Coal resources of the eastern regions of Russia for power plants of the Asian super ring

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Abstract. The eastern regions of Russia have a substantial potential for expansion of steaming coal production. The majority of coal deposits in the eastern regions are located close enough to the objects of the Asian super ring. The large coal reserves make it possible to consider it as a reliable fuel source for power plants for a long-term horizon. The coal reserves suitable for using at power plants of the Asian super ring are estimated in the paper by subject of the federation of the eastern regions for operating and new coal producers. The coal deposits of the eastern regions that are promising for the construction of power plants of the Asian super ring are presented. The paper describes both the coal deposits of the eastern regions that are considered in the projects for power plant construction and included in the program documents and the coal deposits that are not included in the program documents. The coal reserves of these deposits and the possible volumes of its production are estimated. The key qualitative coal characteristics of the deposits: heating value, and ash, sulfur, moisture content are presented. The mining-geological and hydrological conditions for deposit development are briefly characterized. The coals of the eastern regions are showed to contain valuable accompanying elements. It is noted that the creation of industrial clusters on the basis of the coal deposits is the most effective from the standpoints of the economy and ecology. The favorable and restraining factors in development of the described coal deposits are estimated.

1 Introduction

The eastern regions of Russia (East Siberia and the Far East) possess considerable coal reserves and resources. The majority of coal deposits in the eastern regions are located close enough to the objects of the project "The Asian super ring". According to the forecasts of U.S. Energy Information Administration [1] and International Energy Agency [2] the electricity demand in the Asian countries will rise and hence, the demand for energy resources will also increase. The coal reserves of the eastern regions are hard and brown coals and anthracite. The steaming coals form the main portion of the coal reserves (90%). The high-quality hard coals are attractive for export. The low-quality products of hard coal washing, the hard coals that do not comply with the quality requirements for export, and the brown coals are the fuel for power plants. The availability of substantial coal resources in the

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eastern regions and provision with the coal reserves (for about 700 years) allow its consideration as a reliable fuel source for both the existing and new power plants for a long-term horizon. The steaming coal deposits of the eastern regions of Russia are located in the regions that differ in the development of the transport and social infrastructures, in the mining-geological, hydrological and other characteristics. The possibilities for the coal industry development in the eastern regions of Russia were studied by many authors [3, 4]. However, the possibilities for using these coals for power plants of the Asian super ring were not analyzed in these works. The studies of the coal industry development in the country and its regions at Melentiev Energy Systems Institute have been carried out for more than 40 years, which resulted in designing the system of models and the information system [5, 6]. The study of coal resources in the eastern regions of Russia for construction of power plants of the Asian super ring is seen as topical and possible.

2 Coal resources

The inferred coal resources of the eastern regions amount to 3184.9 billion t or 82% of the inferred coal resources in Russia (3927.7 billion t) [7]. The balance reserves of the eastern regions of categories $A+B+C_1$ (the reserves that are promising for development at the current stage of technological advance) make up 88 billion t (Table 1). In the future the large volumes of the coal reserves of category C_2 (39.4 billion t) and the off-balance reserves (28.4 billion t) can be developed on a commercial scale. The exploration level of the reserves (the ratio of the balance reserves to the inferred resources) is low and makes up only 2.8%. Hence, there are prospects for increasing the balance coal reserves. This can be achieved by performing the corresponding exploration works to include the inferred coal resources in the balance ones.

Table 1. Structure of balance coal resource of the eastern regions, billion t

Region / Type of coal	Balance reserves by category			
	$A+B+C_1$	C_2	Total $A+B+C_1+C_2$	Off-balance
Eastern regions, total	88.0	39.4	127.4	28.4
Brown	60.7	25.5	86.2	11.9
Hard	26.9	13.9	40.7	16.5
Including coking	9.0	4.5	13.5	1.4
Anthracite	0.03	0.03	0.05	0.02
Including for open-pit mining	71.3	28.0	99.3	15.2
Brown	57.7	22.6	80.3	10.3
Hard	13.6	5.4	19.0	4.9
Including coking	2.2	0.4	2.6	0.1

The balance coal reserves of the eastern regions contain primarily the reserves of steaming coals. The low-quality products of coking and steaming coal washing are energy resources. The major part of the coal reserves in the eastern regions (81% of the volumes of reserves) is suitable for open-pit mining. As to the brown coal reserves 95% of the reserves are appropriate for open-pit mining. The low-quality brown coals cannot be transported over long distances. They are used primarily for electricity production on the quarry site. The hard coals of the majority of the deposits in the eastern regions can also be used as a fuel for power plants.

3 Coal reserves of the eastern regions by subject of the federation

East Siberia and the Far East possess sufficient proved coal reserves for energy development, provision of domestic consumers, electricity export and construction of power plants, which potentially can be included in the Asian super ring. The steaming coal deposits of the Krasnoyarsk, Trans-Baikal and Primorye Territories, Irkutsk, Amur and Sakhalin Regions and the Republic of Buryatia are situated close enough to the objects of the Asian super ring (Fig.1).

Fig. 1. Coal deposits for construction of power plants. [1]

The Krasnoyarsk Territory possesses substantial steaming coal reserves of categories $A+B+C_1$ – 45.5 billion t, category C_2 – 20.7 billion t. The Abanskoye coal deposit only is situated within the Asian super ring area, the size of its reserves exceeds the total size of the reserves of all remaining considered deposits.

In the Irkutsk Region the proved coal reserves of categories $A+B+C_1$ amount to 8.1 billion t, and those of category C_2 – 6.6 billion t. The structure of the reserves is characterized by the dominance of hard coals (73%), 7.7 billion t (96% of the proved reserves) are appropriate for open-pit mining. The total reserves of the prospective deposits make up 6.6 billion t. Coal production on these deposits can reach 43.5 million t, in particular, 18 million t on the existing open pits and 25.5 million t on the new open pits of the Mugunskoye and Golovinskoye deposits.

In the Republic of Buryatia, the proved coal reserves of categories $A+B+C_1$ amount to 2.2 billion t, and those of category C_2 – 0.3 billion t. In the structure of the reserves the share of brown coals equals 63%, 0.9 billion t (50% of the proved reserves) are suitable for open-pit mining. The total coal reserves of the prospective deposits make up 0.3 billion t. Owing to new construction the coal production on these deposits can reach 19 million tons.

In the Trans-Baikal Territory, the proved coal reserves of categories $A+B+C_1$ are 3.1 billion t, and those of category C_2 – 0.2 billion t. In the structure of the reserves the share of brown coals makes up 62%, 2.8 billion t (93% of the proved reserves) are appropriate for open-pit mining. The total coal reserves of the prospective deposits amount to 1.2 billion t. Coal production on the prospective deposits can reach up to 40 million t, including 20 million t on the existing Kharanorsky open pit.

[1] The map was compiled by an engineer of Melentiev Energy Systems Institute Muzuchuk R.I.

In the Khabarovsk Territory the proved coal reserves of categories A+B+C_1 amount to 1.6 billion t, and those of category C_2 – 0.7 billion t. The structure of the reserves is characterized by the dominance of hard coals (80%), 0.5 billion t (31% of the proved reserves) are suitable for open-pit mining. The Urgalskoye hard coal deposit only is situated within the Asian super ring area. Coal production can be increased on the existing mines and open pits.

In the Primorye Territory the proved coal reserves of categories A+B+C_1 amount to 2.3 billion t, and those of category C_2 – 1.4 billion t. The structure of the reserves is characterized by the dominance of brown coals – 2.1 billion t, 1.4 billion t (63% of the proved reserves) are suitable for open-pit mining. The total reserves of the prospective deposits reach 1.2 billion t. Coal production on the prospective deposits can amount to 9 million tons, including 7 million t on the operating Bikinskoye open pit.

In the Amur Region the proved coal reserves of categories A+B+C_1 amount to 3.6 billion t and those of category C_2 – 0.2 billion t. Brown coals form the bulk of the reserves – 3.5 billion t, which are appropriate for open-pit mining. The total coal reserves of the prospective deposits make up 3.5 billion t. Coal production on these deposits can reach 42 million t basically owing to new construction.

In the Sakhalin Region the proved coal reserves of categories A+B+C_1 amount to 1.8 billion t, and those of category C_2 – 0.6 billion t. The reserves of brown and hard coals are 0.95 and 0.85 billion t, respectively. Only 0.17 billion t are appropriate for open-pit mining. There are plans to increase coal production to 5 million t on the operating Solntsevskoye open pit and to 10 million t per year in the future. The key advantage of the coal deposits of the Sakhalin Region is their maximum proximity to the Asian super ring objects.

4 Prospective coal deposits for coal industry development

Currently the construction of large coal-fired power plants in East Siberia and the Far East, in particular, near the Asian super ring is studied in different state [8], federal and regional strategies and programs. Table 2 presents the list of the coal deposits, on which the construction of power plants with a capacity below 900 MW is considered in the program documents. It is intended to construct coal-fired power plants based on the run-of-mine coals and on the low-quality derivatives of coking and steaming coals.

The analysis of the coal resource potential in the East of Russia makes it possible to consider other coal deposits for construction of large power plants in addition to those enumerated in the Table 2 (Fig.1). They are: Abanskoye deposit in the Krasnoyarsk Territory; Golovinskoye, Voznesenskoye, Karantsaiskoye and Zheronskoye deposits in the Irkutsk Region; Svobodnoye, Sergeevskoye and Tygdinskoye deposits in the Amur Region. The available substantial balance coal reserves in the eastern regions contribute to the development of coal production owing to new construction and expansion of existing capacities. The coal deposits prospective for the coal industry development are presented in Table 3 [9-13].

On the majority of the presented deposits coal can be produced by the most advanced open-pit mining. The mining-geological and hydrological conditions for deposit development are of low and medium complexity. The thickness of coal beds that are prospective for development is 1.5 m and more, for individual deposits (Abanskoye in the Krasnoyarsk Territory) it can reach 25 m. The stripping ratios range from 2 m^3/t to 6 m^3/t. The coal deposits of the Irkutsk and Sakhalin Regions, the Primorye and Khabarovsk Territories, the southern areas of the Trans-Baikal Territory and the Amur Region are situated in the areas with the developed infrastructure. The deposits with the undeveloped infrastructure are characteristic of the northern areas of the federation subjects. The main

difficulty in development of some deposits consists in climatic conditions and water content of the deposits, where the coefficient of the total moisture exceeds 30-40%.

Table 2. Coal deposits for construction of power plants

Deposit	Power plant capacity, MW
Erkovetskoye	4800
Kharanorskoye	2400
Urgalskoye	2400
Ishideyskoye	2000
Zashulanskoye, Krasnochikoyskoye	1500
Mugunskoye	900
Pogranichnoye, Priozernoye, Kutinskoye	900
Deposits of Trans-Baikal, Khabarovsk, Primorye Territories, Republic of Sakha (Yakutia), Amur and Sakhalin Regions	2900*

Source: [8]

Table 3. Description of coal deposits in the eastern regions

Deposit	Reserves, million t	Potential production, million t	Qualitative characteristics			
			Q^r, MJ / kg	A^d, %	S^d, %	W^r, %
Abanskoye	16766.8	35	14-16	8-15	0.3-0.8	31-38
Ishideyskoye	831.7	12	21-31	17-20	0.5-1.8	14-15
Mugunskoye	1639.3	13	17-20.1	16-21	0.5-1.6	18-20.6
Golovinskoye	186.0	5	19.7-23	13-23.1	1.9-2.8	14
Voznesenskoye	518.6	8	23-33	15-29	0.9-1.5	7.8-16
Kharantsaiskoye	3080.5	4	22	15	3.4	8.8-11.8
Zheronskoye	275.8	3	18-20	15.5-18	0.4-0.5	19.9-24.2
Nikolskoye	173.5	14.5	24	18	0.4-0.9	6
Zagustaiskoye	123.0	4.5	19	22	0.7	24
Kharanorskoye	742.4	15	12-13	5-25	0.3-0.7	33-44
Zashulanskoye, Krasnochikoyskoye	837.5	15-20	18-23	10-19	0.5-0.7	6-25/15
Pogranichnoye, Priozernoye, Kutinskoye	360	4.5	14.9-16.6	23-32	0.3-0.8	15-22
Chikandinskoye	12.5	1.2	22	17-23	0.1-0.4	1.5-7
Urgalskoye	1270.6	12	22.6-33.5	17-33	0.2-0.5	4.5-34
Pavlovskoye, Rakovskoye	463.9	2	11-12	16-33	0.3-0.5	41-44.5
Bikinskoye	908.9	7	8-24	18-35	0.4-1.0	34.44
Erkovetskoye	1040.2	18	12.3-13.4	15.4-18	0.3-0.6	35.7-38.2
Ogodzhinskoye	15.4	5	18.1-23.2	16.5-37	0.3-0.5	4.3-6.3
Svobodnoye, Sergeevskoye	1982.2	9	26.8-26.9	18.3-18.9	0.3-0.4	51-53.4
Tygdinskoye	466.3	10	7.3	20	0.3	57.2
Solntsevskoye	93.4	10	16-19.1	11.3-24.2	0.2-0.3	23

Note: Q^r – lower heating value; A^d- ash; S^d – sulfur; W^r– total moisture

Sources: [9-13]

The coals of the eastern regions comprise some valuable accompanying components [14-16]. The coals of the Ogodzhinskoye, Svobodnoye and Sergeevskoye deposits in the Amur Region include gold, sometimes in commercial concentrations [17]. The coals of the Erkovetskoye deposit contain platinum, the Bikinskoye deposit – germanium and

accompanying elements, the Ishideyskoye deposit – silicon. The coals of the other deposits in the eastern regions also contain valuable accompanying components. These components can be extracted directly from coal, from wastes of coal mining, from ash and gases after coal combustion at energy facilities. The content of metals of some deposits exceeds the concentrations rational for their extraction many-fold, sometimes by dozens and even hundreds of times [18]. The coals also contain radionuclides, such as uranium, radon, thorium, radioisotopes of lead and potassium.

5 Conclusion

Availability of substantial coal reserves in the regions adjacent to the energy super ring being created can form a reliable base for fuel supply to the operating and new power plants.

The total balance coal reserves of the deposits prospective for the construction of power plants of the Asian super ring amount to 31.8 billion t. The potential production volumes of these deposits are estimated at above 180 million t, in particular, 60-65 million t owing to the increase in capacity and the reconstruction of the existing coal producers.

The favorable factors for the development of the prospective deposits are the following:

- availability of considerable coal reserves;
- relatively low or medium complexity of mining-geological and hydrological conditions for deposit development;
- location of the majority of the deposits in the areas with the developed infrastructure;
- possibility for the production of considerable coal volumes by the operating coal producers in the areas with the developed infrastructure.

The development of the majority of the prospective deposits can be restrained by the following factors:

- limitations of the existing transport infrastructure or its absence;
- difficulties in the development of individual deposits, particularly, in the Far East, due to the water content of the brown coal deposits;
- environmental restrictions on the development of coal production and coal-based generation.

Creation of industrial clusters on the basis of coal deposits that will unite the enterprises for production and conversion of coal and its man-made wastes, power plants on coal and gas from the coal beds, enterprises of coal chemistry and others is the most promising project from the standpoint of the economy and ecology [19]. The end products in similar projects are electricity and products with a high added value that are produced at coal conversion, degasification of coal beds, mine waters, coal dusts and emissions into the atmosphere after coal combustion at power plants. Extraction of valuable accompanying elements from coal is an important step of the transition to the clean combustion technologies.

The environmental aspects of the large-scale coal production expansion for construction of power plants of the Asian super ring need to be worked out thoroughly.

The choice of the sequence and priorities in development of the deposits requires the studies to be carried out on the efficiency assessment of deposit development and construction of power plants on the considered deposits.

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