Current trends and problems in the formation of heat supply infrastructure in the Russian Arctic

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Abstract. The article deals with the most important problems of the regional energy complex in the subjects of the Arctic zone of the Russian Federation. The main attention is paid to the aspects of formation of territorial heat supply systems which are the basic components of the life support infrastructure in the harsh climatic conditions of the Arctic and the Far North. Despite the predominance of energy sector in the economics of the Russian Arctic, the availability of the raw material base and an increase in the flow of investment resources to the energy industry, there is a further obsolescence and reduction of fixed assets of municipal energy supply. The highest level of heat supply and utility rates is noted here. The strengthening of these energy threats is a factor limiting the social and economic growth of the Arctic territories. The author substantiates the conclusion that some of the previously existing territorial infrastructure advantages of the Russian Arctic territories have been lost. It has led to a reduction in the total number of heat supply units, thermal energy territorial production and also the length of heat and steam networks.

1. Introduction

Focusing on the development of the Arctic's raw materials, transport, production and service base of the fuel and energy complex has created the necessary conditions for economic and technological growth in almost all sectors of the Russian economics. Among them oil and gas production, export and processing of Arctic raw materials will certainly take a leading place for decades to come. The study of aspects of industrial development, transport and rational use of fuel and energy resources has become an important part of interdisciplinary research on the development of national productive forces. A comprehensive transport and energy approach has established itself and taken special place in the strategy for developing the Russian Arctic [1].

According to experts, the formation of the basic elements of the territorial energy infrastructure in the Arctic zone of the Russian Federation (AZRF) is uneven [2]. The main impetus was given to industry systems that operate in a special economic regime. First of all, they provide fuel and energy resources (including electricity and heat) to various categories of industrial consumers. These include manufacturing enterprises that operate in specialized production areas, industrial sites and areas of new industrial development [3]. At the same time, main elements of the socially important energy infrastructure such as municipal heat supply systems, public utilities used for servicing the housing stock are experiencing systemic difficulties in their development [4]. In this study, together with the issues of the fuel and energy complex, it is proposed to consider in more detail the current specifics.
and systemic problems of municipal heat supply as one of the key components of the life support infrastructure of the Arctic.

Fuel and energy sector specialization prevails among the leading branches of the Arctic industry in Russia. Despite this, the problems of territorial energy supply still remain highly relevant [5]. The search for ways to resolve them has been conducted throughout all the historical stages of economics transformation in the Arctic. Its results are of particular scientific importance and significance in the formation of territorial management systems focused on taking into account the specifics of large, but poorly developed territories with vulnerable ecology and isolated energy supply systems. The most difficult to solve are territorial energy problems, the specifics of which are associated with the conditions of focal spatial development, the lack of fuel and raw materials base and limited accessibility of transport networks [6]. Almost all subjects of the Russian Federation within its Arctic zone have characterized by disproportions in the provision of fuel and energy resources. Certain types of fuel used for thermal energy production dominate in the structure of territorial energy consumption. For example, in the Yamalo-Nenets Autonomous Okrug and Nenets Autonomous Okrug the main fuel resource is natural gas, while in the Murmansk Oblast oil products and coal are used. Several large projects are being implemented in the Russian Arctic, aimed at diversifying territorial energy supply systems and increasing the use of renewable and alternative energy that can improve the reliability of socially important energy infrastructure [7]. When studying the practical possibilities of overcoming these problems it is necessary to note the unique experience of creating floating nuclear thermal power plants as one of the basic directions of innovative development of the regional energy complex. Its further development can significantly change both the structure of territorial energy consumption and the existing imagination about the level of technologies domestic energy enterprises are used. The utilization of excess heat generated by nuclear power plants as a by-product in the production of electric energy is recognized as an energy-efficient and safe solution in industrialized countries across the world [8]. Municipal heating and hot water supply based on the use of nuclear energy sources have become widespread in Russia, the United States, Canada and the EU [9]. Research and production subdivisions of the state Corporation "Rosatom" have developed a project for a mobile specialized marine platform that can accommodate auxiliary equipment and reactor blocks of a floating nuclear thermal power plant (FNPP). A special-purpose lead vessel named "Akademik Lomonosov" was built. She is planned to be used for heat and electricity supply to consumers of Pevek, as well as Chausky and Bilibinsky municipal districts of the Chukotka Autonomous Okrug. FNPP is installed on the equipped stationary berth of the sea port of Pevek. Since December 2019 the stage of pilot operation is being conducted. The connection and supply of electricity to the isolated grid of Chausky and Bilibinsky municipal districts was carried out. In 2020 connection to municipal heating networks will be made and "Akademik Lomonosov" should put into commercial operation. There are plans to build a series of 7 mobile transportable low-power units, whose performance characteristics are adapted for supply of large industrial enterprises and municipal consumers in the Arctic zone of Russia [10].

In comparison with such truly revolutionary projects expert’s proposals on the possibilities of using wind power plants for heating in the Arctic look familiar [11]. Some of them also received their practical implementation. On the Kola Peninsula plans are underway to build the largest wind farm beyond the Arctic Circle. Its peak capacity will be more than 200 MW by 2021. In the Arctic there are also small integrated wind-diesel installations that are used in isolated power systems [12]. Research is underway to include them in the heat supply system of remote localities in the Murmansk Oblast [13] and the Chukotka Autonomous Okrug [14].

As weaknesses of alternative and renewable energy projects in Russia, it should be noted that almost all of them are based on the use of foreign components [15]. In the Far North construction and placement of wind farms is extremely fragmentary. There are a number of environmental and technological limitations, which, combined with long payback periods, significantly reduces the investment attractiveness and scope of such energy innovations [16].

Nevertheless, with the joint technological and financial participation of foreign companies and funds, in the Arctic zone of Russia pilot projects have been implemented. They were focused in the
field of thermal energy production based on the burning of peat fuel, wood chips, biomass and waste from the woodworking industry [17]. Also there are a number of joint targeted initiatives to expand cross-border cooperation between municipal authorities of the northern regions of the Arctic states, aimed at reducing environmental risks and consequences of production activities of heat and power enterprises, increasing their energy efficiency. The most well-known are the environmental partnership programs as part of the Northern Dimension policy. Financial support from EU funds is directed to the modernization of municipal heating systems in cities in the European North of Russia (in the Murmansk and Arkhangelsk Oblasts). Some scientific projects have been implemented on the basis of the Northern (Arctic) Federal University named after M. V. Lomonosov (for example, the projects of the Kolarctic cross-border cooperation program "Creating a basis for scientific cooperation on energy efficiency of buildings and infrastructure in the Far North", “Facility management of residential buildings in Barents region” and others). They are important for the formation of future urban engineering and power infrastructure in the Arctic [18].

Thus, experts consider the search for solutions to the problems of territorial heat supply to be a particularly important task for ensuring social and economic growth and improving the quality of life of the local population in the Arctic. The development of the thermal energy sector, especially the work to reduce the rate of growth in the cost of utilities, is recognized as a strategically important area of responsibility of regional authorities [19]. The highest level of cost indicators for heat and power enterprises in the Arctic is due to the state of the regional fuel and energy complex infrastructure. The main impact on the economic efficiency of production activities and the processes of their tariff formation is caused by the loss of previously existing territorial infrastructure advantages of the Russian Arctic. This conclusion was made by the author on the basis of statistical data available in the Unified Interagency Information Statistical System (UnISS).

2. Discussion of possible ways to solve the problem and the results obtained
The analysis of regional heat and power infrastructure traditionally involves a close study of the characteristics of territorial heat and power facilities and heat networks. Let's look at them in more detail.

Table 1 shows changes in the quantitative composition of heat sources in the Arctic zone of Russia during 2000-2018. It can be noted that by 2015 there was a significant reduction in their total number. The share of Arctic thermal generation facilities on a Federal scale decreased. Negative demographic processes, as well as a decrease in demand for thermal energy from the industry, have become the main reason for the decommissioning of some unprofitable boiler plants.

| Regions of the Russian Arctic zone                  | 2000 | 2005 | 2010 | 2015 | 2018 |
|---------------------------------------------------|------|------|------|------|------|
| Nenets Autonomous Okrug                           | 56   | 57   | 51   | 65   | 111  |
| Murmansk Oblast                                   | 117  | 147  | 139  | 121  | 133  |
| Yamalo-Nenets Autonomous Okrug                   | 357  | 305  | 274  | 250  | 246  |
| Chukotka Autonomous Okrug                         | 88   | 74   | 49   | 44   | 49   |
| Number of heat supply units in the Russian Arctic zone, total | 618  | 583  | 513  | 480  | 539  |
| Russian Federation, for reference                 | 67913| 64895| 73120| 75955| 74782 |
| Share of the Russian Arctic zone on a national scale, % | 0.9  | 0.9  | 0.7  | 0.6  | 0.7  |
| Number of residents per heat supply unit in the Russian Federation | 2163 | 2211 | 1954 | 1926 | 1964 |
In the AZRF the prevalence of elimination processes over commissioning new heating facilities has led to a further strengthening of district heating competitive position. There was a steady increase in the number of residents per heat supply unit until 2015. This situation has changed in recent years. The share of new units is growing, mainly in the Nenets and Yamalo-Nenets Autonomous Okrugs. On the contrary, on the national scale, there are signs of a reverse trend. There is an active increase in the potential of decentralized energy. In General, this conclusion is confirmed by the results of earlier studies [20].

Table 2 shows the dynamics of territorial production of heat energy in the AZRF. The data indicate a significant (more than 28%) decline in thermal energy production observed from 2000 to 2018. On a Federal scale the reduction in production over the same period was twice as small (only 14%). There is a decrease in the share of energy production in the Arctic regions in all-Russian volumes. A comparison of data on per capita heat generation in the Russian Arctic zone with similar values in the Russian Federation shows approximately two times their ratio over the entire observation period. Taking this into account, we can draw conclusions about the invariability of the existence of a high-cost energy regime for people to stay and conduct economic activities in extreme Arctic conditions. At the same time the indicators of output per unit of heat supply do not show such a stable ratio. We can say that the change in the quantitative composition of heat sources does not significantly affect the territorial production of heat energy. So the main specific features of the functioning of heat supply systems in the northern and arctic areas of Russia are preserved.

| Regions of the Russian Arctic zone | 2000 | 2005 | 2010 | 2015 | 2018 |
|-----------------------------------|------|------|------|------|------|
| Nenets Autonomous Okrug           | 385  | 379  | 409  | 368  | 344  |
| Murmansk Oblast                   | 10 362 | 9 772 | 9 580 | 7 958 | 7 793 |
| Yamalo-Nenets Autonomous Okrug    | 10 154 | 8 563 | 8 308 | 7 080 | 6 613 |
| Chukotka Autonomous Okrug         | 967  | 1105 | 971  | 1 009 | 961  |
| Heat generation in Russian Arctic zone, total | 21 868 | 19 819 | 19 268 | 16 415 | 15 711 |
| Russian Federation, for reference  | 998 678 | 952 210 | 872 847 | 792 314 | 857 571 |
| Share of the Russian Arctic zone on a national scale, % | 2,2 | 2,1 | 2,2 | 2,1 | 1,8 |
| Heat generation per capita in the Russian Arctic zone, Gcal | 14,2 | 13,5 | 13,6 | 11,7 | 11,3 |
| Heat generation per capita in the Russian Federation, Gcal | 6,8 | 6,6 | 6,1 | 5,4 | 5,8 |
| Heat generation per heat supply unit in the Russian Arctic zone, thousands Gcal | 35,4 | 33,9 | 37,6 | 34,2 | 29,1 |
| Heat generation per heat supply unit in the Russian Federation, thousands Gcal | 14,7 | 14,6 | 11,9 | 10,4 | 11,4 |

Source: UnISS. Federal State Statistics Service (Rosstat).

The decrease in energy demand and production volumes in the national heat and power industry has a significant impact on the state of heat transport subsystems. Table 3 shows the length of thermal and steam pipeline communications in Russian Arctic region. Both in the Federal and Arctic region
scale, there is a steady decline in their absolute values. In Russia the total reduction in the length of networks in 2018 compared to the level of the base year 2000 was 9.8%. In the Russian Arctic zone liquidation processes were more intensive (here the reduction was 16.2%). Also there is a decrease in the share of the Arctic region on the Federal scale, as well as a decrease in the population's availability of heat supply networks.

Table 3. The length of heat and steam networks in two-pipe calculation in kilometers, 2000-2018

| Regions of the Russian Arctic zone | 2000 | 2005 | 2010 | 2015 | 2018 |
|-----------------------------------|------|------|------|------|------|
| Nenets Autonomous Okrug           | 100  | 89   | 71   | 82   | 99   |
| Murmansk Oblast                   | 1 346| 1 388| 1 091| 1 068| 997  |
| Yamalo-Nenets Autonomous Okrug    | 2 256| 2 029| 2 033| 1 985| 1 971|
| Chukotka Autonomous Okrug         | 293  | 230  | 301  | 291  | 280  |
| Russian Arctic zone, total        | 3 994| 3 735| 3 497| 3 426| 3 347|
| Russian Federation, for reference | 186 586| 177 175| 171 276| 171 448| 168 342|
| Share of the Russian Arctic zone on a national scale, % | 2,1 | 2,1 | 2,0 | 1,9 | 1,9 |
| Length of heat networks per thousand of the population of the Russian Arctic zone | 2,59 | 2,55 | 2,47 | 2,45 | 2,42 |
| Length of heat networks per thousand of the population of the Russian Federation | 1,27 | 1,24 | 1,20 | 1,17 | 1,15 |

Source: UnISS. Federal State Statistics Service (Rosstat).

The marked manifestations of negative trends in the development of regional heat and power systems have led to the intensification of relevant investment projects. They are related to the replacement, reconstruction and construction of new heat supply facilities. Most of projects are implemented in the Nenets and Yamalo-Nenets Autonomous Okrugs. However on these territories there is no significant increase in the production capacity of new heat supply units as well as the volume of heat energy produced by them. They are leading in terms of liquidation and disposal of fixed assets of territorial heat supply facilities. Construction of less powerful heat sources with less capacity allows heat supply companies to reduce their own investment costs. Thus, a significant part of the necessary investment costs is redistributed to industrial consumers and local population. In the future, they will bear the increased costs to eliminate temperature discomfort and heat deficit during the peak loads of the autumn-winter heating season.

3. Conclusions
As a summary of the results of the study, it can be stated that during last two decades the Russian heat energy generation sector on the North and Arctic is characterized by negative changes. They are associated with the degradation processes that occurred in the territorial energy infrastructure of the Arctic zone of the Russian Federation. Signs of their manifestation are noted in the municipal energy sector, primarily in district heating systems. The results obtained indicate a clear reduction in the overall production and energy potential in the Russian Arctic, which leads to an increase in energy threats to Russia's presence in such a strategically important macro region. This causes quite reasonable skepticism of experts regarding the ability of the territorial infrastructure to provide sufficient growth in energy production and reliability of the territorial energy supply systems to fulfill the tasks of complex investment plans in the AZRF.
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