Energy industry of the Republic of Sakha (Yakutia): Development Opportunities, Environmental Aspect

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***Abstract*— This study reveals the significant difference between the fuel and energy sector in the North of Russia and that in other regions of the country, driven by severe climatic conditions, the remoteness of communities, and intricate transportation networks. These factors constrain prospects for the development of the region and the advancement of its energy systems specifically. To ensure reliable and uninterrupted energy supply, it is essential to carefully consider all energy development factors. It is crucial to take into account the central role of energy in the socio-economic development of the region, as well as the need to reduce environmental impact and ensure the safety of energy infrastructure. According to the Federal Law "On Strategic Planning," the strategic directions for energy development in the northern and Arctic regions should be continually updated. To accomplish these objectives, the theory and methods of the systems approach in energy development studies are applied. Concurrently, it is essential to use tools that ensure the completeness and integrity of the information base for effective strategic planning.**

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***Index Terms*— northern region, energy sector, energy supply, distributed generation, environmental impact.**

I. Introduction

The Republic of Sakha (Yakutia) is a region of Russia whose energy potential significantly exceeds both its current and future needs. It has the capacity to substantially influence the fuel and energy balance of the Far East, Eastern Siberia, and the entire country. Developing a prospective fuel and energy balance for the regional energy industry requires the use of a systems approach. This approach involves analyzing the situation and justifying appropriate actions.

Within this approach, the object under consideration is a set of enterprises and companies that together constitute the fuel and energy sector as an integrated entity. Their operations are interconnected, as they are linked by the production and consumption of energy resources. At the same time, this set is open to interaction with other regional and interregional economic and energy structures [1].

The energy sector of the Republic of Sakha (Yakutia) is a well-developed system encompassing all the key components of the fuel and energy complex, with the exception of nuclear energy. It includes the coal, oil, and gas industries; electricity and heat supply, as well as networks that supply energy resources to consumers. The energy sector plays a pivotal role in the Republic's economy, determining its state and future prospects. It contributes up to 38% of tax revenues to the republican budget and fully meets the region's needs for coal, natural gas, electricity, and thermal energy.

The contribution of the energy industry to the Republic's

tax revenue increased from 17% in 2007 to 38% in 2020. Notably, the oil and gas sector, with its well-developed pipeline infrastructure, experienced significant growth.

The energy industry and fuel and energy supply systems in the North, as subjects of study, differ considerably from similar systems in other Russia's populated regions. A specific methodology is required for projecting energy needs and justifying energy policy in the North to:

- Ensure reliable and uninterrupted energy and fuel supply to consumers;
- Maintain the leading role of energy in regional development;
- Provide fuel and energy supplies to areas with resource shortages and for export;
- Redirect the development of the energy industry to meet the needs of the population and the social sphere, ensuring the survival and improved living standards of people;
- Reduce the impact of the energy industry on the environment and human health, while adhering to stricter environmental regulations and safety standards for energy facilities.

The development of an innovative strategy for the energy industry must consider several factors that hinder socio-economic development in many Northern regions. These are an underdeveloped natural resource base, inadequate transport infrastructure, high energy and transport tariffs, a reliance on federal budget support, and limited domestic investment resources due to specific regional features. Each of these factors is characterized by inefficiency and requires extensive large-scale research for effective resolution [2].

Harsh climatic conditions, the remoteness of communities, and intricate transportation networks limit the development of the region and its energy supply systems. To effectively organize the operation of the energy system under such conditions, a well-thought-out energy development strategy is essential. The use of standard schemes and programs may be ineffective due to the unique climatic and geographic features of the region.

Let us now consider in more detail the various aspects involved in devising a strategy for energy development in the northern region. Based on many years of research, a logical framework for the formulation and implementation of regional energy policy has been established. It encompasses an analysis of specific trends in energy development in northern regions, given their natural, climatic, and socio-economic characteristics; offers a rationale for various possible scenarios for their socio-economic development, and delivers a mechanism for implementing the energy strategy that creates the necessary conditions for such development [3].

Many areas in the Republic of Sakha (Yakutia), particularly the northern ones, are not connected to the unified energy system. In these areas, electricity is supplied by autonomous power plants. Severe climatic conditions lead to quick wear and tear of equipment, resulting in increased maintenance and repair costs. Heat supply to the residential and industrial consumers in the region is also a critical socio-economic task. However, the heat supply facilities scattered over a large territory pose significant challenges for ensuring a reliable and high-quality thermal energy supply.

II. Stages Of Energy Development in the Republic of Sakha (Yakutia)

In 2020, the first stage of implementing the Energy Strategy of the Republic of Sakha (Yakutia) until 2030 was completed. Its main goal is to identify feasible and economically achievable conditions for the extraction (production) of energy resources, to enhance the existing energy industry, and foster the development of innovative fuel and energy solutions. This is essential to ensure the continued dynamic development of the Republic and improve the quality of life for its citizens [4].

During the review period, large trunk "ESPO-1" oil pipeline and the "Power of Siberia" gas pipeline were commissioned as part of the energy system of the Republic of Sakha (Yakutia). Impressive 110–220 kV power grid facilities were commissioned in the electric power industry. A new gas turbine power plant was built in the Central energy area, and all previously isolated load areas were connected to the Interconnected Power System of the East (IPS East) and the non-price zone of the Wholesale Electricity Market, along with several other advancements [5–9].

The stage from 2035 to 2050 is anticipated to be a period of the innovative energy development in Russia, marked by the transition to new technological capabilities for the efficient use of traditional energy resources and new energy sources, alongside the emergence of the active consumer [10].

Thus, the potential for the sustainable advancement of the Republic's energy industry can be achieved through:

1. The modernization and the implementation of innovative technologies that facilitate the more efficient use of natural resources. Current energy trends – especially the advancement of energy technologies – contribute to a more integrated technological connection across all phases: conversion, generation, transportation, and storage of energy. For example, implementing integrated heating and cooling systems at thermal power plants with gas turbine units, including district cooling supply for consumers through absorption chillers that use exhaust gas heat to generate cooling energy, can significantly enhance the efficiency of combined energy production in summer [11].

2. The integration of energy-efficient technologies in construction and public services, which will lead to reduced energy consumption. The use of advanced thermal insulation materials, automatic lighting and heating control systems, and other innovations will lower heat and electricity losses, thereby reducing the need to generate additional energy. Moreover, energy-efficient buildings and structures improve quality of life and decrease utility costs.

3. The widespread adoption of renewable energy sources for isolated and hard-to-reach consumers, which can significantly decrease reliance on expensive diesel fuel and cut the carbon footprint [12, 13].

An example is the potential for broader use of hydropower in the future. The Department of Energy Problems at the Larionov Institute of Physical and Technical Problems of the North, Siberian Branch of the Russian Academy of Sciences, has assessed the hydropower resources in Yakutia. After years of intensive research, an extensive body of knowledge has been gathered regarding the water energy resources of small rivers in the Arctic zone of the Republic of Sakha (Yakutia). This comprehensive and meticulous work, which involved the analysis and processing of large amounts of cartographic material, alongside years of field expeditions, was conducted for the basins of the Anabar, Olenek, Yana, Indigirka, and Kolyma rivers.

4. The sustainable development and minimization of environmental impact, which must be a priority, given the region’s environmental characteristics. The specific features of local ecosystems must also be taken into account when developing state programs and investment projects for new energy generation solutions. Furthermore, constant environmental monitoring and assessments are necessary to minimize environmental damage. Research on optimizing the interaction between coal mining hubs in South Yakutia and the natural environment reveals critical areas for further investigation. This includes examining resource and natural-geographical conditions such as cryogenic and other hazardous natural processes. Additionally, it is essential to assess the potential for absorption and dispersion of pollutants in emissions and effluents, all while considering region’s specific natural and economic conditions [14–16].

5. An integrated systems approach, which is essential to ensure the safe and reliable operation of complex technical and human-machine systems in industrial enterprises across the Republic of Sakha (Yakutia), particularly under the extreme climatic conditions of the North and the Arctic. The use of materials specifically designed for the climatic conditions of the Arctic and Central Yakutia will reduce failures and accidents [17].

The implementation of these pathways will not only reduce the negative environmental impact but also enhance the efficiency of energy resources.

III. Conclusion

The analysis of the current energy industry of the Republic of Sakha (Yakutia) revealed several categories of factors, which are essential for effective energy development planning. These factors include socio-economic, natural and climatic, industrial, energy-related, and environmental. It is important to recognize that these factors are interrelated and should be considered when building future development scenarios.

The accelerated advancement of the Arctic region necessitates the state support for the “Materials and Technologies for the Russian North and Arctic” program to be formulated as part of the Strategy for Scientific and Technological Development of the Russian Federation.

In accordance with the Federal Law “On Strategic Planning,” the strategic areas for energy development in the northern and Arctic regions must be continually revised and updated. The theoretical foundation for accomplishing the tasks relies on the theory and methods of systems studies of energy development. It is imperative that the tools employed in this context ensure a comprehensive and

cohesive information base required for effective strategic planning.

At present, a vital and urgent priority for the long-term development of our country and its northern and Arctic regions is the formulation of a scientifically informed strategy for the long-term advancement of the fuel and energy sector of the country and its northern and Arctic territories, especially in the context of the ongoing energy transition.

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