NEW "ŠTAVALJ" COAL MINE AND THERMAL POWER PLANT

by

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Original scientific paper
UDC: 620.9:622.33:622.012
BIBLIID: 0354-9836, *13* (2009), 1, 165-174
DOI: 10.2298/TSCI0901165Č

Štavalj deposit has over 180 million tonnes of coal reserves, which is considered by the Ministry of Mining and Energy as large energy potential of national importance. Pre-feasibility study was developed for the purpose of evaluation of new underground coal mine and thermal power plant complex.
Mine is designed with two sets of mechanized longwalls, for the production rate of 2.3 million tonnes per year of run-of-mine coal or 1.68 million tonnes of clean coal. This production is sufficient for thermal power plant of 320 MW, based on circulated fluidised bed combustion boilers and one turbine, with emissions of CO_2 at same level than power plants operated by Electric Power Industry of Serbia.
Following review of the Pre-feasibility study, possibilities for further improvement of underground coal mine are suggested. These improvements comprises of operation with one larger mechanized longwall set and without coal processing plant. Effects of these suggestions are lower initial investments, lower roadway development requirements, improved energy efficiency at coal production and smaller number of workers, all of which contributing to reduction of capital and operational expenditures and lower cost of fuel.

Key words: *energy potential, coal, underground mine, thermal power plant, costs, improvements*

Introduction

Large coal reserves are located at the south-west of Serbia, at Pešter highlands. Underground coal mining started some 50 years ago, in the Central field of Štavalj deposit, which is the smallest one regarding the amounts of coal reserves (fig. 1 and tab. 1). Other parts of deposit, Western, Eastern, and Southern fields, remained intact. Geological explorations at high level were performed at the Central, Western, and Eastern fields, while the geological data are insufficient for Southern filed. Balanced reserves in Western, Central, and Eastern fields are over 187 million tonnes (over 124 million tonnes of measured resources – JORC code), while the geological reserves in Southern field are estimated at some 50 million tonnes [1].

Technical analysis of coal, as well as chemical analysis and thermal parameters of ash are given in tab. 2.

Coal from Štavalj deposit is categorized as brown coal, with low sulphur and ash content. Carbon content is estimated at 21%.

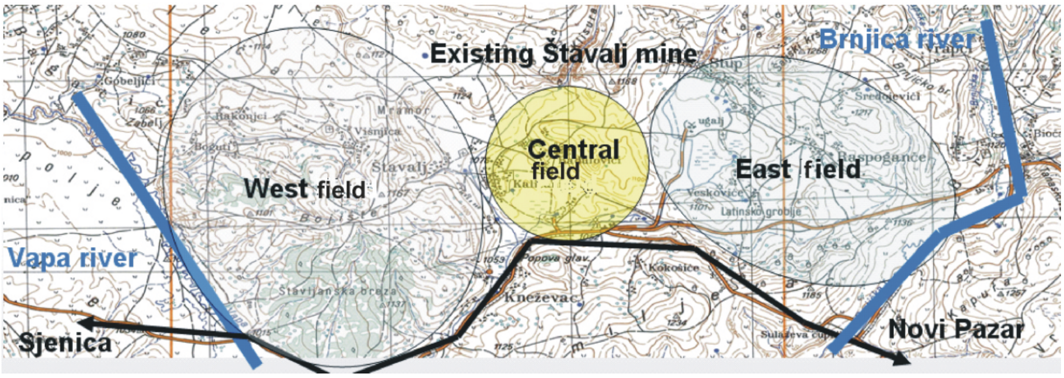


Figure 1. Štavalj deposit coal fields

Table 1. Coal reserves at Štavalj deposit

Category	Reserves [t]			Coal resources – JORC [t]	
	Balanced	Non-balanced	Total	Measured	Indicated
Eastern field					
A	11.598.230	–	11.598.230		
B	18.169.450	–	18.169.450	29.767.680	–
A + B	29.767.680	–	29.767.680		
Central field					
A	345.562	988.753	1.334.315		
B	9.930.607	4.948.297	14.878.903	10.276.169	–
C1	–	107.926	107.926		
A + B + C1	10.276.169	6.044.976	16.321.145		
Western field					
B	84.569.760	801.790	85.371.550		
C1	62.546.720	862.780	63.409.500	84.596.760	62.546.720
B + C1	147.116.480	1.664.570	148.781.050		
Total	**187.187.329**	**7.709.546**	**194.869.875**	**124.640.609**	**62.546.720**
Southern field	–	–	>50.000.000	–	–

Table 2. Chemical and technical analyses of coal and ash from Štavalj deposit

Technical analysis of coal		Ash composition	
Moisture, as delivered [%]	31.43	SiO_2 [%]	25.89
Ash [%]	12.34	Fe_2O_3 [%]	5.91
Sulphur, total [%]	0.98	Al_2O_3 [%]	12.91
Sulphur in ash [%]	0.73	CaO [%]	36.32
Sulphur combustible [%]	0.25	MgO [%]	3.10
Coke [%]	43.21	SO_3 [%]	14.89
C-fix [%]	30.48	P_2O_5 [%]	0.12
Volatiles [%]	40.16	TiO_2 [%]	0.27
Combustibles [%]	67.49	Na_2O [%]	0.14
Upper calorific value [kJ/kg]	18.228	K_2O [%]	0.38
Lower calorific value [kJ/kg]	13.749		
Ash parameters			
Start of sintering			876 °C
Temperature of softening			1148 °C
Temperature of semi-sphere			1222 °C
Temperature of diffusing (melting)			1246 °C

For the purpose of evaluation of this energy potential Ministry of Mining and Energy of Republic of Serbia initiated development of Pre-feasibility study which was planed to assess possibilities for construction of new mine with considerably larger production rate in comparison to existing mine, as well as construction of thermal power plant fuelled by the coal from the new mine. Pre-feasibility study was based on the Western field, since this field is the largest one. This paper provides proposal for the coal mine and suggestions for the improvements and rationalization, as well as energy effects of proposed power plant.

Proposal for new Štavalj coal mine

The main purpose of coal mine development is to supply the power plant, where optimal location of the power plant is the area of the Vapa field, at height of 1.000 to 1.050 m above sea level. Because of this the general accesses to the mine with a diagonal development of deposit is suggested, with one entry at Vapa field (1.020 m above sea level) and other entry north of the Štavalj village (1.080 m above sea level). Capital development roadways and mine accesses are shown on fig. 2.

Basic parameter for defining coal mine production rate is coal consumption at power plant. Power plant of 320 MW consumes 210 t per hour of Štavalj coal or 1.684.000 t of clean coal per year. Average thickness of coal seam at West field is 13 m, where 9.75 m is clean coal

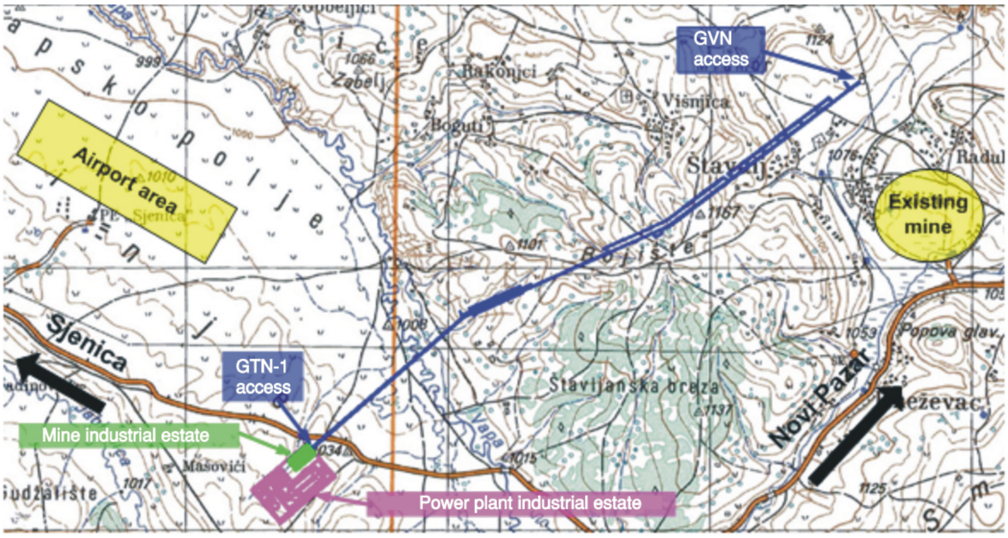
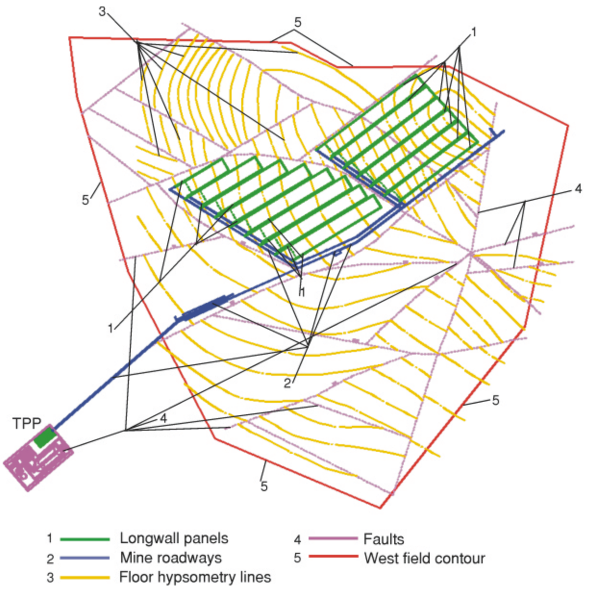


Figure 2. Mine development roadways and accesses

and 3.25 m are intrusions. Therefore, required production of run-of-mine coal is 2.3 Mt per year (2.24 Mt per year for thermal power plant (TPP) and 0.06 Mt per year for small local industry and domestic use).

For achieving this production two longwalls are foreseen. Longwall method of work, in comparison to alternative mining methods, is the most suitable since it can achieve higher productivity at lower production costs. Only alternative considered for new Štavalj mine was mechanized room and pillar method of work, which required at least four production faces for achieving target production. However, specific energy consumption at one room and pillar production face is at least 12% higher in comparison to specific energy consumption at longwall face (>7 kWh/t at room and pillar and 6.22 kWh/t at longwall face).



Figue 3. Blocks 1, 2, and 3 at west mining field of Štavalj deposit (color image see on our web site)

Basic geometry of longwalls panels are: average length of panels of 860 m; average mining length (without protective pillar) of 840 m and longwall length (face) of 130 m. These figures are selected according to detected faults and other mining and geological limitations of the Štavalj deposit. Proposed mine layout, with panels in first three blocks, is shown on fig. 3 [2].

Cutting height of the shearer was selected at value of 4 m, and web width at value of 1 m. Such longwall is capable to complete 3 advance cycles per shift, hence its production rate is 1900 t per shift or 5700 t per day [3]. Coal production is planned in 3 shifts per day and in 5 days per week. After estimating number of production days per year, it was concluded that one longwall can produce 1.088.700 t per year, while the operation of two longwall sets could provide annual production of 2.176.000 t. Remaining amount of coal should be provided from the roadway development.

In order to provide clean coal for the power plant, it is proposed to beneficiate the coal to certain extends. The proposed treatment is simple washing of the coal particles larger than 25 mm in run-of-mine jig device with capacity of 300 t per hour. The coal particles smaller than 25 mm would remain untreated and it will be blended with the washed coal. Such simple coal preparation process is possible since TPP boilers are based on circulating fluidized bed combustion (CFBC). This approach is more energy efficient since CFBC technology eliminates milling of coal (pulverised combustion technology requires milling of coal to particles 100 to 200 m in diameter), thus reducing self-consumption of mine-TPP complex.

Suggestions for improvement and more efficient operation of underground coal mine

Proposal made in Pre-feasibility study with two complete longwalls was selected in order to secure supply of the coal to the TPP. Planned stock yard at the TPP site is sufficient to ensure 21 day operation of the TPP (with daily consumption of 5000 t per day, required amount of coal at stock yard is 105.000 t).

It is clear that this solution is quite conservative. Beside this, estimated period for equipment move is too long. Existing experiences in similar conditions are showing that interval of 30 days for equipment move is sufficient.

Up-to-date longwall equipment operates at high reliability and availability rates, and it is capable to achieve high performances and production rates. Also, this equipment is designed for easy maintenance and repairs. Therefore, required amount of coal can be provided with single but bigger longwall.

This can be achieved by:
– increasing number of days on coal production from 5 to 6 per week,
– installing longwall face 160 m long, and
– increasing shearer speed in order to increase number of cycles.

Increasing number of coal production days from 5 to 6 per week and reducing the interval for equipment move would increase number of days in coal production per year from 191 to 231 days. Additional consequence of operation with single longwall is lower installed power at the face. This approach resulted in increased energy efficiency by 21%, or reduced specific energy requirements at the face (excluding transport) from 6.22 kWh/t down to 4.22 kWh/t.

These modifications are enabling sufficient and larger production rate with one longwall set, as presented in tab. 3.

This calculation is showing that requested performance of 2.3 m per year of run-of-mine coal is realistic to reach with one longwall set. It has to be mention that the production output from the development faces (over 140.000 t per year) is not considered in the calculation and indicates the potential of production increase.

Boilers based on circulating fluidized bed combustion can also utilize a wide range of poor fuels such as high-sulphur and high-ash coals, lignite, petroleum coke, oil shale, wood waste, bark, peat, industrial sludge, which is synonymous for extremely favourable operating costs [4]. Therefore, direct feed of run-of-mine coal to the boilers is further amendment of the process, which means that coal washing plant could be excluded from initial investment.

Table 3. Verification of production rate with one longwall (L = 160 m)

Seam thickness	4.00	m
Face length	160.00	m
Drum web	1.00	m
Run-of.mine tonnes/shear	832.00	t
Best production rate	2496.00	t per hour
Average production rate – efficiency	60.00	%
Average production rate	1.497.60	t per hour
Average production hours / week	108.00	hours
Maximum production / week	161740.80	t per week
Utilization factor	40.00	%
Average production hours / week, applied utilization	43.20	hours
Average production / week	64696.32	t per week
Number of production weeks / year	38.00	weeks
Annual production rate	2458460	t per year

Economical effects and energy savings of suggested improvements

Increase of longwall length from 130 to 160 m is reducing the requirement of development roadways (main gates and tail gates). According to proposal in Pre-feasibility study first three mining blocks have 14 panels of 130 m wide. Total length of main gates and tail gates in these panels is 24.030 m. By increasing longwall length to 160 m, number of panels is reducing to 12, with total length of main gates and tail gates of 20.450 m. Therefore, total length of main gates and tail gates can be reduced by 3.580 m.

Regarding equipment costs and mine development costs we can say that there is some significant decrease of costs in comparison to Pre-feasibility study. This is summarized in tab. 4.

Average production cost per tone is calculated at level of 16.99 €/t (or 1.30 /GJ), while the minimum annual cost during the life of the mine is 15.85 €/t and maximum 18.00 €/t.

Suggested operation with one longwall shall reduce depreciation and maintenance costs due to less equipment. Also, operation costs would be significantly reduced since operation with one longwall face is by 21% more efficient regarding energy consumption for coal excavation, in comparison to operation with two longwalls. Labour costs could be reduced due to smaller number of workers. Suggestions made in this paper can be summarized as:

– mining equipment cost: operation with one longwall set shall reduce initial investment by 10.540.000 €; less equipment shall reduce operating cost of the mine due to less maintenance and lower depreciation, as well as production cost of the coal,

Table 4. Possible savings

Issue	Pre-feasibility study	Suggestion	Impact
Longwall sets	2 sets including main gates belt conveyors	1 set including main gates belt conveyor	Reduced initial investment by 10.54 million €
Mine development (total roadway length)	37.035 m	33.455 m	Reduction by 3.580 m
Mine development (costs)	2.000 €/m (24.030 m)	2.000 €/m (20.450 m)	Reduction of 7.160.000 €
Coal washing plant	5.0 million €	–	Reduced initial investment by 5.0 million €

– roadway development: decrease of costs due to length of main gate and tail gate for 7.160.000 €,
– reduced number of workers both underground and at the surface shall reduce operating costs of the mine; annual labour cost shall be reduced by 445.000 €, and
– coal washing: reduction of initial investment by 5.000.000 €.

Finally, it is estimated that these savings can reduce production price of coal from 16.99 to 16.49 €/t (reduction by 0.3 €/t for roadway development and improved efficiency and 0.2 €/t for labour costs).

Proposal for new thermal power plant

The proposed power plant design is based on the proven process of power production by high pressure steam produced in steam generators fired by solid fuel. Proposed steam generators use modern and reliable technology of coal firing in a fluidized bed. The technology of CFBC has been proven by many practical results and supported by many successfully operating installations. This technology guarantee high efficiency of energy transformation to thermal energy of steam delivered into turbine [4]. At the same time, by adding limestone into the combustor, this technology ensure high level of flue gases desulphurisation and very low nitrogen oxides emission during combustion process (850 °C), coping most stringent emission standards, the condition which is most important requirement of the investor. Other equipment will also fulfil required technical and economical criteria in order to meet load and other given guarantees.

Proposed new coal fired power plant (fig. 4) gross capacity is 320 MW_e, with main parameters as follows [2]:
– two CFB boilers, with drum, natural circulation,
– turbine: condensing type, two casing with reheat and condenser circle/regeneration,
– steam generation: 465 t per hour at 543 ºC and 16.5 MPa,
– boiler(s) efficiency expected: 91.8% (for the represented coal),

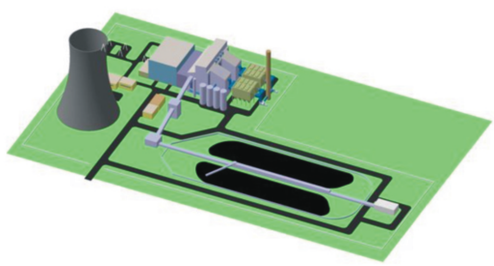


Figure 4. Lay-out of the Štavalj thermal power plant

- unit efficiency expected: 38% (for the represented coal),
- water consumption (cooling): 560 m^3 per hour,
- limestone consumption: 1 t per hour per boiler,
- combustion air: one boiler 450.000 Nm^3 per hour,
- flue gas production: one boiler 516.000 Nm^3 per hour,
- ash production: one boiler approx. 14 t per hour,
- load change: 40-100%, and
- emissions: SO_x < 200 mg/Nm^3, NO_x < 200 mg/Nm^3, CO < 200 mg/Nm^3, dust < 10 mg/Nm^3.

Having in mind carbon content in Štavalj coal, annual coal production and electricity generation, emission of CO_2 is estimated at value below 1000 g/kWh. Estimated emissions of SO_x and NO_x should be much lower than emissions from thermal power plants operated by Electric Power Industry of Serbia (EPS), as given in table 5 [7], mainly due to low content of combustible sulphur and Circulating Fluidized Bed Combustion technology.

Table 5. Emissions from EPS thermal power plants

[g/kWh]	CO_2	NO_x	SO_2	Solid particles
TPP Nikola Tesla A	1194	2.0	10.5	4.0
TPP Nikola Tesla B	1170	2.1	9.9	0.2
TPP Kolubara A	1510	3.3	18.0	13.3
TPP Morava	1072	1.9	13.8	3.6
TPP Kostolac A	1274	1.3	30.2	9.1
TPP Kostolac B	984	1.9	39.8	1.8
TPP Kosovo A	1546	2.4	6.7	14.0

Therefore, regarding emissions, TPP Štavalj can be compared with thermal power plants operated by EPS, and estimated CO_2 allowance, as an external cost, for TPP Štavalj should not be greater than for these power plants. Since 2005 CO_2 allowance ranged from <10 €/t to 30 €/t, while currently is 23 €/t (fig. 5).

It should be noted that experience from existing underground coal mine shows that Štavalj deposit is non-methane deposit, therefore all emissions should be assigned to thermal power plant.

Water will be cooled in the natural draught type cooling tower. The cooling tower will be reinforced concrete structure. Preliminary dimensions of the new power plant are 600 300 m.

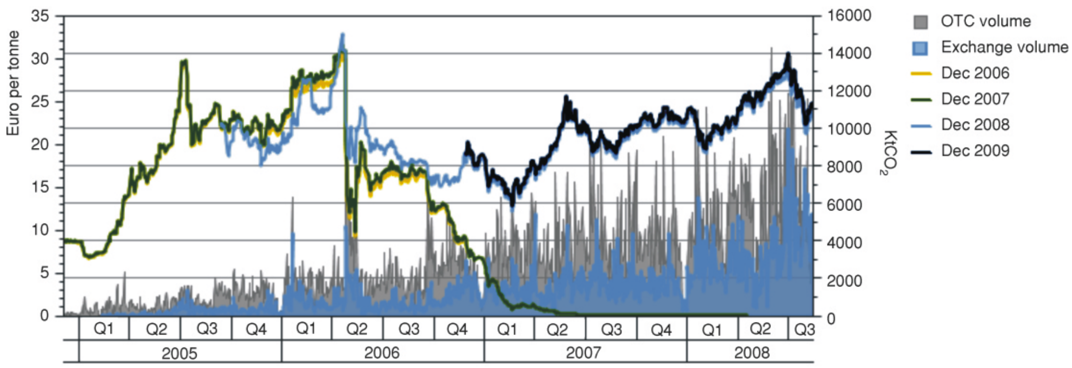


Figure 5. Historic trend of CO_2 allowance (color image see on our web site)

Impacts of TPP Štavalj on Serbian power system energy effects

Analyses performed during development of Pre-feasibility study showed that TPP Štavalj would have large positive impact on Serbian power system as well as great contribution regarding improvement of reliable energy supply [5]. These can be summarized as:
- construction of TPP Štavalj is desirable as soon as possible, since it can supply all its energy and power to the Serbian system,
- emission of CO_2 from TPP Štavalj is at the same level as from other power plants of the EPS, while the emissions of SO_2, NO_x, and solid particles would be much lower. Therefore, external cost for CO_2 emission would be at least at similar level as for existing power plants of EPS,
- realistically, engagement time will be at the maximum during the early years of operation; engagement time is not limited by the system, but due to planned and enforced stoppages,
- engagement time for the EPS and Serbian Transmission System and Market Operator will be between 6.400 hours in 2015 and 2.500 hours in 2030,
- supply of energy up to 2025 is practically guaranteed within the EPS system,
- remaining capacities beyond 2025, could be easy supplied to neighbouring countries and other markets,
- the technical minimum of the thermal power unit does not have an influence on the engagement time,
- energy effects by replacement with alternative thermal power unit are equal to the available power to be delivered,
- low fuel costs are locating this thermal power unit at base load while, on the other hand, a large range of load remains unused (low technical minimum),
- in reality, this facility would have an advantage in comparison to facilities with a higher technical minimum,
- comparison of fuel cost showed that only thermal power units of 600 MW and new ones with 350 MW (located on the open pits) would be cheaper than TPP Štavalj,
- availability factor, self-consumption factor, specific investment, specific heat consumption, and particularly, coal price have the dominant impacts on economic performance of TPP Štavalj [2], and
- suggested improvements for the mine would reduce initial investment (single longwall set) and operating costs (reduced roadway development, improved efficiency and labour costs)

Conclusions

As it can be seen from analysis presented, coal production can be organized with lower initial investments (in equipment) and lower labour costs and coal production costs, achieving even higher annual production rate. This means that rated power of TPP can be increased to 350-400 MW with all preferences mentioned in previous chapter. Therefore, project of new Štavalj coal mine with thermal power plant can be even more attractive to potential investors.

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Paper submitted: July 30, 2008
Paper revised: October 20, 2008
Paper accepted: December 26, 2008