

# Prospects for the use of coal of the Republic of Sakha (Yakutia) for energy needs

Nikita Pavlov<sup>1,\*</sup>, Liudmila Takaishvili<sup>2</sup>, and Vasilij Zakharov<sup>1</sup>

<sup>1</sup>Larionov Institute of the Physical-Technical Problems of the North of Siberian Branch of the Russian Academy of Sciences, Energy Problems Department, Yakutsk, Russia

<sup>2</sup>Melentiev Energy Systems Institute of Siberian Branch of the Russian Academy of Sciences, Department of Complex and Regional Problems in Energy, Irkutsk, Russia

**Abstract.** The Republic has significant resources for the development of mining, export and domestic consumption, including the energy needs of the republic and neighboring regions. The article provides a retrospective analysis of the supply of Yakut coal for energy needs and the structure of capacities by energy resources. The estimation of power-generating coal resources, including low-grade products of coking coal processing of the Republic of Sakha (Yakutia), is given. Characteristics of coal deposits are presented, which are useful for energy needs. Projects for the development of coal-fired energy in the Republic of Sakha (Yakutia) are presented. The Republic of Sakha (Yakutia) has significant coal resources for the development of coal-fired power plants. Coal power facilities play a closing role in meeting the demand for electricity and heat. The use of coal for the development of coal-fired energy in the Republic of Sakha (Yakutia) can be determined by the development of mining industry, the construction of power plants of small capacity in isolated areas, as well as the possibility of exporting coal-fired power plants.

**Keywords.** Energy system, coal, balance reserves, the Republic of Sakha (Yakutia), consumption, projects, trends.

## 1 Introduction

The Republic of Sakha (Yakutia) is the world's largest administrative-territorial unit. Being the largest region of the Russian Federation in terms of area, it occupies 18% of its territory. The republic belongs to the territories of the Arctic zone of the Russian Federation and the Far East. The Republic of Sakha (Yakutia) has significant reserves of energy resources: water resources, coal, oil, gas. Currently, the main resources for generating electricity in the region are hydro resources, gas and coal. Coal, along with gas, is of paramount importance as a type of fuel consumed in the republic. South Yakutia coal power plants act an important role in the energy system of Russia's eastern regions. Coal mined in the republic is supplied to power plants in Yakutia and neighboring regions.

The program of development of the coal industry of Russia for the period up to 2030, involves the construction of coal power plant in the eastern regions of Russia, including the Republic of Sakha (Yakutia) to meet domestic demand and export electricity<sup>1,2</sup>. The development of coal generation is also considered in

regional documents<sup>3,4</sup>. At the same time, program documents of the state and regional levels are often not coordinated with each other.

According to forecasts made by the U.S. Energy Information Administration and International Energy Agency demand for electricity in Asia will increase, [1,2], which creates favorable conditions for the construction of export power plants oriented to the export of electricity.

The research of the prospects for the use of coals of the Republic of Sakha (Yakutia) for energy needs is relevant for a number of reasons:

- the presence of significant coal resources for the energy sector, including in isolated areas and low-grade products of coal processing at coal processing plants;
- high social significance of existing coal mining enterprises, not only for fuel supply, but also as city-forming enterprises.

## 2 The use of coals of the Republic of Sakha (Yakutia) for the energy needs – the current state

\* Corresponding author: [pavlov\\_nv@iptpn.vsn.ru](mailto:pavlov_nv@iptpn.vsn.ru)

<sup>1</sup> Долгосрочная программа развития угольной промышленности России на период до 2030 года; утв. распоряжением Правительства Российской Федерации от 24.01.2012 г. № 14-р /перевод

<sup>2</sup> Об утверждении Программы Развития угольной промышленности России на период до 2030 года: распоряжение Министерства энергетики Российской Федерации № 1099-р от 21 июня 2014 г. / перевод

<sup>3</sup> «О схеме и программе развития электроэнергетики Республики Саха (Якутия) на 2020-2024 годы». Утверждена указом Главы Республики Саха (Якутия) №1171 от 30 апреля 2020 года /перевод

<sup>4</sup> О проектной программе оптимизации локальной энергетики Республики Саха (Якутия) на период до 2017 года правительство Республики Саха (Якутия) постановление от 3 сентября 2011 года N 424 / перевод

Coals of the Republic of Sakha (Yakutia) are supplied to power plants and boiler houses of the Republic and to power plants of the Primorsky and Khabarovsk Territories (Table 1).

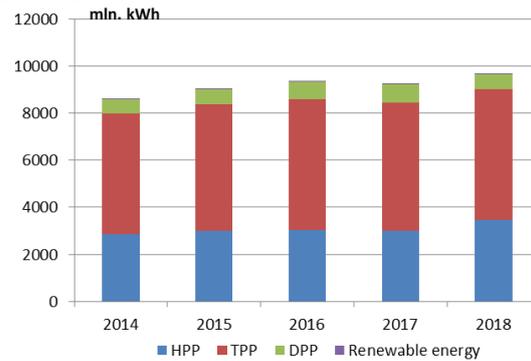
The supply of coal to the power system of the Republic is subject to fluctuations. This is due to the peculiarities of the energy system of the Republic.

A distinctive feature of the power system of the Republic of Sakha (Yakutia) is the presence of zones of centralized and decentralized power supply. The zone of decentralized energy supply includes the territories of the Arctic and northern regions of the Republic of Sakha (Yakutia). This zone accounts for 74% of the territory of the republic and 15% of the population. The centralized power supply zone includes three power regions - Western, Central and Yuzhno-Yakutsk. Centralized power supply covers only 36% of the territory, with 85% of the population. In 2019, the Central and Western energy regions became part of the Unified Energy System of Russia. Due to the isolation of the energy regions of the Republic of Sakha (Yakutia) until now, they have been characterized by an excessive balance of energy and electrical power. In the last decade, due to the adopted policy of eliminating the isolation of energy regions, additional overhead power transmission lines have been introduced.

Large generating companies operate on the territory of the republic, which provide over 95% of the total electricity generation and more than 45% of heat energy in the republic. There are also a large number of stand-alone energy sources. Thermal power plants (TPPs) and hydroelectric power plants (HPPs) form the basis of the

electric power industry. Their share in the total capacity of power plants is estimated at 43 and 30.6%, respectively (Fig. 1).

Diesel power plants (DPP) are stationary and mobile, occupy 25% of the installed capacity. Renewable energy sources (RES) account for an insignificant share in the capacity structure - 0.05%. In retrospect, the installed capacity at power plants of the power system of the Republic of Sakha (Yakutia) from 2014 to 2018 increased by 262.7 MW from 2861.6 MW to 3124.3 MW. The installed capacity of HPPs remained unchanged, TPPs and DPPs - increased by 97.2 MW and by 131.4 MW. The installed capacity of solar power plants (SPP) increased from 0.225 MW to 1.617 MW, with a 6-fold reduction in the installed capacity of wind power plants (WPP).



**Fig. 1.** Electricity production by the power system of the Republic of Sakha (Yakutia), million kWh

**Table 1.** Coal supplies of the Republic of Sakha Yakutia, million tons

Index	2013	2014	2015	2016	2017	2018	2019
Mining	11,9	12	15,3	17	16,8	17,5	19,2
Export	6,2	6,7	6,3	7,9	7,4	6,6	8,6
By-product coke plants	0,5	0,6	1,9	2,2	2,6	2,7	2,1
For energy needs	3,2	2,9	3,3	3,1	2,8	3,3	2,4
At the power plant of the Republic	1,7	1,5	1,7	1,8	1,7	1,7	1,6
At the power plants of neighboring regions	1,5	1,4	1,6	1,3	1,1	1,6	0,9

Source: statistical data of FGBU "CDU TEK", forms 6-TP

Electricity is also supplied from the energy system of the republic to the IES of the East and the Irkutsk region. The share of coal generation in electricity supplies to neighboring regions is 96%. At the same time, the settlements of two districts - Nizhnekolymsky and Oymyakonsky, located in the zone of decentralized energy supply, are supplied with electricity from the Magadan Region and the Chukotka Autonomous Region.

The total volume of fuel consumption by power plants and boiler houses in 2019 amounted to about 5.0 million tons of fuel equivalent, including 2.4 million tons of fuel equivalent of coal. (45.6%), natural and associated gas - about 2.4 million tons of fuel equivalent. (46.8%).

In 2019, thermal power plants consumed 3.2 million tons of fuel equivalent, of which 51.4% was gas (natural and associated), 43.1% - coal. Diesel fuel accounts for 4.6% in the structure of fuel consumption by power plants. In 2019, boiler houses consumed 1.8 million tons of fuel equivalent. fuel, of which 52.7% is coal, 38.8% is gas (natural and associated) (Table 2).

**Table 2.** Fuel consumption by power system objects, 2019, t.o.e.

Type of fuel	Total (% of consumption)	TPP	boiler house
Total	5048	3189	1859
Coal	2354	1375	979
Oil (including gas condensate) and oil products (except diesel fuel)	182	27	155
Diesel fuel	151	148	3
Natural gas	2006	1301	705
Associated gas	355	338	17
Wood	0,6	0	0,6

Source: [3]

The program for the development of gas supply and gasification of the Republic of Sakha (Yakutia) for the period from 2021 to 2025, adopted in 2020, is focused on transferring 21 settlements to gas in the Aldan, Lensky, Neryungri and Olekminsky regions of the republic.

Despite the conversion of individual energy facilities to gas, coal consumption is relatively stable. According to the statistics of the FGBU "CDU TEK", the supply of Yakut coals in the country as a whole from 2014 to 2018 increased from 4.56 million tons to 7.34 million tons with a relatively stable dynamics of coal consumption at power plants. On the domestic market, coals of the Republic of Sakha (Yakutia) are supplied to coke plants, power plants, for use in the household sector and other consumers. At power plants, in addition to raw coal, low-grade products of coking and thermal coal processing are consumed.

Boilers of the republic mainly use low-capacity boilers, as a rule, designed for burning sorted and refined coal. However, at present, all burned coals are used without any cleaning, enrichment, after repeated

reloading, transshipment and long-term storage. When operating boilers on such raw coals, a layer of contamination on the heating surfaces increases, labor costs for servicing boiler houses, and their efficiency significantly decreases. The supply of low-grade fuel, the operation of boilers at an insufficiently high level leads to low efficiency of use and an annual excessive consumption of fuel.

### 3 Balance reserves of coal

The Republic of Sakha (Yakutia) has significant resources and reserves of power and coking coals. The largest coal basins of Russia are located on the territory of the republic: Lensky, South Yakutsky, Zyryansky, the eastern part of the Tunguska basin and also in the northern and northeastern parts of Yakutia - separate scattered deposits. Explored balance reserves of coal in categories A + B + C1 + C2 amount to 14.3 billion tons, or almost 50% of the balance reserves of the Far Eastern Federal District. In terms of geological reserves of coal, the Republic is one of the main subjects of the Russian Federation [3,4]. (Table 3).

**Table 3.** Reserves of coal of the Sakha Republic (Yakutia) by types of coal and method of mining, bln t

Coal type, mining method	Stock category		
	A+B+C1	C2	A+B+C1+C2
Total, including	9,7	4,6	14,3
Coking	4,1	2,6	6,7
Thermal coal, of them	5,6	2	7,6
Brown	4,4	1,5	6
Hard	1,2	0,5	1,6
For open source development, including	6,5	2,1	8,5
Coking	1,4	0,3	1,8
Thermal coal, of them	5,1	1,8	6,7
Brown	4,4	1,6	6

Source: [3,4]

in the republic is 1.1%. In the South Yakutsk basin, the coal resource potential is most significantly realized - 19.2%. For the Lena basin and others, this ratio is less than 1%. This indicates great prospects for the development of coal mining due to the development of not yet developed predicted resources. Prepared for development and is being developed and 4.53 billion tons, which is 46.7% of the volume of reserves of categories A + B + C1.

59.4% of coal reserves are suitable for open pit mining. Thermal coals account for 7.6 billion tons of reserves of categories A + B + C1 + C2 slightly more than 50% of the balance reserves. And from the balance reserves suitable for open-pit mining, power-generating coals account for 79%.

### 4 Coal resources for the development of coal energy

Coal resources for power generation are significantly higher than the balance reserves of steam coal and consist of steam coal and low-grade products of processing of hard and coking coals. With possible production levels in the republic of 45-50 million tons, the resources of coal for the power industry can reach up to 19-22 million tons, including energy concentrate, raw energy coal and industrial products. The volumes of low-grade processed products suitable for the needs of the energy sector can make up from 23 to 42% of the processing volumes

The provision of coal reserves in the Republic of Sakha (Yakutia) at the level of production in 2018 is more than 550 years, and in energy reserves at the level of supplies to the power plants in 2018 for more than 2000 years..

Coking coal deposits of the South Yakutsk coal basin are promising for development: Elginskoe, Denisovskoe, Chulmakanskoe, Kabaktinskoe. Low-grade products after the processing of the coal from these deposits, suitable for combustion at power plants, can amount to up to 8 million tons. Development projects of the deposits presented are in varying degrees of implementation. The largest production volumes under the projects are being considered at the Elginskoye field.

The Elginskoye field is the largest in Russia and one of the world's largest deposits of high quality coking coal. Coal reserves of the Elginsky deposit amount to 2.2 billion tons, including balance categories A + B + C1 - 1599.4 million tons. with a production volume of 27 million tons of coal per year, an enrichment plant with a production output of up to 23 million tons per year and the Elginskaya CHPP has been under way since 2010. In 2018, coal production at the Elga open-pit mine amounted to 4.92 million tons, and exports - 1.74 million tons. When the open-pit mine and the processing plant reach their full capacity, resources for the energy sector can range from 8.5 to 10.6 million tons. The project is constrained by financial problems..

In decentralized energy supply areas, the proven balance reserves of coal deposits suitable for use at energy facilities do not always correspond to real reserves. Additional geological exploration is needed to clarify coal reserves.

In the Lensky coal basin, the most promising deposit for supplying the Arctic regions due to its geographical location is the Belogorsk brown coal deposit, located on the right bank of the river. Lena is 20 km away. from the village Sangar in Kobayaskiy ulus.

In the Zyryansk coal basin, the development of the Nadezhdinsky deposit is of great strategic and socio-economic importance for enterprises and the population of the northern group of regions of the republic and neighboring regions.

The Nadezhdinskoye coal deposit is located 48 km from the village of Zyryanka and 12 km from the village of Ugolnoye.

In the zone of decentralized energy, coal deposits can be promising for energy supply to consumers: Krasnorechenskoye, Kularskoye, Taimylyrskoye coal deposits and bogheads, etc.

Krasnorechenskoye coal deposit is located on the left bank of the middle reaches of the river. Indigirka, 160 km. upstream from the village of Druzhina. The Sogolokh section is remote from the navigable part of the river. Indigirki 1.5-4 km. The deposit is characterized by “heterogeneity of the distribution of the ash content of coal and the heat of its combustion in certain areas” [6].

The Kular brown coal deposit is located in the basin of the lower reaches of the river. Kuchuguy Kuegyulyur. The deposit belongs to the Ust-Yansky ulus of the Republic of Sakha (Yakutia). Coal of the Kular deposit belongs to brown humus coals of B1 group of low degree of coalification (ash - 7.00-50.00%, sulfur - 0.30-0.40%).

The Taimylyr field is located in the Bulunsky district, 15 km west of the village of Taimylyr and 260 km from the village of Tiksi

The resources of thermal coal, including low-grade products from processing plants, significantly exceed the demand.

## 5 Projects for the development of coal energy in the Republic of Sakha (Yakutia)

The Republic of Sakha (Yakutia) has sufficient coal resources for the development of energy, including coal for supplying its own consumers and for the supply of electricity and energy resources to neighboring regions [7, 8].

Various state federal and regional strategies and programs consider the construction of coal power plants in the Republic of Sakha (Yakutia) (Table 4).

**Table 4.** Proposed coal power plants in the Sakha Republic (Yakutia)

Name	Capacity, MW	Years of construction
Elginskaya GRES*	1800	2025-2030
Dzhebariki-Khaiskaya TPP*	150	2020-2030
Expansion of Neryungrinskaya GRES (block 4)**	225	2026-2030

\* Energy Strategy of the Republic of Sakha (Yakutia) for the period up to 2030

\*\* General layout of power facilities until 2035, Program for the development of the coal industry until 2035, program for comprehensive modernization of PJSC RusHydro

The program for the long-term development of the coal industry provides for the construction of the Elginskaya CHPP and the expansion of the Neryungrinskaya TPP.

Three power units with a total electric capacity of 570 MW and a thermal capacity of 1120 Gcal / h are installed at the Neryungrinskaya GRES. The fuel for the power plant is an industrial product obtained during the enrichment of coking coal from the Neryungrinskoye deposit. The average annual demand for solid fuel at full load is 1.6 million tons per year..

Until 2030, it is planned to expand the Neryungrinskaya SDPP by commissioning the fourth unit with a capacity of 225 MW, the installed electric capacity will be 795 MW, the average annual demand for solid fuel will increase to 2.2 million tons per year.

In reality, projects for the construction of coal-fired thermal power plants are often in the initial stage of development or implementation, and the implementation of projects can often be significantly delayed or become unattainable for various reasons.

In the Arctic zone in the village of Zyryanka, the construction of a mini-CHP with electric capacity is underway to supply power to nearby settlements. Coals of the Zyryansk deposit are supposed to be used as fuel. Currently, due to lack of funding for the completion of construction, a decision has been made to mothball the installed equipment.

## 6 Options for the development of coal energy

Possible options for the development of coal energy:

1) Basic scenario of economic development with the implementation of energy-intensive industrial development projects;

2) Optimistic scenario: construction of a thermal power plant to join the super-Asian ring through the IES of the East.

The optimistic scenario is a low probability scenario due to the high risks associated with the implementation of its highly capital intensive projects. Yakutsk high-quality coal is in demand on the world and Russian coal markets. For export and coke-chemical plants in Russia, mainly coal concentrate is supplied from concentration plants. The lack of demand for low-grade coal processing products suitable for the needs of the energy sector may restrain the development of coal exports.

Basic scenario. The internal potential for the development of coal-fired energy is undoubtedly associated with the further operation and modernization of the Neryungrinskaya SDPP (570 MW). There are also two low-capacity coal-fired CHPPs in operation in the republic: Deputatskaya - 7.5 MW (owner of Sakhaenergo JSC, commissioned in 2011) and CHP of the Gross mine - 16 MW (owner of Neryungri-Metallic LLC). Start-up and adjustment works are currently being completed.

Optimistic scenario. A significant change in the share of coal generation in the electric balance of the region is associated with promising projects for the construction of export-oriented generation, primarily at the Elginskoye field, as well as the further development of the IES East towards connection to the isolated Magadan energy system [9, 10]. Approximate technical and economic parameters of Elginskaya GRES were reflected in the Energy Strategy of the Republic of Sakha (Yakutia) until 2030, approved by the Resolution of the Government of the Republic of Sakha (Yakutia) on October 29, 2009 No. 441 [11]. Within this document large-scale export of electricity offered to be realized from the newly built Elga (1.8 GW) and Urgal (2.4 GW)

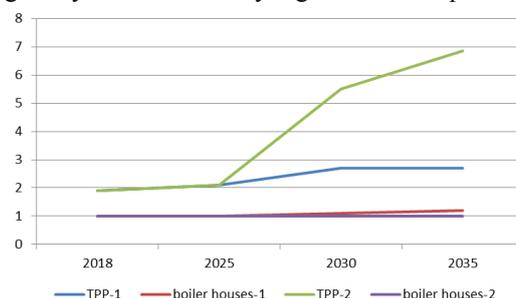
TPP to Shenyang (China). The competitor to this proposal was the construction of a cascade of hydroelectric power plants on the Timpton River with a capacity of more than 1 GW. At the moment, after the design and survey work at the site of the alignment, the hydropower plant construction project is mothballed.

It is planned to form a connection with the Magadan power system between the power plants of the central power district of the Yakut power system and the Magadan power system. The line (about 1000 km) will pass through the administrative center of the Tomponsky municipal district, Khandyga settlement in the immediate vicinity of the Dzhebariki-Khai coal deposit. The construction of a thermal power plant in this section can significantly increase the stability of the power system, as well as the reliability of power supply to the central energy district. An additional factor in favor of construction is the possibility, at the same time, of guaranteed sales of the products of the Dzhebariki-Khaiskiy open-pit mine.

The high fuel component in the cost of municipal energy in the republic forces the utilities to initiate the issues of opening additional small open-pit mines located in more convenient transport locations and in close proximity to hard-to-reach consumers. At the same time, the emergence of several mining enterprises balancing on the brink of profitability poses a threat to energy security. Consequently, the task of expanding the sales market for thermal coal in the central and northern regions is of great importance.

Potential points of expansion of coal generation in the region are associated with a long-term perspective and have strong competitive projects on the part of gas and hydro generation, which have more attractive technical and economic parameters.

The forecast of fuel consumption was made on the basis of forecasts for the generation of electric and thermal energy by power plants, taking into account the peak boiler houses in their composition provided by generating companies, as well as under conditions of maximum utilization of generating capacities. The expected volume of coal consumption at power plants is estimated at 2.7 - 6.8 million tons per year, the maximum consumption in boiler houses is estimated at 1.2 million tons (Fig. 2.). In the forecast period, an increase in natural gas consumption is expected due to an increase in heat loads and an expansion of the service area of heating networks of power plants in Yakutsk, gasification of municipalities adjacent to the Power of Siberia gas pipeline (21 settlements in Aldan, Lensky, Neryungrinsky and Olekminsky regions of the republic ).



**Fig. 2.** The forecasted demand for coal, mln.t.  
1 - baseline scenario, 2 - optimistic scenario**Table 5.** Coal balance, million tons

Balance item	Years			
	2018	2025	2030	2035
Incoming part, total	17,6	39-51	41-55	42-56
including:				
- production, total	17,5	39-51	41-55	42-56
- import	0,1	0,1-0,1	0,1-0,1	0,1-0,1
Consumable part, total	17,6	39-51	41-55	42-56
including:				
- domestic consumption, total	3,7	4-4	4-7	5-9
- processing losses	2,3	5-6	5-7	5-7
- coming out, total	11,6	30-41	32-41	32-40
including:				
- to regions of Russia, total	4,2	4-4	4-4	4-4
- export, total	7,4	26-37	28-37	28-36

Sources: author's calculations

## 7 Conclusion

Coal in the Republic of Sakha (Yakutia) is the most reliable source of fuel for the long term. This is due not only to the presence of significant coal reserves, including in the area of decentralized energy, but also in the long term, the growth in the processing of high-quality coals in demand on the world market.

At the same time, there are the following main problems and limitations for the group of northern enterprises:

- poor technical equipment, deterioration of conditions for the development of coal deposits;
- low level of coal processing and upgrading in the northern group of enterprises;
- complex transport scheme of delivery with several transshipments to various types of transport (sea, river, road);
- restrictions related to the financial support of the work and development of enterprises.

For the group of southern companies:

- the displacement of republican thermal coal in the Far East;
- deficit of the railway transportation capacity, the capacity of the Far Eastern ports;
- issues related to the demand for low-grade products from processing plants.

The development of energy in the Republic of Sakha (Yakutia) should be aimed at eliminating energy-deficient territories as well as with the great potential of industrial development, as well as isolated areas with the possibility of using local raw materials.

The growth of energy consumption in the republic is possible only at the expense of the development of coal generation in the republic. Unstable quality of coal in small areas in the zone of decentralized energy and competition from other energy carriers creates

complexity in the implementation of coal development projects.

Consumption of Yakut energy coal in the neighboring regions of Khabarovsk and Primorsky Krai can be quite stable.

There is a promising introduction of standardization of coal fuel, which will allow to reduce the negative impact of coal energy [12]. The question of the reality of such standardization in the zone of decentralized energy supply is obvious.

Demand for electricity and heat from coal-fired power plants in the Republic of Sakha (Yakutia) is possible thanks to the development of mining industry, construction of new residential complexes and the development of energy security of the population of the republic. Implementation of projects for the construction of power plants on carbon for the export of electricity or the addition of a super-Asian ring in the near future is unlikely. Environmental and economic aspects of large-scale development of coal and the export of electricity require basic processing.

Acknowledgements: The research has been carried as part of research projects XI.174.2. Programs of Basic Research SB RAS, reg. No. AAAA-A17-117030310435-0 and III.17.6.4. Programs of Basic Research SB RAS, reg. No. AAAA-A17-117052210036-2

## References

1. BP Statistical Review of World Energy June 2017/ [bp.com/statisticalreview](http://bp.com/statisticalreview)
2. Country Analysis Brief: Russia / U.S. Energy Information Administration Page Last Updated: October 25, 2016 / [https://www.eia.gov/beta/international/analysis\\_includes/countries\\_long/Russia/russia.pdf](https://www.eia.gov/beta/international/analysis_includes/countries_long/Russia/russia.pdf)
3. State balance of reserves of fossil fuels of the Russian Federation as of January 1, 2016. Issue. 91, Coal, I, Summary data. - M.: Ministry of Natural Resources and Ecology of the Russian Federation, Federal Agency for Non-Utilization, Russian Federal Geological Fund, 2016, 382 p.
4. State balance of reserves of fossil fuels of the Russian Federation as of January 1, 2016. Issue. 91, Ugol, Tom VIII, Far Eastern Federal District. - M.: Ministry of Natural Resources and Ecology of the Russian Federation, Federal Agency for Non-Utilization, Russian Federal Geological Fund, 2016.-378 p.
5. Tarazanov I.G. Results of coal industry of Russia for 2018. Coal, 2019. №3, p. 64-79. DOI: <http://dx.doi.org/10.18796/0041-5790-2019-3-64-79>
6. Khoyutanov EA, Gavrilov VL Modeling of coalfields in the polar zone of Yakutia. Problems of misuse. - 2017. - №4. P.53-60.
7. Sokolov AD, Takaishvili LN, Petrov NA, Pavlov NV Coal industry of the Republic of Sakha

- (Yakutia): the current state and development opportunities. Vestnik IrGTU. -2010. - №4. c 64-69
8. Sokolov Aleksander, Takaishvili Liudmila. Coal resources of the eastern regions of Russia for power plants of the Asian super ring. (2018) E3S Web of Conferences, 27, № 02004. DOI: 10.1051/e3sconf/20182702004
  9. Lagerev AV, Hanaeva VN Priorities for the development of TEK Asian regions of Russia in the long run. Spatial economy. 2017. № 3. C. 154–166. DOI: 10.14530 / se.2017.3.154-166
  10. Smirnov KS Comprehensive assessment of the implementation of projects for the export of Russian electricity from Eastern Siberia to China. Bulletin of the Irkutsk State Technical University. 2017. T. 21. № 10. C. 131–137. DOI: 10.21285 / 1814-3520-2017-10-131-137
  11. Energy Strategy of the Republic of Sakha (Yakutia) for the period up to 2030. -Yakutsk; Irkutsk: Media Holding "Yakutia" and others; 2010. -328 p
  12. Linev BI, Rubinstein Yu.B. The role of standardized coal fuel in the implementation of clean coal energy programs. FGUP "Institute for the enrichment of solid fuel" [Electronic resource] <https://docplayer.ru/50115232-Rol-standartizirovannogo-ugolnogo-topliva-v-realizacii-programmy-chistoy-ugolnoy-energetiki.html> (2018)