01	0,01	0,01
Wind power	0,13	0,75	0,77	0,91	0,85	0,68
Crude oil and natural gas liquids	9,52	9,03	8,38	8,65	9,03	8,92
Firewood, wood chips and residues[1)]	11,08	11,39	14,83	15,67	16,77	13,95
Natural gas	3,93	3,76	3,33	3,14	3,01	3,43
Geothermal power	,05	0,05	0,05	0,01	0,02	0,04
Biogas	0,22	0,28	0,36	0,52	0,54	0,38

[1)] Final biomass consumption was taken from the Ministry of Mining and Energy of the Republic Serbia

Table 2 *Primary energy production (TJ) [3]*

Description / Year	2018	2019	2020	2021	2022	Average
Coal	276.720	285.772	295.647	263.034	250.324	274.299
Hydroelectric power	41.015	36.714	32.524	40.624	31.135	36.402
Solar photovoltaic power	47	49	48	49	57	50
Wind power	542	3.234	3.512	3.904	3.418	2.922
Crude oil and natural gas liquids	40.310	38.990	38.030	36.967	36.432	38.146
Firewood, wood chips and residues[1)]	46.931	49.151	67.334	66.938	67.640	59.599
Natural gas	16.653	16.247	15.133	13.414	12.145	14.718
Geothermal power	219	220	212	63	64	156
Biogas	939	1.190	1.624	2.221	2.193	1.633

[1)] Final biomass consumption was taken from the Ministry of Mining and Energy of the Republic Serbia

Coal is by far the most used fossil fuel in the Western Balkans and Ukraine [10]. In Europe, only Germany and Turkey have larger reserves. Deposits are located in two main coal basins, Kolubara and Kostolac, as shown in Figure 5. In 2022, Serbia mined 35.1 million tons of coal, but imported an additional 2.2 million tons of lignite. Lignite reserves amount to 7,112 million tons, with total resources of 20,186 million tons. Imports of hard coal amounted to 204 thousand tons. Hard coal reserves stand at 402 million tons, with total resources of 855 million tons [11].

Production, processing, and transport of coal, electricity generation, distribution system operation, renewable energy production, and steam and hot water generation in cogenera-

tion plants are carried out by Elektroprivreda Srbije (EPS). The total gross electricity production in 2022 was 36 TWh, net imports amounted to 2.6 TWh, while total supply was 34.9 TWh. Net electricity production from hard coal was 0.7 TWh, from lignite 21.5 TWh, while the net capacity for electricity production from hard coal was 486 MW and from lignite 5,661 MW [11].

Directly in lignite-based electricity production, 16,700 employees work, while the total number of employees in the mining sector is shown in the following table. Based on the presented data, it can be seen that about 1.3% of the total workforce is employed in the mining sector [12].

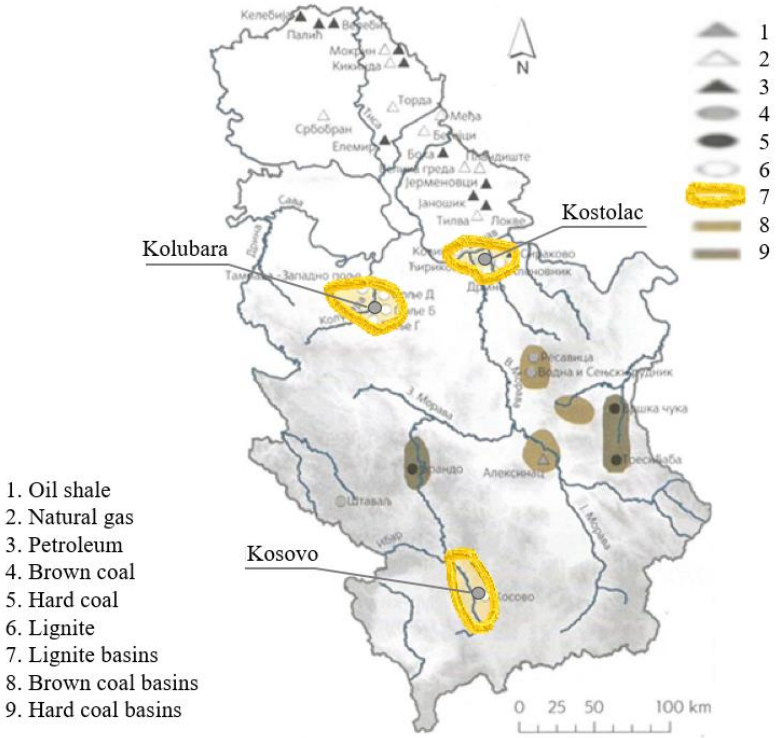

Figure 5 *Non-renewable energy sources - lignite coal in Serbia [12]*

Table 3 *Registered employment, 2020-2024 [3]* *annual average*

Description / Year	2020	2021	2022	2023	2024
Total number of employees	2.149.099	2.212.631	2.253.473	2.306.955	2.319.535
Mining	28.969	27.286	29.124	30.275	30.783

The mining sector in Serbia plays a significant role in the country's overall economic development. Thanks to its natural resources, it forms the basis of industrial development in the country and holds an important role in regional development. One of the indicators of the impact of the energy and mining sectors on economic growth is presented in the Table 3 and Table 4 [3].

Table 4 *Basic indices of industrial production by purpose and sectors, 2019-2023. [3] 2021=100*

Description / Year	2019	2020	2021	2022	2023
Industry - total	93,9	93,8	100,0	101,9	104,6
Energy	96,2	98,5	100,0	98,6	102,8
Intermediate products, except energy	89,7	88,5	100,0	104,2	104,0
Capital products	93,4	89,2	100,0	107,4	115,6
Durable consumer goods	98,7	103,0	100,0	9,38	91,8
Non-durable consumer goods	96,5	96,3	100,0	101,0	103,5
Mining	74,8	77,8	100,0	125,9	126,0
Manufacturing	94,9	94,2	100,0	101,4	102,4
Electricity, gas, steam and air conditioning supply	98,3	99,3	100,0	92,9	104,6

Based on data on the consumption of hazardous chemicals, Table 5 (covering the sectors: Mining, Manufacturing Industry, Electricity, Gas and Steam Supply, Water Supply and Wastewater Management), the negative effects of the energy and mining sectors are also presented in Table 6 [3].

Table 5 *Consumption of hazardous chemicals [3]* *thousand tons*

Description / Year	2022	2023
Dangerous to health	1.096	1.098
Dangerous to the environment	904	935

Table 6 *Waste generated by sectors KD1) and from households [3]* *thousand tons*

Description[1] / Year	2022	2023[2]
Total	176.879	182.319
— Hazardous	29.862	39.670
— Non-Hazardous	147.017	142.649
Agriculture	88	92
Mining	164.903	170.974
Manufacturing	1.072	1.086
Electricity, gas and steam supply	6.531	6.016
Water supply and wastewater management	970	1.088
Construction	630	503
Services[3]	459	394
Household waste[4]	2.225	2.167

[1] Classification of activities
[2] Data not final
[3] Sectors covered by G-S KD
[4] Estimate

4 DISCUSSION OF THE RESULTS

Coal still plays a significant role in many energy systems, but its use is increasingly limited due to environmental and economic reasons. Evaluation of its use shows that the costs and environmental impacts are high, and trends indicate the need for a faster transition to cleaner and more sustainable energy sources, Table 7.

Table 7 *The role of coal application*

Aspects	Importance	+	-	Comment
Economic Evaluation	Low production cost per kWh	●		
	Well-developed infrastructure in existing thermal power plants	●		
	Employment of a large number of workers (especially in mining and thermal energy sectors)	●		
	Rising CO_2 emission costs (e.g., EU ETS)		●	
	Costs of plant modernization due to pollution regulations		●	
	Reduced attractiveness to investors		●	
Aspects	Importance	+	-	Comment
Environmental Impacts	Greenhouse gas emissions (CO_2, CH_4)		●	For these reasons, many countries are implementing decarbonization strategies and plans to close coal-fired power plants
	Air pollution (SO_2, NO_x, particulate matter)		●	
	Water and soil contamination (waste ash and slag)		●	
	Land degradation due to surface mining		●	
Technical Improvement Possibilities	CCS technologies (carbon capture and storage)	●		However, these requirements often demand large investments that are not cost-effective compared to transitioning to renewables
	Cofiring – burning coal together with biomass	●		
	Modernization of plants to increase efficiency and reduce emissions	●		
Replacing Coal in the Energy Mix	Solar and wind power	●		EU countries and other developed countries are increasingly using alternative options
	Hydropower and nuclear energy	●		
	Natural gas as a transitional fuel	●		

The conservation of mineral resources, including coal, plays a significant role in the sustainable management of natural resources and long-term planning for the development of the energy sector. Although it is one of the key sources of energy in industry, the power industry and households, its use is declining due to environmental reasons and the global transition to cleaner energy sources.

Investing in the rational use and preservation of coal deposits allows countries to provide a backup source of energy in situations when other energy systems are unstable or unavailable (in emergency conditions, energy crises, disruptions in gas or oil supply), coal remains a reliable support). Such planning contributes to long-term sustainability and the reduction of negative environmental impact. In some regions, coal is still an important factor in local development — it provides jobs, supports metallurgy, the chemical industry, and other supporting industries.

Preserving coal resources allows for a gradual and controlled transition to alternative sectors, without a sudden economic downturn. Although coal is considered the most polluting fossil fuel, conserving the deposit also has an ecological dimension: the size and structure of mineral reserves are preserved, which allows for more precise planning of rehabilitation and reclamation, uncontrolled exploitation is prevented, which can lead to collapse, erosion and contamination of soil and water and allows for the gradual closure of mines with a reclamation plan that is aligned with natural processes.

Conserving mineral resources allows countries to gradually replace coal with renewable energy sources, without sudden disruptions to supply and the economy. Controlled and planned exploitation represents an important bridge to the energy transition.

5 CONCLUSION

Under its emissions reduction strategy, Serbia is expected to comply with the EU Carbon Border Adjustment Mechanism (CBAM), which will be gradually introduced starting January 1, 2026. To meet EU environmental standards, Elektroprivreda Srbije has recently invested in the modernization of power plants and environmental protection projects, particularly in its thermal power plants, where projects for flue gas desulfurization, electrostatic precipitators, ash and slag transport, and wastewater treatment have been completed.

Serbia still produces around 65–70% of its electricity from coal but is developing energy transition strategies. According to the draft National Energy and Climate Plan, Serbia will increase the share of renewable energy sources in electricity production, which will require new capacities. In any case, the production and utilization of electricity from wind, solar, and biomass should be developed to the greatest extent possible, while maintaining hydropower potential and using imported gas to the extent it is available at a favorable price.

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