

A Study of Factors Influencing the Development Prospects of the Coal Industry in the Eastern Regions of Russia

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Abstract — The study provides an overview of the coal-producing regions in Russia. A set of factors influencing the development of coal mining in the regions is determined. An analysis of the interdependence of factors is carried out. The extent to which various factors affect the development of the coal industry in the eastern regions of Russia is assessed. Most of the factors are capable of influencing the development of the coal industry only in the long run due to the inertia inherent in the industry development. The findings indicate that the development prospects for the coal industry in the regions are largely determined by the development of coal energy facilities and the demand for coal in the international market. Russia's regions differ significantly in terms of their coal industry development, coal resources, coal category with respect to its carbon content rank, mining and geological conditions, the geographical location, and other characteristics. There are also significant differences between the sets of main factors that influence the opportunities for coal production development in a region. The study shows that forecasting the development of the coal industry in the regions calls for a case-by-case approach, including the development of an individual model for each coal-producing region.

Index Terms — coal industry, region, factor, coal, characteristics, consumption, production, exports, energy industry

I. INTRODUCTION

Unlike oil and gas, coal is a widely available resource. Coal reserves in the world and individual countries are significantly larger than other fossil energy reserves. The availability of coal reserves ensures energy security in many countries. Coal is mainly used to produce electricity and coke for the steel industry. The former use is constantly increasing, while the latter is constantly decreasing. Coal serves as the backbone of the world's electricity supply.

Coal resources are available in many countries. Coal mining plays an important role in both national economies and the economies of coal-producing regions. The effect of various factors on the volume and dynamics of coal mining was studied by many scholars [1-9]. Many factors influencing the development of coal mining have been revealed. The above studies outlined, on the one hand, the factors that lend themselves to being evaluated and can be taken into account quantitatively in the studies of the dynamics that make use of economic and mathematical models [10-24] and, on the other hand, the factors that are difficult or impossible to take account of.

For different countries and different regions of coal mining, the sets of main factors affecting the development of coal production differ greatly. This is due to significant differences between these regions in some of the aspects of their industrial development. This is, first of all, the role of the coal industry in the region's economy, coal mining and transportation conditions, coal quality indicators, to name just a few.

The countries (as well as regions of the countries) possessing coal resources can be provisionally divided into three classes based on their use: for domestic consumption, mainly for export, and both for domestic consumption and export. For Russia, and especially for the eastern regions of Russia, coal has become an important resource for the development of export in recent years. Whereas in 2000 the share of coal supply to the international market in the overall supply of the Russian coal was 11.4%, in 2018 it amounted to a mere 55% [25].

Various organizations studied the prospects for coal

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industry development at the national level and the regional level, i.e. for the federal districts (FD) and federal subjects (FS), as well as individual companies and their groups [1-22, 26-34].

Models, software, and information support developed with the participation of the authors were used in the studies carried out at the Melentiev Energy Systems Institute, SB RAS [23,24,35, 36]. An analysis of the long-term experience of research conducted by the scholars both in Russia and abroad, including that with participation of the authors [30-34], and an analysis of the statistical data and other resources, revealed the trends of the coal industry development in the coal-producing regions of Russia as shaped under the conditions of previous years and expected to unfold further in the future. This made it possible to identify the factors influencing the development trends of the coal industry in Russia and its regions. The objective of this study was to systematize and identify the

most significant factors affecting the development of coal mining for various regions.

II. OVERVIEW OF THE RUSSIAN COAL INDUSTRY

The coal industry, being one of the largest energy systems, has certain properties [37]: those of its entities (structural units of the industry and coal products) and those that are information-based. Entities are defined as companies or groups of companies. Of the entity properties, the most important are structural complexity, large scale, heterogeneity, and scarcity. Properties of coal products are heterogeneity, poor interchangeability, and high demand. Information-based properties include incompleteness of information on entities and uncertainty of future conditions of economic and energy development in the regions, and international coal markets, including coal demand and coal prices [38]. Factors influencing the development of the coal industry are directly related to

Table 1. Profile of coal mining federal subjects (as of 2017)

Index	Production mln. t	Processing, as % of production	Export mln. t	Share of locally produced coal in total consumption, %	Structure of supplies, %		
					exports	regions of Russia	
						total	Coal – producing region*
Export coals							
Siberia and the Far East							
Novosibirsk region	10.8	51	9.8	2	96	4	4
Kemerovo region	241.3	57	135.8	95	64	36	24
Republic of Khakassia	20.6	57	7.3	26	39	61	4
Zabaykalsky Territory	22.1	54	9.0	96	57	43	40
Republic of Sakha (Yakutia)	17.5	62	7.4	97	57	43	21
Khabarovsk Territory	6.6	90	2.6	30	59	41	20
Sakhalin region	7.6	1	7.5	100	64	36	18
Regions of European Russia							
Rostov region	5.8	71	2.3	99	34	66	66
Murmansk region	0.12		0.04	0	100	0	0
Nationally significant coals							
Regions of European Russia							
Komi Republic	8.8	88	0.03	92	6	93	19
Siberia							
Krasnoyarsk Territory	39.3		2.2	89	5	95	58
Locally significant coals							
Regions of European Russia							
Tula region	0.2			0	0	100	100
Orenburg region	0.2						
Chelyabinsk region	0.7			7	0	100	100
Siberia and the Far East							
Republic of Tuva	0.7		0.08	1	0	100	100
Irkutsk region	11.5	26	1.0	71	9	91	90
Republic of Buryatia	2.4			24	0	100	100
Primorsky Territory	8.5	0.2	1.2	81	2	98	98
Amur region	3.4			90	0	100	100
Magadan region	0.3			65	0	100	100
Chukotka Autonomous Okrug	0.2			70	0	100	100
Kamchatka Territory	0.03			10	0	0	0

Note: * a share of the supplies to the regions of Russia

Sources: Statistical data by Federal State Unitary Enterprise “Central Dispatching Department of the Energy Sector”, calculations performed by the authors

the above properties. Factoring them in is important when researching the development prospects of the coal industry and performing a computational experiment based on economic and mathematical models.

The large scale and structural complexity of the Russian coal industry are evident not only in the presence of numerous companies but also in their being scattered across a vast territory of the country in different climatic zones and time zones. The Russian coal industry is made up of more than two hundred coal mining (180) and coal processing (65) companies located in 21 Federal entities. It supplies consumers in the regions of Russia and supplies coal for exports. Coal reserves are available in 34 federal subjects. The heterogeneity is due to the uniqueness of coal deposits in terms of coal quality characteristics, coal mining conditions, and other indicators. Scarcity manifests itself in available reserves, demand, interchangeability of products, labor, and financial resources, etc. To this end, it would be more correct to consider specific deposits rather than coal-producing regions. Statistical data used for analysis and projections, as well as other resources, are usually linked to regional structures. This study does not deal with the coal of individual deposits, but rather with the coal of federal subjects, which is in line with the official statistical data.

The coal industry is one of the most important sectors of the Russian economy. Russia has great potential for the development of coal mining. The majority of coal mining entities of the Russian Federation are located in the Siberian Federal District and the Far East. Together, they produce more than 95% of all coal produced in Russia. In this study, the coals are distinguished by their significance

in terms of markets, i.e. local, regional (significant for adjacent Federal entities), national, and international. The coal significance is determined by the quality rank of the coal deposit, which is being developed or is to be developed in the future, and is assessed based on the 2017 statistical data (Table 1). The coal is considered to be of export and nationwide significance if its larger share (above 30%) is supplied to these markets; whereas locally significant coals are those which are consumed mainly within the region of their production with insignificant volumes consumed in the adjacent regions. Some federal subjects may produce coal of various significance when several deposits are developed there. In the event that the regions producing locally significant coals implement coal mining development projects and create an appropriate transport infrastructure, they may also start to export about 90% of the production volumes, as is the case, for example, the Republic of Tyva and Kamchatka Territory.

Coal-producing regions of Russia differ significantly in terms of their structure of supplies, availability of coal preparation plants, and coal mining development projects. Only three regions (Kemerovo region, Republic of Sakha (Yakutia) and the Republic of Komi) supply coal for the by-product coke industry, and only 14 regions produce coal for export. According to the coal industry development program (long-term program for the development of the Russian coal industry to 2030; approved by Resolution of the Government of the Russian Federation No. 14-r dated January 24, 2012), only four regions have the projects for constructing coal-fired power plants: the Republic of Sakha (Yakutia), the Sakhalin, Irkutsk and Amur Regions; whereas in the case of the coal chemical industry, respective

Table 2. Factors influencing the development of the coal industry

Internal factors		External factors	
Factors that are common for all regions			
1. resource base		3. natural factors: water availability in rivers (in the case of HPPs), winter temperatures	
2. the geographical location (remoteness from coal markets or coal suppliers)			
Coal-producing region			
4. coal quality characteristics and coal significance		8. projects for the reconstruction of existing companies and establishing new coal mining and processing companies, inclusive of availability of resources for project implementation: investments, labor resources, etc.	
5. mining, geological, and hydrological conditions of coal deposit development		9. projects for construction of coal-fired power facilities	
6. technical and economic indices of the company: production capacity of the company, etc.			
7. processing capacities available			
Factors common to coal-producing and coal-consuming regions but classified as belonging to different categories			
Coal-consuming region		Coal-producing region	
10. internal demand for coal and coal products		10. demand for coal and coal products	
- a fuel that power plants are designed to run on		- internal (in the case of a coal-producing region)	
- miscellaneous demand.		- in other regions of Russia	
11. economic indices of coal use as a fuel		- for export	
12. availability of transport and social infrastructure		- competition with other energy carriers	
		11. economic indices of coal production and processing	
		12. availability of transport and social infrastructure	
Production and consumption relations			
13. economic indices: coal prices at mine, coal transportation rates, domestic and global market coal prices			
14. existing coal supply pattern			
15. development of port and transport infrastructure, including that for coal export			
16. scientific and technological advances affect all components of the coal market			

Source: estimates by the authors

projects are in place in the republics of Khakassia and Sakha (Yakutia), Krasnoyarsk Territory, the Amur, and Magadan Regions.

III. FACTORS INFLUENCING THE DEVELOPMENT OF THE COAL INDUSTRY

We will distinguish between three key aggregated components of the coal market: A "Coal-producing region (a set of coal-mining and coal-processing companies that operate in a region or a Federal entity), a "Coal-consuming region", and "Production and consumption relations". "Production and consumption relations" implicitly include intermediaries between the seller and the buyer, as well as coal and energy companies that are both coal producers and coal consumers.

Factors influencing the development of the coal industry in Russia and its regions for each of the coal market components can be divided into internal and external. Internal factors are determined by the profile of the region: the status of energy sector companies (coal mining and coal processing companies; power plants and boiler houses that use coal as their fuel; other consumers); transport infrastructure condition; resource base, etc. External factors depend on the forecast scenarios of coal industry development in the region and scenarios of the overall economic development. The scenarios cover the measures aimed at changing the volume and structure of production, consumption, and supply of coals in terms of their uses. External factors also include poorly predictable factors, for example, natural, geopolitical factors, and others.

The identified factors were ranked and structured for coal-producing regions and coal-consuming regions (Table 2). The presented factors differ in their impact on the development of coal production.

IV. EFFECT OF FACTORS ON COAL MINING DEVELOPMENT

The effect of individual factors (coal transportation rates, coal demand, coal resources, etc.) has been studied when forecasting the development of the coal industry in the country and its regions [30-34]. Some factors were assessed based on expert estimates relying on the findings of the studies and the analysis of the historical dynamics of the indices showing the performance of the coal industry of the country and its regions: production, inter-regional and export supplies, consumption, etc.

The greatest impact on the development of coal mining is that of the demand for coal. Coal is consumed in most federal subjects of Russia. An analysis of the historical data of coal consumption indicates that domestic consumption (power plants and boiler houses, by-product coke plants, households, and other consumers) is decreasing, while export is growing. Domestic coal consumption also decreased in absolute terms from 207.5 million tons in 2000 to 169 million tons in 2018, while coal export supplies increased from 35.4 million tons to 205 million tons over

the same period. At the same time, the proportions in the structure of coal consumption remained relatively stable: energy industry facilities (thermal power plants and boiler houses) account for 50%, by-product coke plants - 20%, and other consumers - 30%.

The main components of the demand are the demand for coal in the production region itself, the demand in other regions of Russia, and the export demand. An analysis of the dynamics of coal consumption in the regions in terms of its use in retrospect as well as the studies show the relative stability of coal supplies to by-product coke plants, households, and other consumers. The most significant impact on coal production levels is that of the demand for coal to be exported, for coal to be used by power plants and the future demand for coal in the coal chemical industry. Forecasting the demand for coal is rather challenging, and requires both dedicated models and expert estimations [27]. In the short run, coal consumption by power plants varies depending on natural factors, and, in the long run, it is affected by the implementation of projects for construction of coal-fired power plants, and the planned replacement of an energy carrier. The need for coal at existing energy facilities will decrease due to the modernization and replacement of obsolete equipment and, accordingly, an increase in the efficiency of these facilities.

The export demand for coal is also affected by the competitiveness of coal, the remoteness of markets, and the throughput capacity of transportation facilities. Growing export demand for coal stimulates the development of production and processing of the coal that is in demand in the global coal market. The lack of demand for low-grade coal processing products for the energy industry may restrain the growth of coal production and processing, and, consequently, limit the resources for exports. This is especially relevant for companies that produce large amounts of export coal.

As the domestic demand for coal in a coal-producing region grows, the following measures are used to increase production:

- full utilization of production capacities;
- reduction in coal supplies to other regions of Russia.
- If there are no constraints on the resource base and if local production is economically justified compared to coal delivery from other regions, coal production may increase due to:
- reconstruction and expansion of production capacities;
- preparation and commissioning of new capacities.

The resource base and mining, geological and hydrological conditions for coal deposit development determine the feasibility of constructing new production facilities and expanding the existing ones, shutting down companies, and using the methods and technologies for the development of deposits.

Economic indices are of paramount importance,

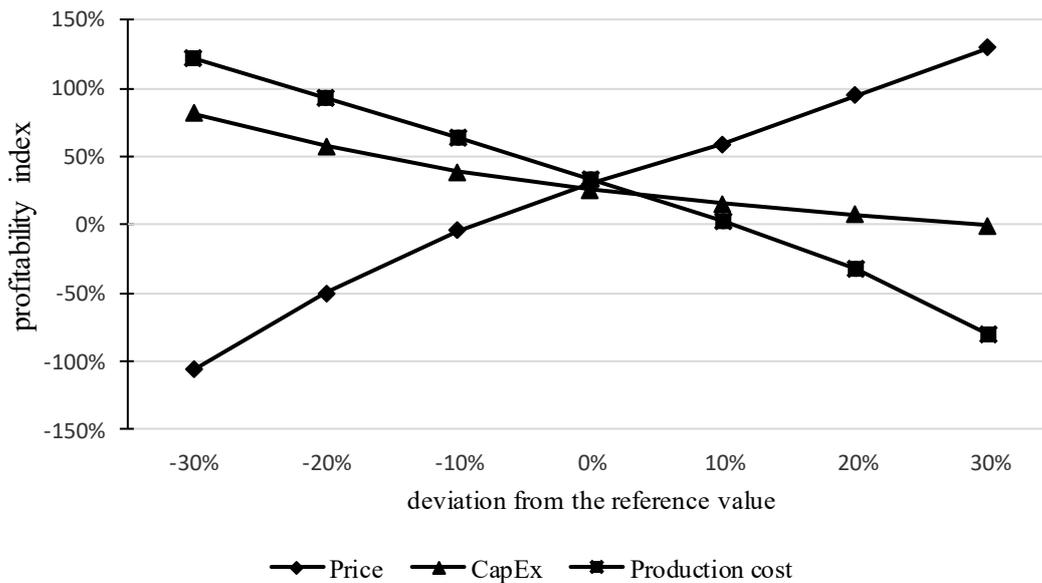


Figure 1. Profitability index versus deviations of input parameters from reference values

especially when making decisions on the implementation of new deposit development projects. At the stage of investment project valuation, there is an uncertainty of future conditions for economic and energy development in the regions along with incompleteness of information about the facilities. Sensitivity analysis enables one to determine the limits of changes in economic indices that still make the project implementation feasible. Figure 1 shows the change in the profitability index of a project depending on the deviations from the assumed reference values of coal prices, production costs, and required investments.

The availability of processing capacity in the regions producing the coal of export quality influences possible export volumes. With the increase in coal processing volume, it is possible to increase the volume of coal production and export given the demand for this coal and favorable prices in the global coal market. While the volume of coal processing in the country as a whole grew from 117.6 million tons in 2010 to 199.0 million tons in 2018, the volume of exports increased from 116.4 million tons in 2010 to 193.2 million tons in 2018. The growth of export supplies, given the growing processing volume, is

typical of the majority of the Federal subjects that supply coal for export.

The geographical location (remoteness from the target coal markets) of the mining region, the quality characteristics, and the significance of coal may restrain or encourage the development of coal mining. This includes (un)availability of transport infrastructure between coal mining companies and railway stations, coal shipping ports, land border crossings; constraints on the capacity of railways, seaports, and coal terminals. The transportation rate to a significant extent depends on the remoteness from the target markets, which affects the volume of coal supplies.

The availability of projects for reconstructing the existing facilities and building new coal mining and processing facilities determines the development of the coal industry in the region. Factors affecting the feasibility of the project depend on the conditions of project implementation (Figure 2) and its focus (Table 3).

Competition with other energy carriers may have a catastrophic impact not only on the decrease in demand for coal and, consequently, on the production volume but also on the social stability in coal-producing regions, especially in company towns, of which there are more than 30 in Russia, including 8 ones with the most problematic social and economic status. Moreover, the reduction in coal mining will have an impact on related industries, primarily on the transport system [39].

Natural factors, not easily lending themselves to forecasting (winter temperatures; water availability of rivers, given the availability of hydropower plants, and others), have the most significant impact in the short term. This impact is most noticeable for local coal supplies when hydropower plants are involved.

Production and consumption relations affect the

Table 3. Factors affecting the implementation of coal production projects as a function of the project objective

Project objective	Factors
Coal export	prices in the international market, competitiveness, processing volumes, coal transportation rates, the throughput capacity of transport facilities, availability of transport and social infrastructure
Coal-fired electric power generation	demand for electricity in domestic and international markets, electricity sales prices
Coal chemical industry	the demand for coal chemical industry products, availability of coal processing technologies acceptable in terms of economic and other indices of coal processing technologies

Source: estimates by the authors

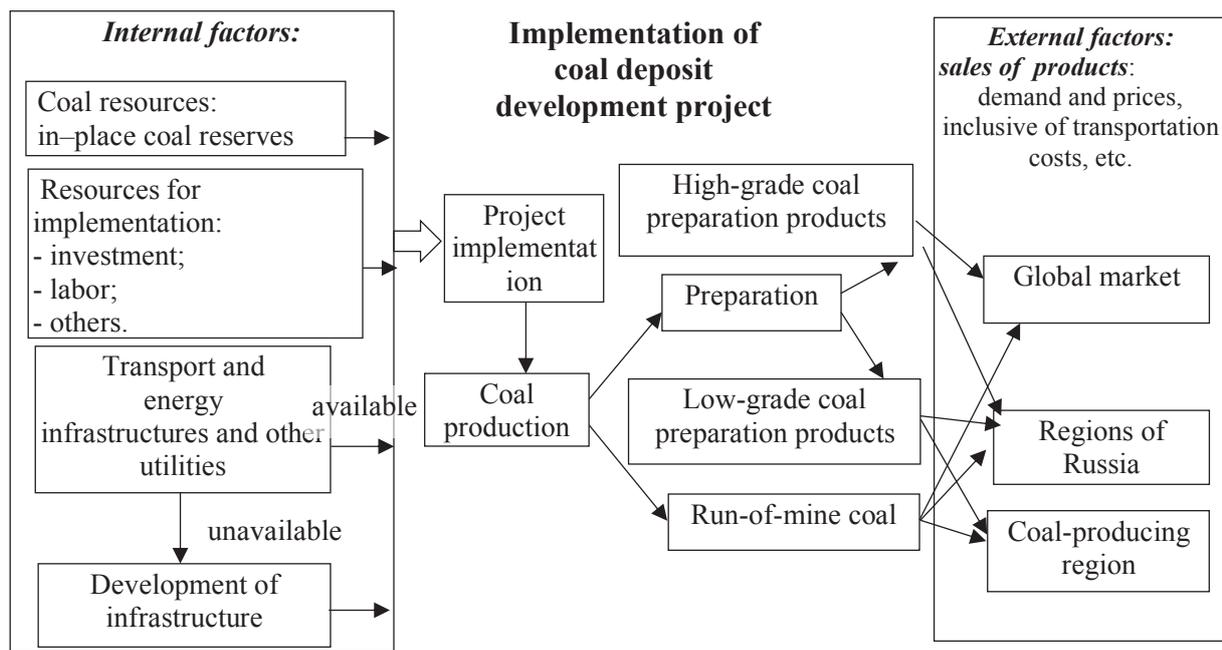


Figure 2 – Implementation conditions for the project of establishing a coal mining enterprise

pattern and volume of coal supply through prices at mine, and coal transportation rates. The impact of railway rates on the development of production and supply of steam coal was assessed for various energy development scenarios and consumption levels, respectively. The studies examined the change in transportation rate by a factor of 1.5 and 2. The findings of the study indicate that the increase in the railway rate encourages the development of local coal mining of not very high quality, whereas the decrease in the railway rate leads to the expansion of the market for quality coals and fosters the development of their mining [29]. Changes in the railway rate may alter the pattern and volume of coal supply, depending not only on the transportation rate but also on the qualitative characteristics of coal. If railroad rates are increased, nationwide coal supplies (e.g. Kuznetsk and Kansk-Achinsk coal) compete with each other:

- high-quality Kuznetsk coal acquires more local significance and the overall demand for it increases as the target market shrinks;
- the demand for Kansk-Achinsk coal decreases.
- Supplies of coal that serves as the fuel for power plants are not affected by changes in coal prices and transportation rates.

(Un)availability of transport infrastructure facilities, the capacity of ports and other facilities, including those intended for coal export, may limit coal supply, and, consequently, the production volumes that depend on demand.

Scientific and technological advances due to the inertia of the coal industry development may have a major impact on all components of the coal market only

in the long term. This manifests itself through long lead times for the adoption of new coal mining, processing, consumption, and transportation methods. In the short term, the development of coal mining is influenced only by the projects commenced in previous years. Modification of technologies for production, processing, transportation, and use of coal (key production processes) based on innovations that improve them are linked to medium- and long-term cycles of development of scientific and technological advances [40]. The energy sector industries, if judged by the number of patents held, without decomposing the sector into individual industries including the coal industry and coal-fired power industry, lag behind all other sectors of the economy, accounting for less than 5% of the total number of patents. The ranking is topped by the pharmaceutical industry and food chemistry industry (over 15%). Furthermore, the time it takes to adopt advanced scientific technologies exceeds six years for 50% of patents in the energy sector [41].

V. FUNCTIONAL DEPENDENCIES

Possible functional dependencies that take the form of equations and constraints are formulated in optimization and simulation economic and mathematical models [21, 22, 24, 27, 29] that were developed for the study of prospects for the development of the coal industry. The models take into account the impact of constraints on the resource base, the established supply chain, demand for the fuel that power plants are designed to run on, coal prices at mine and transportation rates, implementation of projects for construction of new facilities and reconstruction of existing ones.

Production volume in the coal-mining region is limited by the total production capacity of the existing and, in the long run, new companies, in-place coal reserves, and the demand for coal of individual deposits.

Some factors, such as mining and geological conditions and hydrological conditions of coal deposit development, etc. can be taken into account through economic indices. Energy carrier switching and projected amounts of electricity export can be allowed for through coal demand. Consideration of natural factors, such as water availability in rivers, winter temperatures, etc. is beyond the scope of the industry-specific problem but this can be done by the scenario approach to projecting fuel consumption at energy facilities and by other consumers. The effect of most factors on the development of the coal industry in the regions is difficult or even impossible to formalize, which contributes to the leading role of the expert in performing such studies.

VI. REGION-SPECIFIC FEATURES OF COAL-MINING FEDERAL SUBJECTS

Russia's regions differ significantly in terms of resources and quality characteristics of coal, the production structure (underground mining, surface mining, grades), mining and geological, hydrological and economic conditions of coal deposits development, potential opportunities for coal production development, the existing structure of coal consumption and supply, transport and social infrastructure, natural and other factors.

Most coal-producing regions of Russia have significant coal reserves for meeting their demand, for supplies to other regions, and for exports. Only a few regions have a limited resource base. These are the Republic of Buryatia, Primorsky Territory, and the Novosibirsk region. Constraints on transport infrastructure are characteristic of northern regions and regions with low population density, such as the Republic of Tuva, the north of Krasnoyarsk Territory, the Republic of Sakha (Yakutia), and the Amur region, Magadan region, and Chukotka Autonomous Okrug.

The sets of factors influencing the development of production in the regions depend on the significance of coal supplies dominating the region and the period of development prospects under consideration, i.e. short-term and long-term prospects. For any coal-mining region, regardless of the period under consideration, significant factors include the availability of a resource base and absence of constraints on its development; economic indices of coal deposit development, demand for coal, resources required for project implementation (investments, labor resources, etc.); transport and social infrastructure. In the short term, natural factors have a greater or lesser impact on the internal consumption of all types of coal.

For the regions where export and nationwide coal supplies prevail, apart from the above-mentioned factors, the most important ones are the availability of processing

capacity and demand for low-grade coal processing volume; coal transportation rates; development of transport infrastructure, including port infrastructure. In the long term, almost all internal and external factors, including production and consumption relations, affect production volume.

For the regions producing coal for local supplies and the supplies to the adjacent regions, the sets of factors remain virtually the same. The most important of them, in addition to the ones mentioned above, are energy carrier switching; commissioning of HPPs and other measures to reduce/increase coal consumption at coal-fired power plants.

In what follows we provide an overview of several coal-producing regions that have significant differences in various parameters.

The Kemerovo region is Russia's largest region in terms of coal production. Over the years, the region's coal production volume ranged from 50% to 60% of the country's total coal production volume. Coal from the Kemerovo region is in demand in both domestic and international coal markets. Export supplies from the Kemerovo region over the years ranged from 75% to 84% of the total export from Russia. The share of Kuznetsk Basin coal in domestic coal supplies amounted to about 40%, and the share of coking coal alone was from 80% to 89% of the total supply of coking coal in the country. There are about 100 coal mining companies operating in the region that produce coal by surface mining and underground mining, along with more than 20 coal preparation plants. Kuzbass mines are among the most challenging ones in the world in terms of the gas hazard, methane content in mine workings, and the coal dust explosion hazard, which results in high on-the-job injury rates and human casualties. Almost all the presented factors (Table 2) influence the development of coal mining in the region. For individual companies, there are constraints on the available resource base. Since the coal reserves of the Kemerovo region account for 45% of Russia's coal, this constraint can be considered negligible. Taking into account the challenging conditions for the development of coal deposits in the Kemerovo region, apart from the other factors, of the utmost importance is the scientific and technological advances. The prospects for the development of the coal industry in the Kemerovo region are related to the creation of coal clusters, the development of the coal chemical industry, and the introduction of innovative coal mining technologies as well as the growing demand for coal exports [21, 42].

In previous years, The Republic of Sakha (Yakutia) had 10 to 13 coal mining companies, including one mine and two coal preparation plants. The Republic produces coals of various significance. According to the criteria of transport accessibility and key target markets, coal mining companies of the Republic of Sakha (Yakutia) can be provisionally divided into two groups: northern and southern. Most of the coal is produced in the southern

coal-mining regions that have access to the Russian and international markets. The group of northern companies operates in the domestic market of the republic and their development is limited by infrastructure capabilities. These companies have only seasonal sales of their products: in summer, coal is supplied by inland transport, in winter this is done by motor vehicles via winter roads [32].

The Republic has coal reserves for export, nationwide, and local coal supplies, with few to no constraints on the resource base. The JSC Yakutugol provides the bulk of the total production volume (over 50%) and export supplies. Export supplies coming from the republic tended to grow and, in 2016, amounted to 7.9 million tons out of 13.8 million tons. In 2018, the export of Yakut coal decreased to 6.6 million tons. The change in the international coal market in 2017-2018 and the emergence of new exporters (Khabarovsk Territory) or the increase in export from regions with a more favorable geographical location, in terms of the importing countries (Sakhalin region, Zabaikalsky Territory), had an impact on the overall situation. Yakut coal supplies to the power plants account for 35-45% of domestic supplies.

Production volume in the republic depends on the demand for local coal supplies, coal for supplies to regions of Russia, including by-product coal plants, and export coal supplies, as well as the availability of processing facilities, demand for low-grade processed products, transport tariffs and transport infrastructure development.

In Krasnoyarsk Territory, 11 coal mines were involved in coal production in 2018. Three of them (71% of total production) are owned by OJSC "SUEK". Only about 60 percent of the production capacity is utilized due to the low demand for Kansk-Achinsk basin coal. There are no constraints on the resource base. The region provides about 75% of all domestic Russian supplies that are used for energy needs. Coal is supplied mainly by railway. The prospects for coal production development may depend on the increase in domestic demand by energy facilities, including those for electricity export, development of the coal chemical industry, and the demand for Kansk-Achinsk basin coal in regions of Russia. The environmental aspects of Kansk-Achinsk basin coal production and consumption are a limiting factor.

In the Irkutsk region, three coal mining companies and one coal preparation plant operated in 2018. OJSC "SUEK" provides the great bulk of production (99%). Coal is produced by surface mining techniques. There are no significant constraints on the resource base in the region. Irkutsk region coal is mostly consumed locally. Coal supplies from the Irkutsk region to neighboring regions and for export do not significantly affect the demand for coal. Coal is supplied by rail. More than 98% of coal is consumed by power plants and boiler houses. Production volume depends mainly on coal consumption by local energy facilities, fuel switching prospects, hydropower plants capacity, and, in the short term, climatic factors.

Thus, coal production in the Irkutsk region in 2013 was 13.3 m tons, while totaling 13.3 m tons in 2014. These data indicate that coal production decreased by more than 20%, mainly due to a warm winter. Low quality of coal (high sulfur content, etc.) can be a limiting factor in the development of individual deposits. The main opportunities for the development of coal mining in the Irkutsk region are likely to be related to the construction of power plants for electricity exports.

The Republic of Tuva has coal reserves for export and local supplies with no constraints on the resource base. All coal mined at the two surface coal mines, with an annual production capacity of 750 thousand tons, had been consumed within the republic until 2016. Since 2017, coal produced in Tuva has been exported in small amounts (80-160 thousand tons). The main constraint on coal production is the lack of transport infrastructure, whereas the demand for export serves as the main driver.

In 2018, five coal mines and one coal preparation plant operated in Zabaikalsky Territory. The great bulk of the production volume (84%) is provided by OJSC "SUEK". The region has coal reserves for export and local supplies with no constraints on the resource base. More than 50% of the production volume is processed at the coal preparation plant, with most of the produced coal concentrate being exported. Run-of-mine coal is also exported. Export quality coal is produced at two deposits: Tugnuyskoye deposit and Apsatskoye deposit. The coal of export quality is mainly the coal from the Tugnuyskoe deposit. Challenges facing the development of the Apsatskoye deposit are related to the geological features of the rock structure and the hard-to-reach location of the deposit. In 2018, production at the deposit totaled only 7% of the planned production capacity. The key opportunities for the development of coal mining in the Zabaikalsky Territory may be related to the construction of power plants, mainly for electricity export and further development of coal export.

In the Amur region, two surface coal mines produce 99% of the production volume. For internal consumption, coal produced in the region (90% of the consumption) and imported coal are used. The region's significant coal reserves are more suitable for the coal chemical industry and the construction of energy facilities at the edge of surface coal mines. This is due to the mining, geological, and hydrological conditions of deposit development and quality characteristics of coal.

In the Chukotka Autonomous Okrug, until 2014, two companies had mined coal to satisfy the demand within the Okrug, while in 2015-2016, there was only one company active, the Ugolnaya mine. Coal mined in the Chukotka Autonomous Okrug was used for local consumption. The pattern of fuel delivery to the districts of the Okrug is quite complicated, which leads to a significant variation in price indices. In 2017, one more company, Beringpromugol LLC, started operating there to produce coal for export. The owner of this company is the Australian company

Tigers Realm Coal Limited. Chukotka coal export began in 2018. The main target markets are the countries of the Asia-Pacific Region.

In the Sakhalin region, there is one major surface mine, the Solntsevsky (Sakhalinugol 2) surface coal mine, along with small companies. Over the years, the number of such companies varied (from 12 to 18) with the production capacity ranging from 50 thousand tons per year to 1 million tons per year. Coal production at the Solntsevsky surface mine in 2018 amounted to 7.5 million tons, while other companies produced from 10 thousand tons to 1.3 million tons. Coal reserves available to small companies are low. The Sakhalin region stands out from other coal-producing regions by dynamic changes in the list of small companies and their frequent rebranding. The existing coal mining companies fully meet the internal demand for fuel of the Sakhalin region, with the excess coal exported to Japan, South Korea, and China. In 2018, 9.9 million tons of coal out of 10.8 million tons mined in the region were exported. The geographical location of the Sakhalin region, its proximity to major coal importers (Japan, South Korea, and China) are instrumental in developing coal exports. As for the domestic coal market, the presence of a large number of suppliers, coal grades, and modes of transportation (rail, sea, road, water-rail, road-rail) creates great difficulties in addressing the issues of fuel volume to be supplied.

The coal deposits in the Sakhalin region are of high quality and diverse properties, which means that they can be used in a variety of ways - for export, as both an energy-producing fuel and as feedstock for the coal chemical industry. The most important factors for the development of coal production in the Sakhalin region are the development of transport infrastructure, scientific and technological advances, economic indices, and mining and geological conditions for coal deposit development.

VII. CONCLUSION

The studies carried out for the coal mining eastern Federal Subjects show that the regional features are smoothed over when considering Russia as a whole or its federal districts. Thus, in Russia as a whole, it can be assumed that all coal is supplied by rail and the cost of inter-regional supplies can be calculated using railway rates for coal transportation. When projecting the development of the coal industry in some regions, this assumption does not hold, since coal is supplied there by various modes of transport. Coal-producing regions are located in various climatic zones. The development of promising coal deposits in the northern regions is complicated by the presence of permafrost, lack of transport and social infrastructure, and depends on the availability of resources for the development of deposits (investments, labor resources, etc.).

The main factors determining the development of coal mining are the demand for coal and the possibility

and economic feasibility of implementing coal mining development projects. These, in turn, depend on a combination of other factors that differ from region to region.

Structural complexity, the large scale, heterogeneity, and inertia of the coal industry development, availability of different areas of coal use determine the lack of unambiguous dependence of the opportunities of coal industry development in the regions of Russia on individual factors. Quantitative assessment is not possible for all of the factors due to the lack of explicit functional dependencies, the incompleteness of available information, and uncertainty of conditions for the development of the regions of Russia and the global coal market. Most of the factors may affect the development of the Russian coal industry as a whole, and coal-producing regions as well only in the long run, due to the inertia inherent in the industry development.

Each of Russia's coal-producing regions is unique in its way, and the conditions that determine the opportunities for the development of coal mining in the region are also unique. Forecasting the development of the coal industry in the regions calls for a case-by-case approach, and, when it involves modeling, the development of models for each coal-producing region is required.

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