Assessment of rational options for energy supply to remote consumers of the Arctic zone in the context of the development of renewable energy

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Abstract. The article deals with the problem of power supply of various types of consumers of electric energy in remote regions of Russia and the Arctic zone in the context of the intensification of the development of renewable energy. The article substantiates the position that in order to ensure sustainable and rational energy supply to the largest group of consumers - small remote settlements-it is advisable to consider a set of measures in three main areas: energy saving and improving the energy efficiency of consumers, electricity supply based on geographically accessible energy sources, including renewable ones. It is shown that the key indicator of the development of renewable energy technologies in the Arctic zone and remote regions is the level of economically justified reduction of the "northern import" of fuel in the zone of decentralized energy supply, as well as cross-subsidization of energy tariffs for consumers of different target groups.

1. Introduction
For the first group of consumers, which includes enterprises for the development of oil, gas and coal deposits, it is advisable to use geographically available hydrocarbons for the production of heat and electricity and optimize their own costs through integrated management of the energy economy for the production and consumption of the extracted primary energy resource. As an example, it is worth mentioning the scheme of isolated power supply of the Novoportovskoye field (GTPP 96 MW), the Bovanenkovskoye field (GTPP 85 MW), the Yamal LNG integrated project (GTPP 376 MW). These technologies are widespread and widely used in the fields, with technical and economic indicators of domestic producers' generating equipment often lower than foreign analogues, therefore, the main objective of supply for this group of consumers is increasing the competitiveness of Russian power engineering industry, based on real demand from individual customers.

For the second group of consumers, which carries out energy-intensive mining away from the transport and energy infrastructure, it is advisable to consider the possibility of applying new technological developments in the nuclear industry, which eliminate the need for "northern delivery" of fuel in large volumes and provide a guaranteed source with a smooth schedule for the production of heat and electricity. At the same time, the availability of state support for the nuclear industry can ensure the financial attractiveness of this technology for large industrial consumers, whose high share of costs is the production of electricity at their own diesel power plants. Examples of implemented
projects are not yet available because the Low Power NPP technology is just beginning to develop and requires specific orders to turn production, but in the future, perhaps the construction of such sources in the fields of metal ores, rare-earth metals, diamonds and other minerals in Krasnoyarsk Krai, Chukotka Autonomous Okrug Sakha (Yakutia) and other Arctic regions, as an alternative to large-scale power grid construction.

State Atomic Energy Corporation Rosatom, with the involvement of specialized scientific departments, is working on options for creating Low Power NPP in a wide range of installed capacities. The Vityaz (1 MW), Shelf (6.6 MW), ABV-6 (9.5 MW), Iceberg (21 MW), and RITM-200 (50 MW) reactor plants are considered the most promising [1]. It is worth noting that the corporation is already implementing a project for the construction of a floating nuclear power plant with a capacity of 70 MW in the city of Pevek with planned commissioning in 2019, and is also working on the possibility of using Low Power NPP in mineral deposits in the Republic of Sakha (Yakutia) and in the Chukotka Autonomous Okrug. The objects of the North-Yakut Support Zone and the Russian Defense Ministry in the Arctic are also considered as possible sites for the use of Low Power NPP.

Consumers of the first and second groups belong to large infrastructure projects for the creation of reference development zones in order to create conditions for accelerated socio-economic development of the Arctic zone. The implementation of these complex projects is carried out with the participation of direct federal funding, including within the framework of the state program "Socio-economic development of the Arctic Zone of the Russian Federation" [2]. Individual projects on energy supply to consumers are implemented as part of other state programs. Thus, the construction of the floating NPP is included in the list of the main activities of the state program "Development of the Nuclear Power Industry" [3].

2. Materials and methods
The purpose of this study is to evaluate rational options for providing energy supply to consumers in remote areas in the Arctic zone and remote regions of Russia. To achieve this goal, the following tasks are set:

- To conduct a comprehensive analysis of the problems of functioning and development of isolated power supply systems for various groups of electric energy consumers;
- To determine the role of renewable energy sources that allow the most extensive use of the potential for the development of centralized and local energy systems in accordance with the long-term priorities of socio-economic development of remote regions of the Arctic zone.

The study used the following general scientific and specific methods that allowed the authors to solve the set goal and objectives of the study: statistical research, system analysis and synthesis, the method of analogy and comparison, the method of expert assessments.

3. Results and Discussion
The development of isolated power supply systems for consumers of the first and second groups is of considerable interest from scientific organizations and large businesses. In search of evidence-based decisions to select the most rational variant of supply for the long term there are various fundamental studies of resource potential of the Arctic zone regions, development of centralized and local energy systems in accordance with the long-term priorities of socio-economic development of regions. Of particular interest are the activities of the divisions of the Russian Academy of Sciences. In particular, Melentyev Energy Systems Institute of the Siberian Branch of the Russian Academy of Sciences (ESI) has been implementing the project "Research of Problems and Formation of Strategic Directions for the Development of Energy and Fuel Supply systems in the North-Arctic Zone in the East of Russia" for many years, and currently the project "Comprehensive assessment of energy supply schemes for the development of mineral resources in the Eastern Arctic sector of the Russian Federation" is being implemented [4-5]. Within the framework of these works, preliminary feasibility studies were carried
out for the construction of cogeneration plants on local hydrocarbon resources, as well as sites for the implementation of Low Power NPP construction projects at mineral deposits in the Republic of Sakha (Yakutia) and the Chukotka Autonomous Okrug. The feasibility of implementing projects for the construction of wind and solar power plants in the Arctic zone is also being considered. Based on the research conducted, interested investors can work out in more detail the possibility of raising funds for the implementation of specific projects within a separate feasibility study. At the same time, it is worth noting that the number of such projects is estimated in dozens, their development is limited by a high level of capital investment and the presence of the interest of large investors.

In order to ensure reliable and economical energy supply to the third largest group of consumers, which is small remote settlements where the main source of energy supply is power plants with "northern delivery" of fuel, it is advisable to consider a set of measures in three main areas: energy saving and improving the energy efficiency of consumers, electricity supply based on geographically accessible energy sources, including renewable, and improving the efficiency of housing and communal services. It is important to note that the development of each of these areas separately throughout the country is engaged in the relevant departments: The Ministry of economic development Ministry of energy and Ministry of construction, Ministry of industry and trade of Russia – in order to achieve synergies in the implementation of the development strategy of the Arctic zone and the Far East should strengthen their collaboration in the execution of the General plan and specific projects.

It is worth noting that leading organizations are conducting serious scientific work in this area as part of the state policy implementation in the field of energy conservation and energy efficiency improvement. Of particular interest is a comprehensive study conducted by the Center for Energy Efficiency (CENEF) on the topic "Low-carbon solutions for isolated regions of Russia with high energy costs" [6]. In this work, an analysis of the current situation of small consumers in the area of decentralized electricity supply was carried out and it was concluded that, despite the high cost of electricity production and the low efficiency of diesel power plants with "northern delivery", a significant share of the electricity produced is spent irrationally. At the same time, it is noted that only by eliminating problems with heating systems and upgrading lighting systems, the potential for energy savings can reach 35 – 45 %. Saving water and heat creates an additional indirect effect in the form of energy savings, the potential for saving thermal energy in many settlements of the Arctic zone is estimated at 40%. With additional costs for insulation and insulation of building facades, the potential for savings can be increased to 60-70%.

As an example, the CENEF "Energy Saving and RES Development Program in the urban settlement of Sangar for the period up to 2025" developed in 2017 in the Republic of Sakha (Yakutia), the results of which show that with a total capital expenditure of 943.5 million rubles for the period from 2017 to 2025 for the comprehensive modernization of the energy supply system and housing and communal services, the total cost of budget funds for energy supply to the municipality will be at least 37 %, and the cost of purchasing fuel at current prices will decrease by 30 %. Unit costs for energy supply will be reduced from 141 thousand rubles to 90 thousand rubles per person, for fuel from 49 thousand rubles to 30 thousand rubles per person. The total cost savings in 2017 prices will amount to about 1.4 billion rubles [7].

The investment performance assessment carried out in the work has the following indicators of project implementation: NPV for 10 years (from 2018 to 2027) - 33.5 million rubles, IRR - 30.4 %, discounted payback period - 5 years.

The following options are proposed as sources of funding: budget financing (federal, regional and municipal levels); integrated energy contract; use of tariff deductions of the Far Eastern surcharge; combined sources of financing; of which the first and third have the best economic indicators.

As environmental effects of the program, it is expected to reduce greenhouse gas emissions (carbon monoxide, methane and nitrous oxide) by 55% and reduce the emission of pollutants (sodium oxides, sulfur oxide, solid particles, etc.) into the atmosphere by reducing the consumption of coal, diesel fuel and oil by 54%.
Taking into account the budget deficit for the implementation of measures to save energy and improve the energy efficiency of municipalities, a regulatory framework has already been developed for the organization of such works on the basis of an energy service contract [8-9]. Organizational model assumes the same level of subsidies from the region for the energy supplying organization in the municipality for compensation of lost income for a period of energy service subject to payment of an energy service company. The energy supply organization enters into an energy service contract with the investor, who carries out the modernization of the generation at its own expense.

If it is necessary to attract bank financing, a scheme for concluding a concession agreement between the region and the energy company may be considered. As an example, we can cite the implemented project of modernization of inefficient diesel generation through the use of photovoltaic systems in the rural settlement "Menzinskoe" of the Zabaykalky Krai with the use of bank financing.

Organizational model includes the conclusion of a concession agreement between the Administration of the Zabaykalky Krai (the grantor) and IDGC of Siberia (the concessionaire), which assumes the responsibilities of the energy supply organization and invests in energy management of municipal formation under the guarantee of return on investment due to regional subsidies for reimbursement of lost income in accordance with the protected rate. The concessionaire attracts bank financing, carries out the modernization of the power grid facilities and enters into an energy service contract for the modernization of generating sources with the energy service operator (OAO Avelar Solar Tehnology). The operator at its own expense modernizes old plant in settlements with the construction of autonomous generating units (AGU) on the basis of photoelectric converters, the compensation due to the energy service payments.

Despite the obvious advantages of implementing similar projects in the decentralized power supply zone of Russia, in many localities, instead of realizing the potential for saving electricity and using renewable energy to eliminate its deficit, the regional authorities have already built or are planning to build new diesel plant stations with "northern delivery" of fuel, or are planning to build capital-intensive power grid facilities to connect to the centralized power supply system, which is associated with the distribution of costs between budgets and energy companies at different levels. Therefore, the coordinated development of programs of electric power development, and regional and municipal energy efficiency programs and energy efficiency with the allocation and control of financial resources for the implementation of reasonable measures are essential.

A particularly clear example of inconsistency in the implementation of measures to ensure the energy supply of small remote consumers is the project for the development of the Solovetsky Archipelago. At the current maximum electrical load is less than 2 MW and heat is less than 2 Gcal/h and the presence of a characteristic of the above-mentioned problems of the effective use of limited "northern delivery" to the energy resources of the government of the Arkhangelsk region, due to the high costs of the regional budget for the subsidization of tariffs for electric and thermal energy for consumers and expected growth of consumption because of new construction in the future, consider the option of building a submarine cable overhead lines with a length of about 130 km attaching the village of Solovetsky to the Arkhangelsk energy system as part of the UES of Russia, and as alternative options, the construction of a new diesel power plant and an LNG terminal with "northern delivery" of fuel is being worked out [10].

However, it is noted that in the framework of the decree of the Government of the Russian Federation dated 05.02.2016 No. 163-R on approval of the list of measures for the conservation and development of the Solovetsky Archipelago [11] along with efforts to ensure the energy supply provided by the construction of new and reconstruction of existing objects of social, cultural, educational, housing and tourist destination, which provide a promising growth in energy consumption. While ensuring the interaction of interested agencies at various levels, it is possible at the design and construction stage of these facilities to provide technical and organizational solutions for the effective use of limited energy resources and to prevent their shortage in the long term, and to implement the state energy policy in the Arctic zone in relation to small remote consumers in the zone of decentralized energy supply.
The result of this approach will be to achieve a rational use of scarce energy and financial resources on the basis of introduction of modern technologies and the formation of an illustrative example of a comprehensive caring attitude of the state to the cultural heritage, the environment, improve the comfort of living of the local population and tourist attractiveness of the region, which will stimulate increased interest in sustainable innovation among public institutions, citizens and businesses across the country.

The need for further development and implementation of renewable energy technologies in the Arctic zone for large-scale use is regularly discussed by the interested community in the framework of thematic conferences and forums, including such well-known ones as "The Arctic as a territory of dialogue", "The Arctic: present and future", "The Arctic: offshore projects and regional development", "Development of renewable energy in Russia" and many others, where the scientific and technical groundwork in this direction is presented, including the implementation of paragraph 59 of the previous Action Plan [12].

4. Conclusions

Based on the conducted research, it can be concluded that it is necessary to develop federal measures to support projects to reduce the dependence of consumers on the "northern delivery" of fuel, which will be based on increasing the responsibility of regional and municipal authorities for the systemic effect when implementing a set of interrelated measures in the framework of developing energy saving programs, improving energy efficiency and using renewable energy based on the consideration of a single fuel and energy balance of a locality.

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