PROVIDING ENERGY SYSTEMS OF THE ARCTIC TERRITORIES OF THE REPUBLIC OF SAKHA (YAKUTIA) WITH RESOURCES: PROBLEMS AND PROSPECTS

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Abstract: *This article presents analysis of the energy system of the Arctic zone of the North-East of Russia - the Republic of Sakha (Yakutia): by heat supply objects and production of electricity. This system in question features autonomy and dependence on provision of resources during short navigation periods of cargo delivery through complex transport schemes. The main problem expressed of transportation of resources, a high transport component in cost of production is designated. This causes energy companies to use mechanisms of cross-subsidies, which fact in general affects the price policy of public utilities in the region. Development of Russian Arctic territories requires reliable sources of electricity, thus in connection with the geographical features the region needs new solutions and technologies. It is necessary to provide measures of state support for the formation of pricing policy aimed at stimulating the use of renewable energy sources.*

Keywords: *Arctic Zone, Autonomy Energy Supply, Heat Supply Objects, Transport Component, Cross-Subsidies, Renewable Energy Sources.*

1. INTRODUCTION

Challenges and threats to Russia's national interests in Arctic region raise the need for a rethinking of position and role of the country's Arctic territories in ensuring its strategic economic and social development, in strengthening its defense capability and national security. The Arctic zone of the Russian Federation (Russian Arctic) is a special, very specific combination of regions and parts thereof, which differs from the rest of the country's territorial entities not only by a well-known set of natural factors (climate severity, lack of insolation and oxygen, sudden changes in atmospheric pressure, polar night and day, widespread permafrost, several-fold reduced ability of landscapes and ecosystems to self-repair, including effects of techno genic impacts), but also by uncertainty of the legal status.

Supplies to isolated energy systems of Arctic Territories are characterized by a high production cost, which entails increased expenditures from regional budgets for subsidizing electric power supply, subsidizing transportation costs for the resources delivery, companies' implementation of "cross subsidizing" mechanisms to cover the transport costs. One of the principal factors affecting the high cost of energy production in Arctic is the transport factor. Basis of the Arctic territories' energetics is imported fuel. Necessary resources are supplied via complex transport schemes within short navigation periods twice a year (for example in the Republic of Sakha (Yakutia)), including in connection with the need to deliver oil products for diesel power plants

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and boiler stations from other nearby territories. Therefore, uninterrupted heat supply and electricity supply to population and budgetary enterprises depends on smooth functioning of „the northern deliveries" system and on level of transport infrastructure development. During the short period of the Arctic navigation from August to October months are delivered about 400 thousand tons of life-supporting freights from which:

- Coal of 182 thousand tons;
- Crude oil of 58 thousand tons;
- Gas condensate of 13 thousand tons;
- Oil products of 107 thousand tons;
- Food products of 1,3 thousand tons;
- Production of PTN of 24 thousand tons;
- Construction materials of 4 thousand tons;
- Production of agricultural – 0,5 thousand tons.

Delivery of cargoes in the navigation season in the Arctic and Northern areas is made from Dzhebariki-Huy's mine, the item of Handyga (24%), across the Northern Sea Route (21%), from Ust-Kut (16%), from the Zyrian coal mine (14%), from the Lensk oil depot, Olekminsk (14%), from Yakutsk, with the item Nizhny Bestyakh (5%), with the item Kysyl-Syr Vilyuyskogo of the area, the item Taas-Yuryakh (4%) and from other points (2%).

Figure 1. Distribution of cargo flows of energy resources in the Republic of Sakha (Yakutia)
Source: authors, calculations

Development of Russian Arctic territories requires reliable sources of electricity, thus in connection with the geographical features the region needs new solutions and technologies. Taking into account the remoteness of settlements, using of standalone power supply facilities and of renewable sources are of particular importance.

The high potential of solar energy exists in the Republic of Sakha (the amount of solar energy is comparable to southern parts of Russia and Germany). Other parts of the region are perspective for effective seasonal use of solar energy. Geographical and climate conditions of the Arctic require special adaptive design for solar plants (low sun declination angles, wide ranges of azimuth, low temperature, energy accumulation, etc.).

Currently 13 municipal districts of the Republic of Sakha (Yakutia) with total area of 1 620.8 thousand sq. km (52.2% of the republic's territory) are assigned to the Russian Federation Arctic zone territories. Number of permanent residents of the territories at the beginning of 2019 has made 67 674 people (7% of the republic's population). The population density makes 0,04 people per 1 sq. km. (for reference: population density in Canada makes 3.5 people per 1 sq. km, Alaska - 0.4). Duration of heating season in the Arctic municipal areas ranges from 265 to 312 days per year (table 1). It means that almost throughout a year, heat supply enterprises of the Arctic territories provide heat, light and water to the population and budgetary-financed organizations. In order to ensure occupational and vital safety of the population under the existing transport scheme for the resources supply within the short navigation periods, permanent state stocks of coal and oil products are reserved in fuel and energy complex enterprises of the Republic.

One of the main factors hampering social and economic development of Arctic and northern territories of the Republic of Sakha (Yakutia) is a sparsely populated and vast territory with a complex transport scheme for cargo delivery, low level of transport accessibility and severe geographic and climatic conditions. Due to the growing interest in the development of territories and natural resources of Arctic regions, issues of integrated development of the energy infrastructure, providing comfort level of living and working conditions, are becoming increasingly relevant. Complexity of supplies of resources to fuel and energy complex of Arctic territories of the Republic of Sakha (Yakutia), due to high transport costs, determines the need to find radical solutions and change approach to the energy supply to the region. The main step towards solving this problem may become elaboration of the Small Energy Development Strategy for Arctic.

Table 1. Duration of the heating season and indicators of climatic parameters in the Arctic regions of Yakutia

		Area of the territory 1000.km^2	**Number of population**	**Air temperature of the coldest five-day week, °C**	**Absolute minimum air temperature, °C**	**Duration of a heating season, days**
Yakutia`s Arctic districts		**1620,5**	**67 674**			
1	Abyysky	69,4	3979	-53	-58	284
2	Allaikhovsky	107,3	2708	-52	-61	297
3	Anabar	55,6	3597	-55	-60	308
4	Bulunsky	235,1	8340	-56	-62	295
5	Verkhnekolymsky	67,8	4049	-51	-59	265
6	Verkhoyansk	137,4	11133	-61	-68	272
7	Zhigansky	140,2	4178	-54	-60	275
8	Momsky	101,7	3973	-58	-62	267
9	Nizhnekolymsky	86,8	4290	-53	-63	274
10	Oleneksky	318,1	4148	-57	-60	284
11	Srednekolymsky	125,2	7424	-52	-58	277
12	Eveno-Bytantaysky	120,3	2827	-58	-65	275
13	Ust-Yansky	55,6	7028	-53	-62	312

Source: Sleptsov, 2015.

2. ENERGY SYSTEM OF THE ARCTIC ZONE OF THE REPUBLIC OF SAKHA (YAKUTIA)

The Republic of Sakha (Yakutia) is one of the Russian Federation regions, featured by decentralized system of energy zones, i.e. on its territory there are several energy regions with energy sources different by types and in terms of fuel used. Arctic municipal areas of the republic belong to the northern energy area, where small diesel power plants are used, and now the zone is energy-excessive.

2.1. Electric power industry

Power system of Arctic municipal regions of the Republic of Sakha (Yakutia) by electric power generation includes 85 diesel power plants of JSC Sakhaenergo.

Total installed capacity of diesel power plants is 162 MW. To generate electricity to ensure vital activity of population of Arctic territories of the region, it is necessary to provide 56,569 th. tons of diesel fuel and 1,031 th.tons of crude oil (table 2).

Table 2. Annual fuel consumption on power production in the Arctic regions of Yakutia, 2018.

		Number of diesel power plants, piece	Rated capacity, MW	The average annual fuel consumption on production of electricity, ton	
				diesel fuel	crude oil
Yakutia`s Arctic districts		**85**	**162**	**56 569**	**1 031**
1	Abyysky	7	7,6	3 190	0
2	Allaikhovsky	5	9,4	2 526	0
3	Anabar	2	6,6	2 773	0
4	Bulunsky	8	20,7	8 150	785
5	Verkhnekolymsky	5	15,9	5 453	0
6	Verkhoyansk	20	20,7	9 249	0
7	Zhigansky	4	8,8	3 592	246
8	Momsky	4	5,8	3 156	0
9	Nizhnekolymsky	4	11,7	2 084	0
10	Oleneksky	3	6,5	2 904	0
11	Srednekolymsky	10	11,6	5 136	0
12	Eveno-Bytantaysky	3	4,1	1 376	0
13	Ust-Yansky	10	32,6	6 980	0

Source: authors, calculations

2.2. Heat supply

Currently 155 boiler stations for heating and water supply operate on the territory of Arctic municipal regions of the Republic of Sakha (Yakutia), 83 of which are heated on coal and 72 - on oil products (crude oil, diesel). Total length of the main heat supply network is 577 km. In 2018, boiler stations of Arctic territories produced 1394.1 thousand Gcal, of which 25% were lost (Table 1). All boiler stations of Arctic settlements of the republic belong to SUE „Housing and community amenities of RS (Ya)" - the leading monopolist in the utility services market of the republic by territorial presence and number of served heat generation sources as well as by coverage of budgetary institutions. According to the enterprise's investment program, annually, in order to up-

grade heat supply facilities and develop fundamentally new low-energy technologies, production branches replace boiler, combustion equipment, as well as replace utility heat supply networks.

Table 3. Annual fuel consumption on power production for heat supply of the Arctic of Yakutia

		Quantity of boiler rooms of heat supply		The average annual need for resources for heat supply, ton		The volume of the developed heat for 2018, thousand Gcal
		coal	crude oil	coal	crude oil	
Yakutia`s Arctic districts		**83**	**72**	**241 191**	**59 868**	**1394,1**
1	Abyysky	11	3	18 000	3 350	96,5
2	Allaikhovsky	0	10	-	9 238	69,6
3	Anabar	0	8	-	-	73,7
4	Bulunsky	0	11	-	16 264	153,2
5	Verkhnekolymsky	12	0	36 914	-	114,4
6	Verkhoyansk	24	0	66 189	320	203,4
7	Zhigansky	7	1	20 763	320	81,7
8	Momsky	4	9	4 762	9 000	105,7
9	Nizhnekolymsky	4	2	22 413	4 198	97,8
10	Oleneksky	0	17	-	6 254	75,7
11	Srednekolymsky	13	1	36 860	494	133,3
12	Eveno-Bytantaysky	3	6	-	4 550	38,2
13	Ust-Yansky	5	4	35 290	5 880	150,9

Source: authors, calculations

3. METHODOLOGY

Purpose of the study is to develop practical recommendations for improving the mechanisms of provision of fuel and energy resources to Arctic municipal regions of the Republic of Sakha (Yakutia).

To achieve the purpose, the following tasks were set: to analyze current state of the energy system in Arctic municipal regions of the republic; identify economic problems associated with the specifics of the region; to offer practical recommendations for improving the mechanisms of provision of fuel and energy resources in Arctic conditions of the Republic of Sakha (Yakutia). The main study methods include system approach, analysis and synthesis, comparative analysis, analysis of statistical data, expert method. The study information base included annual reports of fuel and energy complex enterprises of the Republic of Sakha (Yakutia), such as PJSC Yakutskenergo, JSC Sakhaenergo, SUE „Housing and community amenities of RS (Ya)", as well as tariff plans for transportation of oil products of JSC Sakhaneftegazsbyt.

4. ANALYSIS OF PROBLEMS OF PROVIDING RESOURCES TO ENERGY SYSTEM OF ARCTIC OF THE REPUBLIC OF SAKHA (YAKUTIA)

4.1. Provision of resources to electric power industry facilities

The following contractors deliver diesel fuel for the production program: PJSC AK Yakutskenergo, OJSC NK Tuymaada-neft, OJSC Vostek, JSC Sahaneftegazsbyt, JSC Artikoil and SUE „Housing and community amenities of RS (Ya)". CJSC Irelyakhneft, JSC Teploenergoservis, JSC Teploenergo supply crude oil. In 2018, 56,569 t. tons of diesel fuel and 1,031 t. tons of crude oil were transported.

Annual delivery of diesel fuel for the needs of Arctic small diesel power plants is carried out by complex transport schemes using points of long-term storage until the next navigation. For example, let us consider the scheme for provision of resources for electricity generation in Srednekolymsky Municipal Region: 1 transport scheme „Ust-Kut river port – oil depot in Nizhnekolymsk – storage within 107 days – delivery by motor transport through winter snow road – Srednekolymsk oil depot".

The price of transportation of diesel fuel consists of the cost of transportation by river tankers and road transport in the winter period from nearby oil depots. The average cost of delivery of diesel fuel to the Arctic regions exceeds the cost of delivery to the southern regions of the Republic by 8-11 times. Thus, share of transport component in the cost of electricity production makes 36% - 48%.

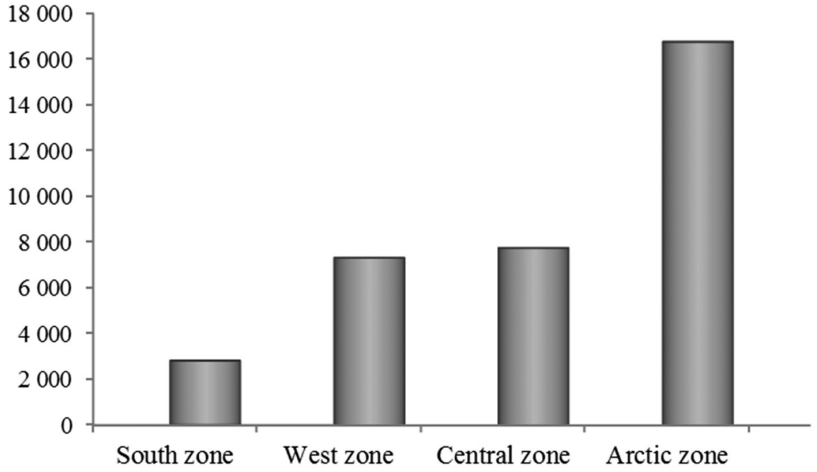

Figure 2. Cost of delivery of diesel fuel, RUB / ton, calculations 2018 year

Source: authors, calculations

In order to avoid high electricity tariffs for the population of the Arctic municipal districts the Government of the republic use subsidization of power supply at the expense of the large industrial enterprises. Thereby, using the unique instrument of „cross subsidizing" in region power industry. Economic reasonable price of production of electricity in the Arctic of Yakutia goes above the established tariffs by 10 times. The half-received profit is compensated for the account of overestimate of tariffs in the central part of the republic and financial investments of large industrial companies.

4.2. Provision of resources to heat supply facilities

To ensure uninterrupted operation during the heating season 2018, totally 709,551 t. tons of resources were delivered, of which 437,726 t. tons of coal and 186,551 t. tons of oil products. Currently, SUE „Housing and community amenities of RS (Ya)" independently organizes delivery of fuel and energy resources and provision of non-reducible reserve of fuel and energy resources. Department of Fuel Supply of the Enterprise organizes management of fuel and energy resources supply to the regional branches and distribution thereof. Coal for the needs of SUE „Housing and community amenities of RS (Ya)" is transported from Zyryansky coal mine and from Verkhnekolymsky branch storage base. Oil products supplied during the short navigational period are being delivered from oil depots of JSC Sakhaneftegazsbyt. Principal transport services providers are local shipping and transportation companies. At the same time, JSC Sahaneftegazsbyt provides storage services to SUE „Housing and community amenities of RS (Ya)" in its oil depots in Arctic territory for RUR 11.17 per ton per day.

Since the main supply of oil products is carried out during navigation period, the enterprise does not have enough own funds to purchase annual volume of fuel. In this regard, the enterprise has to tap a credit facility, interest on which is included into sale prices. Taking into account the policy of government support for providing fuel and energy resources to areas with local energetics, the enterprise receives publicly funded loans. Also, transportation costs for delivery of fuel and energy resources for Arctic municipal needs are annually subsidized from the republican budget.

5. FORECAST OF DEVELOPMENT OF ARCTIC ENERGY SYSTEM IN THE REPUBLIC OF SAKHA (YAKUTIA) BASED ON RENEWABLE ENERGY SOURCES AND LOCAL FUELS.

Renewable energy sources (RES) due to high capital intensity thereof at present time and in the immediate future can be effectively used only in decentralized power supply zone. The main objective of applying renewable energy sources is to reduce consumption of diesel fuel, reducing the cost of its delivery. The electric power generated by the Batagai station allows to save up to 300 tons of diesel fuel annually. The Republic of Sakha (Yakutia) has a significant potential for renewable natural energy resources, which makes it possible to effectively apply them in local energy facilities. In this regard, use of renewable energy sources is extremely relevant.

As at beginning of 2019, 10 renewable energy sources with total capacity of 2125 kW operate in the arctic municipal territories, including 8 solar power plants (SPP) with total capacity of 1225 kW and 1 wind power plant (WPP) with capacity of 0.9 MW. Forecast of development of the energy sector in terms of renewable energy sources is currently based on investment plans of JSC Sakhaenergo and PJSC Yakutskenergo. Until 2022 it is planned to introduce a complex of wind power plant in the settlement of Tiksi (Bulunsky district) with total capacity of 3 MW, as well as power storage and automatic control systems, commissioning of new generating equipment at 13 diesel power plants to replace the old units with total capacity of 8,65 MW.

Table 4. Installed capacity of renewable energy sources in the Arctic zone of the Republic of Sakha (Yakutia)

Municipal district	Human settlement	Total installed capacity, kW	Diesel fuel economy, tons / year
Solar power plant			
Abyskiy	Cyberganja	20	6,39
Verkhoyansk	Dulgalah	10	8,53
	Batagay	1000	230,4
	Betankes	40	12,15
	Yunkyur	40	14,15
	Stolby	10	4,1
Zhigansky	Cystatyam	40	14,15
Oleneksky	Ayk	40	13,05
Eveno-Bytantayskiy	Djargalah	15	5,86
	Subtotal	1225	313,22
Wind power stations			
Bulunskiy	Tiksi	900	250
	Total	2125	563,22

Source: Ivanova, 2018.

Prospective use of local fuels is planned due to construction and commissioning in 2020 of Zyryanskaya midget power plant for power supply to nearby settlements. Coal from Zyryanskoe

field will be used as fuel. Rated output power capacity of the midget power plant will be 10 MW, the thermal one - 25 Gcal / h. Russian Arctic possess vast local resources of renewable energy, which can be widely utilized for the industrial and household needs. Still, the use of combined and renewable power plants is limited in the Arctic region both in Russian and worldwide due to the specific climate conditions and corresponding challenges. The analysis of several years of operation of solar power plants in the Arctic regions of the Republic showed that the generation of electricity by solar power plants during the year has a spring maximum and is almost zero in the winter, regardless of the latitude of the terrain. The latitudinal location also does not influence the payback period, but the dependence on the price of substituted diesel fuel is traced. The payback period on average is about 10 years. The appearance of an additional source of energy increases the reliability of the power system of isolated settlements.

6. CONCLUSION

Within the framework of spatial development and strengthening of energy security of the regional energy systems of the Arctic zone, the long-term objectives are to implement a set of measures to ensure:

- formation of coal mineral resource centers in the Arctic zone;
- territorial and production optimization of coal mining and transportation of coal products;
- optimization of transport logistics and development of transport infrastructure.

In order to create favorable conditions for the use of renewable energy sources on the territory of the Arctic municipal districts of the Republic of Sakha (Yakutia), state support measures should be provided:

- formation of pricing policy aimed at promoting the use of renewable energy sources, as well as energy produced from renewable energy sources;
- formation of mechanisms to stimulate investment activity by attracting credit resources for the implementation of renewable energy projects, including the creation of profitable conditions for investors.

The high cost of production and annual costly measures to ensure the resources of the energy system of the Arctic municipal regions of the Republic of Sakha (Yakutia) cause the need for a state policy to increase the share of renewable energy sources. Creation of a system of legal and financial and economic mechanisms that provide economic incentives on part of public authorities for operations in the sphere of renewable energy sources use will ensure environmental protection and rational use of natural resources.

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