Coal industry of the Republic of Sakha (Yakutia): tools and forecast

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Abstract. An approach to the development of tools for the formation of promising indicators characterizing the development of the coal industry of the Sakha Republic (Yakutia) is considered. Briefly, a possible version of the development of coal mining and coal consumption in the energy sector of the republic is presented.

1 Introduction

The coal industry is one of the key branches of the Sakha Republic (Yakutia) economy. On the scale of the Russian Federation, the republic coal industry is the largest exporter to the countries of the Asia-Pacific region for the supply of coke concentrate. The Asia-Pacific region is the world's largest coal market. This is due to both the scale of the economies and the small volumes of coal production in most countries of this region [1]. A characteristic feature of their import policy is the diversification of suppliers. Sakha Republic (Yakutia) has sufficient potential for increasing supplies of coal for export and to the eastern regions of Russia.

In these conditions, in order to justify the pace and scale and proportions of the development of the fuel and energy complex, it is necessary to develop mathematical models for forecasting the development of the coal industry, as well as software and information systems for their implementation.

"The coal industry has, in common with other large energy systems, and specific properties that are unique to it" [2, 3].With reference to the republic, this task touches upon issues related to the exploration of the development of the coal industry in the North, taking into account regional specifics [4].

2 Regional Features

The achieved level and trends in the development of the energy complex of the northern regions depend significantly on their natural and climatic and socio-economic conditions, which also determine the specific features of the regional energy and coal industries. So far, the main problems of socio-economic development in many areas of the North: a low level of development of the natural resource base; insufficient level of development of transport

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infrastructure; high tariffs for energy and transportation; the financial dependence of the republic on the federal budget and the limited nature of its own investment resources, conditioned by specific regional characteristics, are characterized by irrationalism and each requires a deep, large-scale research to resolve it. [5]; for the coal industry this is a multiple excess of coal production over its consumption - large-scale extraction is possible only for export, very good quality characteristics of coal supplied for export - sulfur and nitrogen content is half the average for the coal market in the Asia-Pacific region, seasonal nature of the bulk of supplies in a short navigational period, with a complex and multifaceted delivery, less than 50% of the coal produced, virtually unlimited reserves of both high-quality coal and brown.

The coal industry is one of the traditional basic sectors of the economy of the Sakha Republic (Yakutia), occupies the third place in the structure of the output of industries, after the oil and diamond mining industry (Fig. 1).

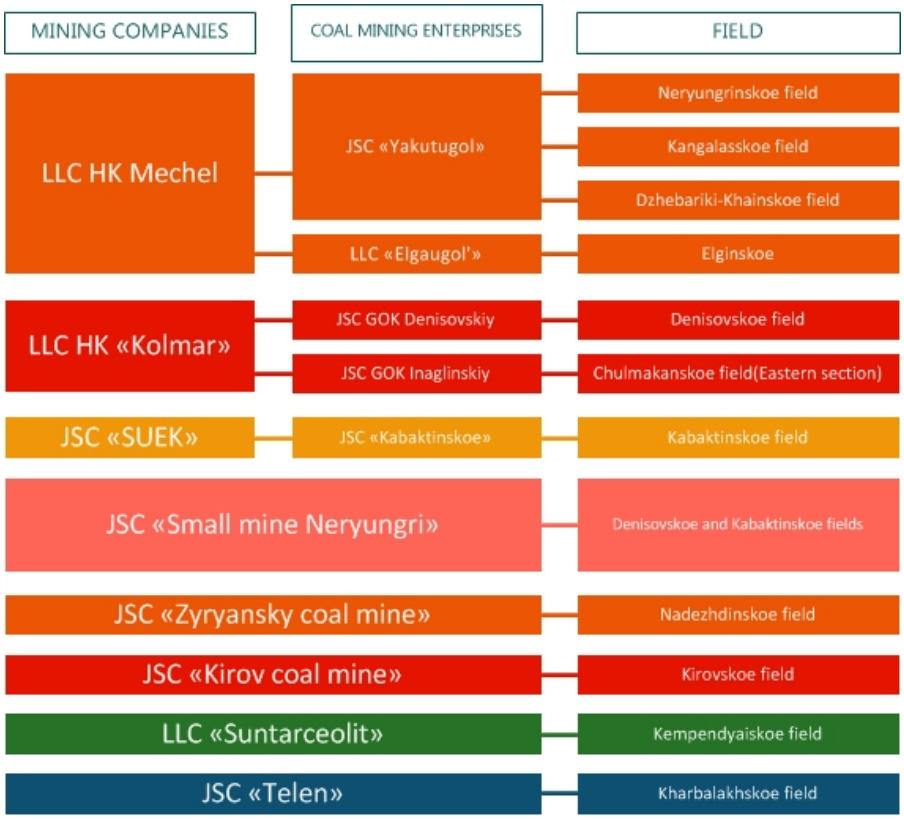

Fig 1. State of the fund of coal mining enterprises as of 01.01.17.

Although the composition of the industries forming the fuel and energy sector of the Sakha Republic (Yakutia) has not changed significantly over the period, significant structural changes in quantity and quality have occurred in production and consumption.

In the production (extraction) of fuel and energy resources (FER), the changes are increasing. So if the production of fuel and energy for the period in question in quantitative terms increased by 2.3 times (from 13252 to 30836 thousand tons of equivalent fuel), in structural terms it changed as follows: the volume of oil and gas condensate production increased by 23.2 times , from 588 to 13658 thousand tons of fuel equivalent, and in the

structure of TEB increased 10-fold, from 4.4 to 44.3%; the extraction of natural and associated gas in volumes increased by 1.7 times, while in the structure it decreased from 14.2 to 10.5%; the volume of coal mining also increased by 1.3 times, but in the structure it decreased from 1.8 times. The main jump in the extraction of energy resources takes place in the oil and gas industry, through the implementation of the export-oriented project of the Talakanskoye oil and gas condensate field (NGKM), which also contributes to an increase in associated gas production. In the southern part of the republic, coal mines with concentrators are being replaced by an open method of coal mining. One of the major projects introduced in the coal industry over the period under review is the development of the export-oriented Elginsky coal deposit, which now produces 1/4 of the country's production. The increase in fuel and energy resources is associated with the growth of exports and exports to the regions of the country. In 2015, the volume of export amounted to 79.1% of produced fuel and energy resources (about 24.4 million tons of fuel equivalent), compared to 63.5% in 2006. If in 2006 the export of energy resources consisted essentially of coking coals of South Yakutia (98.6%), then starting from 2011, the bulk of the export of fuel and energy is accounted for by the exported oil from Talakanskoye oil and gas condensate field – about 54.0%. Domestic consumption of primary energy resources for the period increased by 35%. In the general structure of consumption of energy resources, the share of gas increases. In 2015, it was 35% compared to 30% in 2006. The share of coal in total consumption remains at the same level, in the consumption structure – is decreasing.

3 On the methodical approach

There are two directions for the development of tools for studying the development of the coal industry: as part of a complex of energy complex facilities [6, 7, 8, 9, 10] and in the form of specialized tools [11, 12, 13].

For the forecasting of coal production and consumption parameters, an approach approaching the approach is used in the work, Sokolov A.D, Takaiashvili L.N. used for forecasting the development of the coal industry of the Russian Federation and its regions [12].

One of the main features of the coal supply (fuel supply) of consumers located in the Sakha Republic (Yakutia) is the use of long sections of waterways (river and sea) that have different and short navigation periods, which cause several intermediate trans-shipment and the inter-naval storage of fuel and energy resources in transit. Automobile transport also delivers the planned volume of coal, which is not transported during navigation. In order to take into account some regional peculiarities, it is proposed to supplement the existing instrumentation with the production and transport model.

4 Production transport model

The transport model of regional coal transportation is an optimization model with minimizing the costs of transporting coal with the allocation of modes of transport (rail, water and road), taking into account the total losses at all stages of transportation. The model allows taking into account domestic consumption and export supplies of coal, time restrictions for the period of navigation for water transport and for the period of validity of caravans for vehicles. The loss factors are based on the norms of natural loss during transportation and storage according to the Decree of the Government of the Sakha Republic (Yakutia), as well as experimental measurements of coal losses during

transportation of coal from the Jebariki-Khayskoe deposit [14]. As part of the railway traffic flow is differentiation for domestic consumption and exports.

Restrictions are set - the total volume of shipped coal from coal-mining enterprises does not exceed the total volume transported by all modes of transport. Transport by water or road transport on a certain transport segment does not exceed its capacity. The calculation of the capacity is based on the number of units of water or road transport, their average carrying capacity and the average number of flights.

All indicators meet the condition of non-negativity. All prices are in rubles, and the mass in tonnes.

$$\min\left[\sum_{ioj} m_{ioj}^{wt} \times p_{ioj}^{wt} \times w_{ioj}^{st} + \sum_{ijh} m_{ijh}^{ut} \times \left(p_{ij}^{ut} \times u_{ij}^{st} + p_{ih}^{ut} \times э_{ih}^{st}\right) + \sum_{oj} m_{oj}^{zt} \times p_{oj}^{zt} \times z_{oj}^{st}\right] \quad (1)$$

$$\sum_{ij} x_{ij}^{st} \le \sum_{ioj} w_{ioj}^{st} + \sum_{ijh} \left(u_{ij}^{st} + э_{oj}^{st}\right) + \sum_{oj} z_{oj}^{st} \quad (2)$$

$$\sum_{s} w_{ioj}^{st} \le y_{ioj}^{wt} \quad (3)$$

$$\sum_{s} z_{oj}^{st} \le y_{oj}^{st} \quad (4)$$

$$y_{ioj}^{wt/zt} = k_{ioj}^{w/zt} \times г_{ioj}^{w/zt} \times l_{ioj}^{w/zt} \quad (5)$$

$$x, w, u, э, z, y, m, p \ge 0 \quad (6)$$

$$0{,}6 \le p_{ioj}^{w/u/zt} \le 1 \quad (7)$$

i =1,…, I_f ; s=1,…,S; j=1,…,J; h=1,…, H_f ; t =1,…,T

as

i – coal mining index $i = 1,...,I_f$;

h – coal mining index $h = 1,...,H_f$;

s – index of qualitatively similar energy coals $s=1,...,S$;

j – consumer index $j=1,...,J_r$;

t – forecast period index $t =1,...,T$;

$k^{w/zt}_{ioj}$ – the units' number of water *w* or automobile *z* transport engaged in transportation of coal from the coal mining enterprise *i* or from the storage or transfer point *o* to the consumer *j* in the period *t;*

$г^{w/zt}_{ioj}$ – the average carrying capacity of water *w* or automobile *z* transport engaged in transportation of coal from the coal mining enterprise *i* or from the storage or transfer point *o* to the consumer *j* in the period *t;*

$l^{w/zt}_{ioj}$ – the average number of flights for the navigation's period or the winter road action of water *w* or automobile *z* transport engaged in the transportation of coal from the coal mining enterprise *i* or from the storage or transfer point *o* to the consumer *j* in the period *t;*

$m^{w/u/zt}_{ioj}$ – the cost of transportation of coal by water *w* or railway *u* or by road *z* from the coal mining enterprise *i* or from the storage or transfer point *o* to the consumer *j* in the period *t*;

$p^{w/u/zt}_{ioj}$ – the loss coefficient from the weight of the transported coal by water *w* or railway *u* or by road *z* from the coal mining enterprise *i* or from the storage or transfer point *o* to the consumer *j* in the period *t*;

$y^{w/u/zt}_{ioj}$ – the capacity of coal's transportation by water *w* or railway *u* or by road *z* from the coal mining enterprise *i* or from the storage or transfer point *o* to the consumer *j* in the period *t*;

w^{st}_{ioj} – the volume of the *s*-th type of coal transported by water from the coal mining enterprise *i* or from the storage or transfer point *o* to the consumer *j* in the period *t*;

u^{st}_{ij} – the volume of the *s*-th type of coal transported by the railway from the coal basin *i* to the consumer *j* in the period *t*;

z^{st}_{oj} – the volume of the *s*-th type of coal transported by the road from the storage or transfer point *o* to the consumer *j* in the period *t*.

The methodical and software tools implementing the model of the consolidated TEB are integrated into the software component complex (SP FEB) implemented in the Turbo Delphi environment and in the Microsoft Excel spreadsheet processing environment. An approach is used in the form of related individual applications, which provides the flexibility of using complex components and enables experts to be involved at each stage to verify the received data for compliance with actual parameters (Fig. 2).

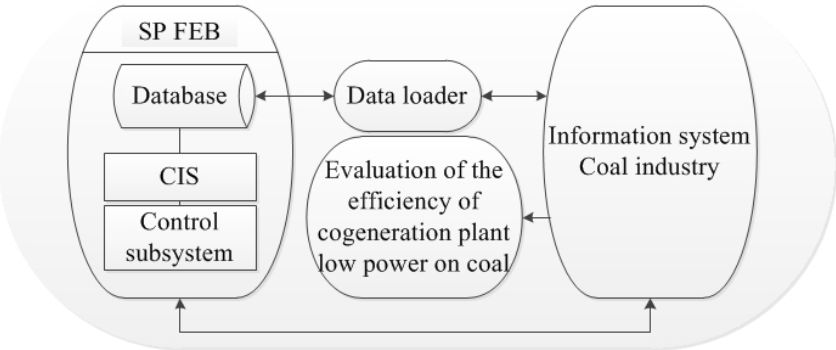

Fig. 2. Enlarged scheme.

The tasks of the SP FEB are: compilation of balance sheets on the basis of statistical and other information in natural and conventional units of measurement; calculation of options for the fuel and energy balance of the region and indicators of efficiency in the use of fuel and energy resources.

At the first stage, the maximum possible volumes of coal mining (technically possible) are determined, which are transferred in aggregate form to the region's FEB model. At the second stage, the necessary volumes of coal are transferred from the region's FEB model to consumer categories. The task is to find the most appropriate options to meet this demand. The difficulty in accurately determining these options in the FEB is due to the need to take into account regional specificities (seasonality, complexity of the transport scheme, storage time, uncertainty with existing transport schemes, etc.). Further, a multivariate calculation of the optimal options for coal delivery in different periods is made. The obtained results are used to refine the FEB. After passing the peer review, the final version of the consolidated FEB is approved in the SP FEB and the coefficients of the useful use of energy resources are calculated. At the main stages of the calculations, an expert evaluation of the data is made for compliance with the actual parameters (Fig. 3).

As it was said earlier in terms of mining conditions, the coal mining enterprises of the republic are divided into two groups: the southern and northern ones. Additional mining opportunities for the northern group of enterprises are opportunities associated with the processing of coal, this is a proven economically successful experience of using automated and highly mechanized modular boilers and thermal boilers operating under the coal-heat scheme, and this is the implementation of projects for the construction of a cogeneration plant low power on coal.

The main task of the steam turbine cogeneration plant low power on coal is to reduce fuel costs in the production of electricity by using cheap coal instead of expensive diesel fuel. However, during the operation of the CHP for consumers of housing and communal services without a constant load of the industrial consumer, steam turbines are not loaded during the year, which does not allow efficient use of the installed electric power of back-pressure turbines. The use of condensation turbines with controlled steam extraction, because of their low vapor parameters and imperfection of the thermodynamic cycle, lead to a fuel over expenditure – 1.5–2.0 times higher than for DES. As a result, high costs for consumed coal and payment for a large number of qualified personnel lead to high costs of

the CHP. From this it follows that the use of small CHP plants on coal is advisable to consider in settlements located near coal deposits or near river transport arteries.

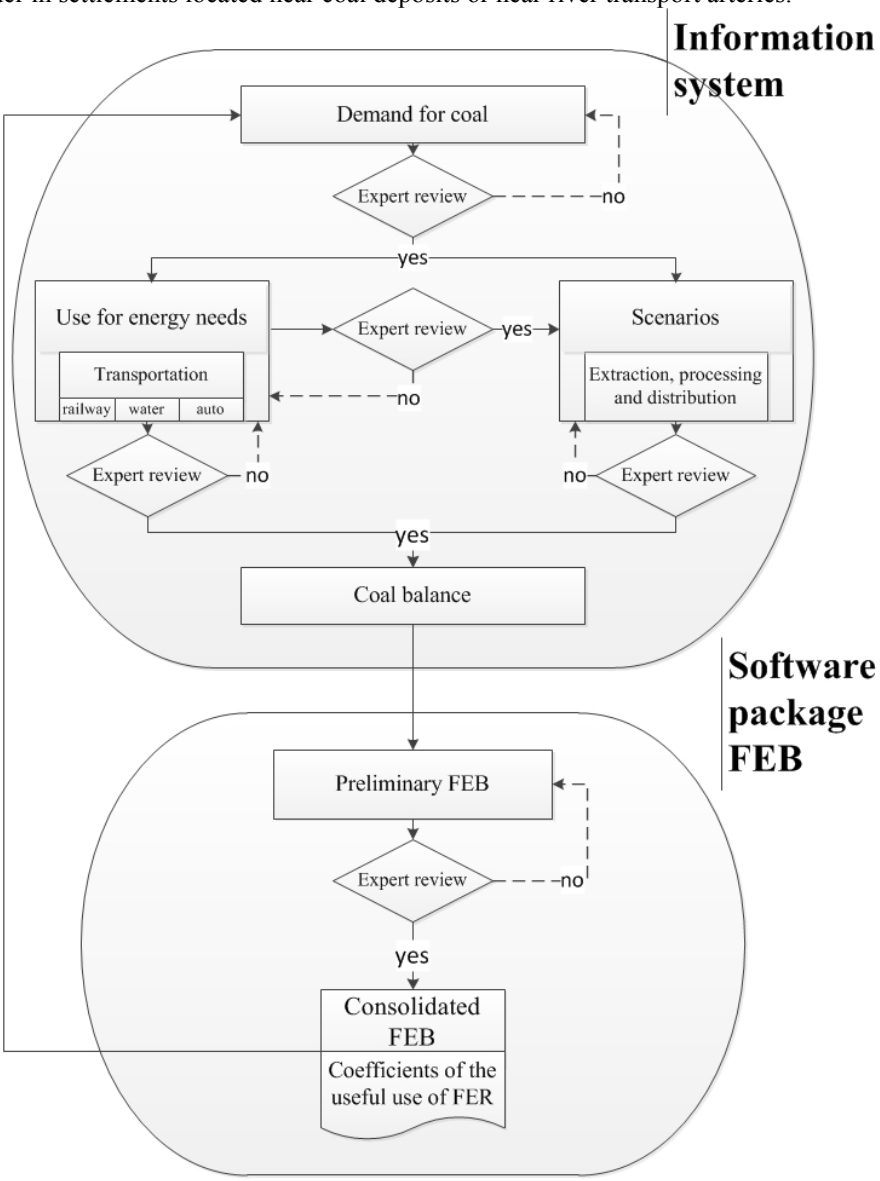

Fig 3. Algorithm for predicting the coal industry.

The construction of promising small CHPs at the coal is actual: in Zyryanka near the eponymous coal deposit, in Sangar – during the development of the Belogorsky coal deposit located 30 km from the village, in the town of Srednekolymsk and Chersky, located from the place of extraction of Zyryansky coals respectively at a distance of 342 and 861 km downstream of the river. Kolyma, in with. Zhigansk, located in 1,090 km along the river transport route (river Aldan, Lena) from the Jebarika-Khaya mine.

5 Implications

Prospects for the development of coal mining enterprises are determined on the basis of the results of analysis of the supply of reserves, the current state and prospects for the development of production capacities.

The growth in coal production in the Sakha Republic (Yakutia) will largely depend on the realization, first of all, of the Elginsky deposit and coal projects in South Yakutia. Taking into account the adjustment for capacity inputs, coal production by 2030 will be over 40 million tons per year and will reach the forecast values of Sakha Republic (Yakutia) Energy Strategy–2030 in a moderate scenario.

The main growth in the volume of FER production (production) may occur by 2025 due to an increase in the production of three main energy resources: coal, oil, natural gas. Coal production will increase by 2.5 times, oil – by 1.7 and natural gas by 9 times to the level of 2015. The given data slightly outstrips the strategic scenario of Sakha Republic (Yakutia) Energy Strategy–2030. In such a course of events, the peak of production can be reached by 2035, after which there will be a decline, mainly in the oil and gas industry.

The forecast of consumption of fuel and energy resources laid down in Sakha Republic (Yakutia) Energy Strategy-2030 is 2 times higher than the proposed option, taking into account the latest changes. According to the adjusted scenario, there will be no sharp leaps in consumption of fuel. Growth will be gradual: if at the beginning of the period under consideration the consumption of coal, natural gas and oil products as motor fuel was mainly increased due to an increase in the number of connections to the centralized energy supply and improvement of the quality of life of the population, then the consumption of energy resources will increase due to the connection of large energy-consuming facilities. The consumption of coal for electricity production by 2030 will increase by 64% in comparison with 2015, natural gas by 63.7%, hydro power generation will increase 2.6 times. Since 2020, the structure of coal consumption for electricity production will include about 1/3 of the share, respectively for the production of heat energy will remain 2/3. After 2030, the volume of coal consumption will be on the same level, but in the structure there will be an increase in favor of heat energy production.

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