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ANALYSIS OF COAL RESERVES WITH THE POTENTIAL FOR UNDERGROUND EXPLOITATION IN THE REPUBLIC OF SERBIA

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ABSTRACT

The issues addressed in this paper are dedicated to the balancing and analysis of coal reserves for the system of underground exploitation in the Republic of Serbia, both in active mines - deposits and in prospective deposits for activation in terms of production. The basic message emphasizes the importance of coal as the leading domestic energy source for the production of mainly electricity and thermal energy to a lesser extent.

In addition to the balance of coal reserves in the deposits, importance was given to the quality of coal as an important thermal energy factor. For active mines-deposits, thermal values are given for assortments of piece, cube and fine coal, while for inactive deposits, quality values are shown for coal from coal seams.

Based on the obtained research results, it is concluded that coal will maintain the leading position for electricity production in the energy sector of the Republic of Serbia in the coming decades, while coal from underground exploitation should increase its share in the energy balance.

Key words: *coal, coal reserves, mine, mine development, underground exploitation, energy production*

INTRODUCTION

Energy system is key industry branch for national economic development, which must meet the needs of society, the economy and environmental factors. In the case of the Republic of Serbia, the energy generation system consists of coal mines (underground, underwater and surface exploitation), electricity generation, oil and gas economy and decentralized heat exchange systems. The most important energy raw material is coal, whose share in total energy reserves is over 80%, with the largest share of lignite, which is mainly obtained by surface exploitation systems (RB Kolubara, TE-KO Kostolac), and a small share of underwater exploitation (Kovin).

The current share of coal in electricity production is about 70%, hydropower 28% and natural gas up to 2%.

All adopted and valid national strategic documents to date envisage that coal will be used as the main energy source for electricity production in the coming period, while in recent years some lobby groups have strongly advocated solar energy, wind energy, small hydropower and occasionally nuclear power

plants, which are still subject to applicable moratorium on construction, and at the same time a complete abandonment of coal is required.

Rapid changes in the energy sector did not give the expected effects anywhere, so now the rapid suppression of coal carries a high risk for stable supply of energy to consumers, which is confirmed by the current energy crisis. The euphoria of "renewable-green" energy sources has forced the EU member states to return nuclear energy and gas power plants to the category of "non-hazardous" for the environment.

Numerous studies have been conducted on this topic for and against the use of coal in electricity production, but practice has shown that the use of coal now and in the coming decades cannot be avoided due to insurmountable barriers in the application of solar energy, wind and small hydropower plants (small capacity, limited resources, difficult regulation of power supply networks).

At the beginning of the 60's of the last century, mass closures of underground mines began in Serbia, but at the same time surface mines were opened and coal production increased significantly, and the construction of thermal power facilities ensured its consumption. [1].

Coal production from mines with underground exploitation in Serbia during 1964 amounted to 2,574,188 tons, while surface exploitation resulted in over 4 million tons. Coal production in the Republic of Serbia reached the maximum level of 40.3 million tons in 2011, and during 2020, coal production of over 39 million tons was achieved.

In the preparation of this paper, analytical methods and methods of analysis and synthesis were used, while in the collection of data, technical analyses of the state of documents were used, namely primary and secondary materials and observations. The analytical method was applied here for the analysis of the condition and content of important technical documentation related to active underground mines-deposits and prospective deposits for activation.

Research has proven the need to maintain underground coal mining in the energy sector of the Republic of Serbia, with a changed approach to active mines in deposits with larger reserves and the possibility of using modern mechanized equipment in technological processes.

RESEARCH RESULTS

Reserves and quality of coal assortment in active mines-deposits

In the currently active eight (8) underground mines in the Republic of Serbia, layers of hard coal (Vrška Čuka and Ibar mines), brown coal (Rembas, Bogovina, Soko, Jasenovac, Štavalj) and lignite (Lubnica) are being exploited. It is obvious that this is an excavation of quality coal, especially favourable for use in the sector of electricity and heat production.

In these mines - deposits, excavation works have been performed for a longer period of time, ranging from 170 (Senjski Rudnik-Rembas) to 60 (Štavalj) years afi, so that some deposits are about to run out of reserves (Jasenovac, Ibar mines…) while other mines (Soko, Štavalj) have concentrated significant reserves for a longer period of exploitation and with the possibility of a significant increase in the production capacity. [2].

These facts point to the need to change the approach to the development of underground coal mines, by concentrating production from several simultaneously active pits, and/or production excavation fields in deposits with larger reserves (Soko, Štavalj), while in deposits with lower reserves the process of suspending excavation works should be initiated.

Table 1 shows the summarized balance of coal reserves in active underground mines - deposits as at 31.12.2020 by classes and categories, where it is evident that the balance reserves of A, B and C_1 categories amount to 259,380,427 tons. Off-balance reserves total 18,832,817 tons, and a detailed

analysis of natural-geological and technical-technological conditions by deposits shows that only a small volume can be translated into balance reserves.

At the same time, there is a fact that a certain amount of balance reserves should be transferred to off-balance, because when balancing them, small layer thicknesses was taken into account and without taking into account complex microtectonic conditions, as well as the presence of clay deposits in the immediate floor or roof of the mine.

Table 1. Balance of coal reserves at active underground mines - deposits, as at 31.12.2020

Mine -deposit-	Balance reserves per category (t)				Off-balance reserves (t)	Type of coal
	A	B	C_1	A+B+C_1		
V. Čuka	25.687	626.383	1.624.608	2.276.678	350.000	Hard coal
Ibar mines	-	928.154	283.434	1.211.588	1.326.580	
Rembas	710.275	2.187.052	4.531.823	7.429.150	581.590	Brown coal
Bogovina	-	1.647.267	676.248	2.323.515	1.652.058	
Soko	245.642	13.529.675	37.160.407	50.935.724	2.997.725	
Jasenovac	-	176.744	-	176.744	25.960	
Štavalj	1.477.710	99.326.316	84.197.469	185.001.495	7.423.342	
Lubnica	660.239	8.859.215	506.079	10.025.533	4.565.562	Lignite
UKUPNO	1.641.843	127.290.806	128.983.071	259.380.427	18.832.817	

Data source: Technical documentation JP PEU-Resavica [3]

The pie chart presented in Figure 1 shows the coal reserves in active mines-deposits, individually and in total, which shows that the largest share in the reserves of category A + B + C_1 are found in the deposits of mines Štavalj and Soko, followed by Rembas and Lubnica

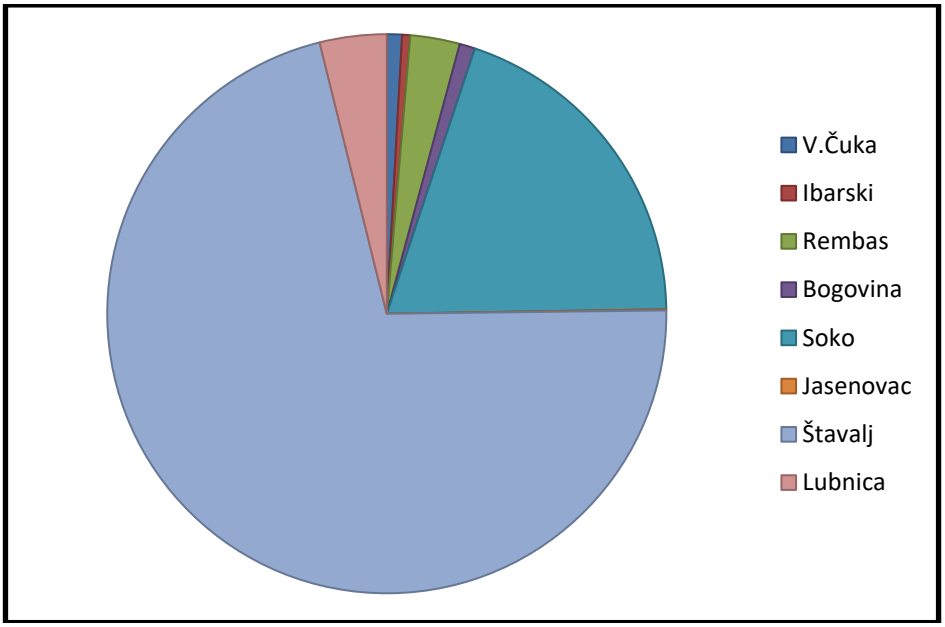

Figure 1 Pie chart of the size of coal balance reserves in active underground mines

Table 2 gives an overview of potential reserves of C_2 category of about 211 million tons per active deposits, which indicates the prospects of individual deposits and priorities of research and conversion of reserves of category C_2 into higher categories B and C_1.

In order to point out the importance of coal from active underground mines and their use value, the authors give an overview of quality in Table 3 - thermal values of basic commercial assortments, namely pieces and cubes that are placed in mass consumption and small assortments used in thermal power plants.

Table 2. Overview of the size of potential coal reserves in active deposits of PE PEU – Resavica

Mine-deposit	Reserves of C_2 category (t)
Vrška Čuka	6.000.000
Rembas	15.000.000
Soko	140.000.000
Štavalj	50.000.000
TOTAL	211.000.000

Data source: Book of coal reserves of the mine PE PEU - Resavica as at 31.12.2018, Technical documentation of PE PEU - Resavica

Table 3. Overview of the calorific value of commercial coal from active mines

Mine	Coal assortment / calorific value (MJ/kg)		
	Piece	Cube	Small
Vrška Čuka	-	-	24,11
Rembas	25,30	24,19	17,24
Bogovina	21,76	22,12	16,97
Soko	19,15	18,21	14,74
Jasenovac	19,05	14,07	9,50
Štavalj	19,26	14,90	13,31
Lubnica	15,67	14,67	7,37

Coal reserves and coal quality of prospective deposits for underground exploitation

The authors classified eight deposits, and/or coal basins to the group of prospective deposits of coal for activation in terms of production by underground excavation. Significant coal reserves for long-term operation of the mine are concentrated in them, and their present natural-geological conditions enable the application of modern highly productive mechanization in all technological phases of the exploitation process. This would meet the conditions of productivity, security, economy and environmental protection.

It should be noted that these deposits were previously partially covered by exploitation works, except for the Dragačevo deposit, that they have been researched by geological and mining works comparatively well, and that coal reserves were determined and presented with high accuracy.

Table 4 shows the balance of coal reserves in these deposits, with a total volume of reserves of 450,815,032 tons, while Table 5 provides data on the quality of coal in the coal seams.

Table 4. Balance reserves of coal in inactive deposits with potential for underground exploitation

Deposit	Determined reserves per categories (t)				Type of coal
	A	B	C_1	A+B+C_1	
Jerma	-	5.767.600	-	5.767.500	Hard coal
Melnica	-	21.121.761	8.899.908	29.921.669	Brown coal
Aleksinac	2.732.960	17.017.380	7.776.280	27.919.620	
Poljana		48.467.000	10.527.270	58.994.540	Lignite
Ćirikovac		121.036.207	27.881.661	147.517.868	
Despotovac		15.080.000	9.710.000	24.790.000	
Zap.basen		72.111.343	21.792.492	93.903.835	
Dragačevo		-	-	62.000.000	
TOTAL	2.732.960	300.601.291	86.587.611	450.815.032	

Data source: literature [4] i [5]

* According to the literature [6], coal reserves in the Kostolac deposit (deeper level) of category C_2 are estimated at 162,414,000 tons

Table 5. Determined coal quality of coal seams in inactive deposits with potential for underground exploitation

Parameter	UoM	DEPOSIT						
		Jerma	Melnica	Aleksinac	Poljana	Ćirikovac	Desotovac	Zap.mor
Moisture	%	1,50 - 3,70	27,86	13,85	42,53	39,57	29,60	35,50
Ash	%	17,33 - 30,48	24,24	27,98	13,15	18,73	30,89	16,28
Sulfur	%	4,90 - 5,49	2,64	5,26	2,26	1,10	1,60	1,65
Coke	%	82,69 - 84,04	44,01	53,05	33,37	36,04	47,23	57,84
C.fix	%	54,56 - 65,36	23,10	25,07	19,74	16,88	16,34	21,36
Volatile	%	11,96 - 13,61	26,70	33,10	24,61	24,93	23,17	26,86
Combustible	%	66,52 - 78,97	44,86	58,17	45,67	41,66	39,51	48,42
DTV	MJ/kg	22,85 - 28,05	12,85	12,97	10,45	9,42	9,21	12,05
GTV	MJ/kg	22,23 - 24,60	14,07	17,45	11,96	11,41	10,36	13,57

Data source: Technical documentation of PE PEU - Resavica

Note: Data on the coal quality of the Dragačevo deposit are not shown in the table, considering that these are layers of brown coal and lignite developed in parts of the deposit.

CONCLUSION

The current energy crisis in most European countries with pronounced negative effects on the economy has shown that coal as an energy source for electricity production cannot be eliminated and will maintain its position for some time. At the same time, the situation related to the lack of energy in the required volume shows that in crisis situations, their prices escalate and cause disruptions, especially of economic flows, and then all countries seek solutions individually within domestic sources to absorb some of the negative effects of unrealistically high prices.

The main energy source for electricity production in the Republic of Serbia is coal from domestic sources with a share of 64% in the energy balance, which is mainly lignite whose quality varies, and one of the solutions is to increase the share of quality coal from underground mining in the consumption in EPS thermal power facilities.

Research within this topic has determined that within active mines – deposits, balance reserves of $A+B+C_1$ category amount to 259,380,427 tons, off-balance to 18,922,817 tons, while reserves of C_2 category are estimated at 211 million tons. In addition, in inactive deposits that are estimated with potential for underground exploitation (Jerma, Melnica, Aleksinac, Poljana, Ćirikovac, Despotovac, West Moravian Basin, Dragačevo), total reserves of 452,411,132 tons have been determined, and the quality of coal from the layers is shown in the paper.

The presented raw material potential is significant and can ensure long-term exploitation, and technical - technological solutions of the exploitation process should be based on the application of highly productive mechanization in order to ensure economic and safety parameters. These facts represent the contribution of the paper to science and mining and they explain the basic hypothesis contained in the position "that coal will be the main energy source for electricity production in the Republic of Serbia in the coming decades" and that it is necessary to increase the share of quality coal from underground mines.

In the continuation of research on this topic, it is a priority that the natural and geological conditions in each deposit should be considered in detail, both active and prospective, parts of deposits where coal reserves can be rationally excavated should be analysed, and then dynamics of activation of new deposits should be defined, which will result in the increase in the capacity of quality coal production.

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