On Development Prospects of the Energy Industry in the Russian Far North

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Abstract — **This paper reviews the research activities of the Energy Department of the IPTPN SB RAS from 2018 to this day with a focus on development prospects of the energy industry in the Far North of the country through a case study of the Republic of Sakha (Yakutia). Systems studies of the energy industry require accumulating a wide array of information that vary in terms of its granularity. We review published research that addressed the issue of how researchers the raw data and what established sources of data are available to facilitate the analysis of energy systems operating in Yakutia. The aim of this study is to outline approaches to enhancing the quality of both fuel supply and modeled projections of the outcomes of integrated heating and cooling systems deployment in the city of Yakutsk. The simulations we performed attested to the availability of a sufficient amount of the waste heat as long as they have been in operation, including the periods of maximum possible cooling load. The values of key economic performance metrics support our claim of economic feasibility of such a project, given sufficient demand for cooling. The study also details recurring failures of one of the components of engineering systems operating in an Arctic village of Yakutia and proposes possible solutions. We conclude that either the design of the boiler or the material of the pipes has to be changed there. This is due to the fact that the pipes fail to operate properly under the extreme operating conditions, since the low ambient temperatures cause the intensification of heat transfer, and a lower temperature of exhaust gases contributes to moisture condensation and corrosion of the pipes. Finally, we outline main directions to be pursued in ensuring environmental protection by the efficient use of fuel and energy resources of Yakutia and detail the methods to be used to this end.**

Index Terms: **Russian Far North regions, energy sector, power supply to isolated and remote communities, environmental Impact assessment of operation of fuel and energy facilities.**

I. Introduction

The Energy Department of the IPTPN SB RAS has been involved in several studies on energy development prospects in the Republic of Sakha (Yakutia) since 2018. This paper attempts to recapitulate the main research findings obtained so far.

II. Main Part

The energy potential of the Republic of Sakha (Yakutia), one of the regions (subjects) of the Russian Federation, is abundant enough to cover the current and future needs of the region multiple times and has a significant impact on the formation of the fuel and energy balance of the Russian Far East and Eastern Siberia, and Russia as a whole.

The large-scale dynamics and structural changes in extraction (production) and consumption of primary energy resources in the RS(Y) date back to the 1980s. A revival of large-scale development and structural change in the energy sector of the Republic began only after the recession during the period of transition from a centrally planned and controlled economy to a market-driven economy at the end of the first decade of the 21st century. It occurred in line with the main anticipated trends laid down in the Energy Strategy of the Republic of Sakha (Yakutia) to 2030 [1–6].

The definition presented above along with the basic principles of the regional energy policy of the Far North of the country are at the core of a hierarchy of tasks for elaborating the vision of future large-scale development of the energy sector of the Republic of Sakha (Yakutia) and the methodological foundations for its development (Fig. 1).

Embracing the development presupposes a solid

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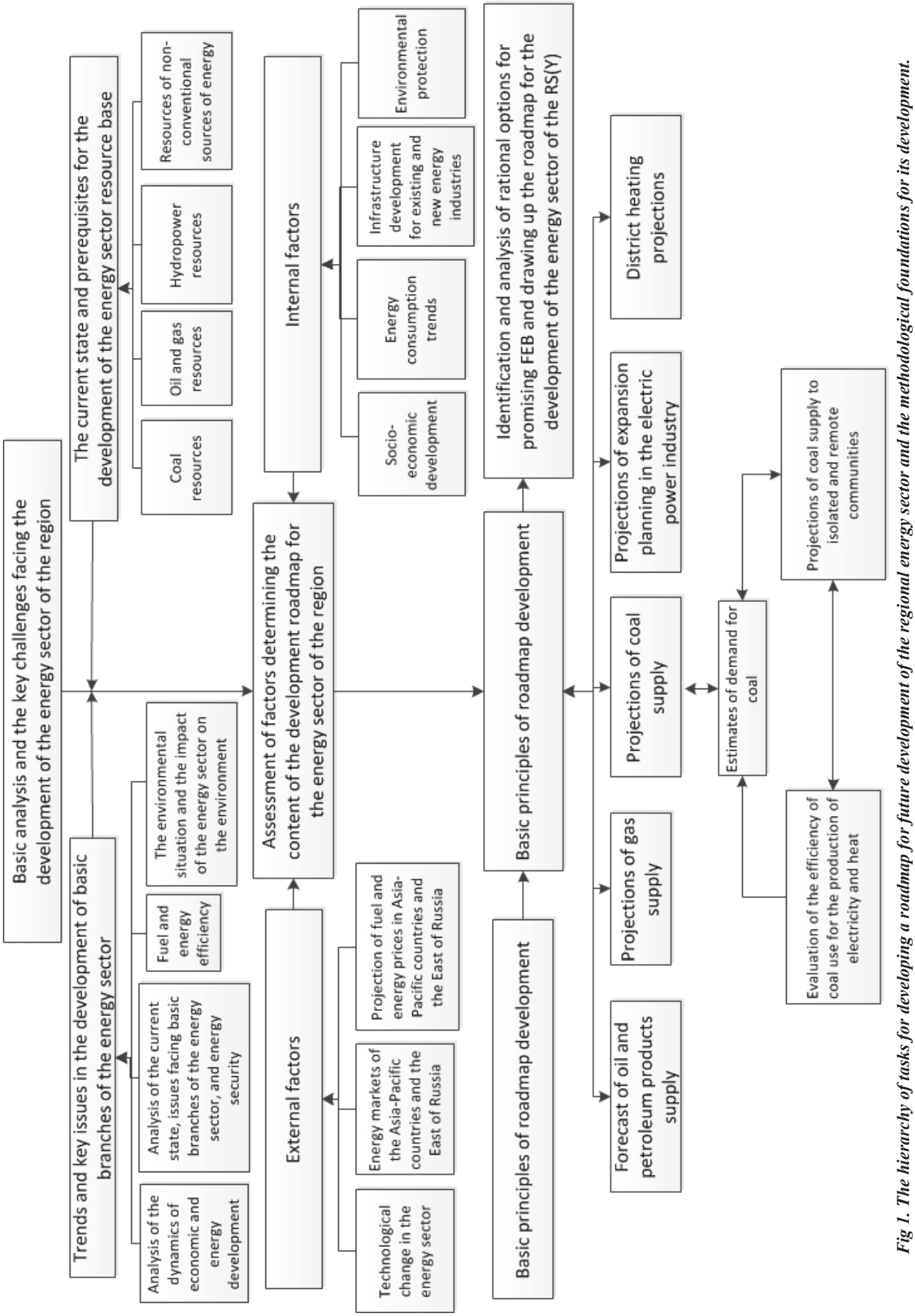

Fig 1. The hierarchy of tasks for developing a roadmap for future development of the regional energy sector and the methodological foundations for its development.

Table 1. The Structure of Key Information Retrieved from the information and Analytical Database on the Operation of the Energy System of the Republic of Sakha (Yakutia), Based on the Results Reported for Years 2016 to 2020

Type of activity of enterprises	Parameter group	Parameters
Heating companies	Heat balance	Production
		Auxiliary consumption
		Heat output
		Net heat output
		including
		public sector entities
		households
		by OKVED (All-Russian Classifier of Types of Economic Activities)
		for on-site production
		Loss due to transmission
	Parameters of heat networks	Length of pipelines, by diameter
		Specifications of pumping equipment
		Equipment health assessment
	Heat source parameters	Specifications of boiler equipment
		Installed capacity
		Type of the main fuel
		Backup fuel type
		Fuel consumption
	Scope of work to repair the heating system	Length of replaced pipelines, by diameter
Power generation companies	Power plant parameters	Actual basic circuit diagrams
		Main parameters of power grid equipment
		Information about generator equipment
		Installed capacity
		Available power
		Maximum load
		Fuel consumption
		Specific fuel consumption
	Electricity balance	Electricity generation
		Auxiliary electricity consumption
		Electricity supply from substation busbars
	Heat balance	Production
		Auxiliary consumption
		Heat output
		Net heat output
		including
		public sector entities
		households
		by OKVED (All-Russian Classifier of Types of Economic Activities)
		for on-site production
Power grid companies	Parameters of electrical networks	Basic circuit diagrams as of the beginning of the year
		Length of power lines, by voltage class
		Transformer power, by voltage class
		List of substations with a voltage of 35 kV and above, with their make, capacity, and number of power transformers indicated
		List of overhead lines with a voltage of 35kV and above, with their parameters (type of towers, make, and conductor cross-section) indicated
		List of power centers with restricted utility connections
		Electricity loss due to transmission

Large consumers	General information	Manufacturing KPIs
		Annual heat consumption
		Annual electricity consumption
		Maximum own load
	Information about own sources of thermal energy	Source type
		Installed capacity
		Connected load
		Specifications of boiler equipment
		Type of fuel
		Fuel consumption
	Information about own sources of electricity	Installed capacity
		Available power
		Information about generator equipment
		Connected load
		Fuel consumption
		Specific fuel consumption
		Electricity generation

understanding of the current situation. We regularly analyze key metrics measuring the performance of the energy sector of the Republic of Sakha (Yakutia), both in terms of production and consumption of energy resources and in terms of investment dynamics. To conduct energy studies at the level of entire systems, one has to collect a broad range of information of varying granularity. At the regional level, the degree of data aggregation decreases and, to a greater extent, it is necessary to collect primary information directly from each company that is involved in the energy supply process or is a large consumer. The mode of consumption of fuel and energy resources is influenced to a large degree by both by the operating conditions of the energy system and its structure. The conditions listed above for the collection of information on energy systems justify the need for independent collection and formation of data and analytical information databases of the parameters of investigated objects. The organizational complexity of information collection warrants the effectiveness of collecting data on a broader range of entities than is required for current research. This approach guides the search process allowing for quickly testing working hypotheses on the feasibility of more in-depth studies as they emerge. The information obtained as part of the work carry out includes that from the heating companies that cover more than 90% of the heating load of the municipalities of the republic. Other pieces of information come as the data obtained on the production and consumption of thermal energy by large industrial enterprises that make up more than 80% of the total industrial output. The information on power supply is received from all electricity generation and distribution companies, as well as from suppliers of last resort operating in the republic. The information is also collected about major companies in different sectors of economy that utilize their own electricity sources. Second, we have to face the challenge responding promptly to changing circumstances and enhance our strategic energy planning tools [7].

There is ongoing work to enhance the fuel supply. Despite the expansion of the scope covered by gas supply and a wide coverage of the households by district heating, the firewood still makes up a significant share of the regional energy balance. Firewood continues to be the primary fuel used for heating by the residential sector in rural areas. There are wood-fired boilers that supply heat to social sector consumers and households of the remote and isolated villages in addition to the decentralized sector. Here, the annual consumption of thermal energy is calculated on the basis of actual data for a region of the republic and the amount of firewood consumed for heating in those parts of the residential sector that are unconnected to any form of energy supply. A projection of the consumption of firewood by households to 2030 has been made according to the estimates provided above.

The technologies to produce and burn high-quality fuels from wood and agricultural waste could also be a contributing factor. Such technologies are the only available option for certain consumers. Today and almost up to the 1980-90s of the last century the firewood was used as main fuel for heating. In most municipalities, wood stocks have been severely depleted. The rate of deforestation has been higher than the reforestation rate up until now. Regular wildfires also contribute to a significant extent to the depletion of reserves. The production of wood pellets to cover the same heat load can reduce deforestation by two times due to a fuller use of wood. This also comes with a significantly higher energy efficiency of automated pellet boilers compared to wood harvesting and combustion in conventional wood-burning furnaces, according to preliminary estimates.

The performance of the coal supply system could be improved by introducing the coal grading and beneficiation process flows at local mining companies. Introduction of modern transport technologies and improvement of the coal metering system may also prove relevant. A case in point is the use of flexible intermediate bulk containers (big

bags) for coal bagging which makes it possible to eliminate a notable deterioration of the quality and mechanical losses that otherwise come with a complex coal supply chain, and to form an accurate metering system for transportation of coal purchased [8].

Energy development trends are currently leading towards the integration of energy of various types in a single complex. We consider the issues of justification of development of the Russian energy sector as those coupled with the new vector of development of its one specific component, most notably the introduction of integrated heating and cooling systems. The introduction of integrated heating and cooling systems, according to a preliminary evaluation, can significantly reduce the total electricity demand of consumers in Yakutsk by as much as 20%. Provisional estimates indicate that the project could prove economically feasible, even under current market conditions, if there is sufficient demand for cooling. In this article, a comparative evaluation of energy efficiency is carried out with respect only to potential energy savings. The relevance of introducing the technology of integrated heating and cooling systems has been confirmed by the results of modeling and it is also in line with key global energy trends (including decarbonization and globalization, along with the introduction of CO_2 emission quotas, etc.) [9].

The extreme cold weather characteristic of the Republic of Sakha (Yakutia) requires greater reliability and efficiency of engineering systems during their entire lifespan of operation in local settlements. The duration of the heating season in Yakutia averages 8–9 months per year, and is year-round in some Arctic settlements. Therefore, recurring failures of individual components of engineering systems merit special attention.

The authors analyzed the operation of the air blower pipe of the coal-fired boiler KVm-2.5LB of the boiler plant operated in one of Arctic villages of the Republic of Sakha (Yakutia), and studied several samples of the faulty section of the pipe using optical and electron scanning microscopy. The composition of the metal was identified and the inhomogeneity of mechanical properties was evaluated by micro-hardness distribution analysis. Although the primary microstructural analysis indicated that the pipe steel was subjected to severe overheating, more than twofold thinning of the pipe walls, and the presence of wormholes along with the fact that the pipe was subsequently repeatedly welded, provided evidence supportive of the claim that the fracture was due to corrosion. The calculation of the dew point attested to the unavoidable moisture condensation on the pipe walls due to non-standard low-temperature operating conditions in a wide range of air humidity values during the operation of the boiler. The design of the boiler, or the material of the pipes, therefore, has to be changed due to the fact that they proved inadequate under the extreme operating conditions, since the low ambient temperatures caused an intensification of heat transfer, a decrease in the temperature of the exhaust gases, moisture condensation, and corrosion of the pipe steel [10].

Finally, as for the environmental component, in addition to fieldwork, remote research methods were used for the first time to study certain areas of Southern Yakutia, which was due to their remoteness from industrial centers and inaccessibility of objects of our studies. The interaction of the Elga coal complex, represented as the coal-mining geotechnical system «Coal-mining complex – Natural environment – Human», with natural complexes was studied in line with the geosystem approach. The factors of influence on the components of the natural environment and the directions of their change were identified. The functional, cause-and-effect, and local relations between the subsystems of the geotechnical system were also systematically arranged. We performed assessments of the degree of resilience of landscapes in the area of development to human-induced impact and the change undergoing by such landscapes. We proposed a map of environmental zoning. The map rendered various levels of environmental protection measures specified in a set of documents regulating them. That took into account the extent to which human-induced transformation altered sustainability.

We built a planimetric map with point and non-point features of the Elga coal complex. To this end, GIS technologies were applied. They included satellite imagery for studying natural and man-made systems and the use of unmanned aerial vehicles. The map will allow modeling the spread of pollution from point and nonpoint sources of air, land, and water pollution. Such a map could be used to create a unified model that captures changes in natural environment components and the degree of landscape disturbance within the premises of the facility. Zoning of the disturbed lands of that are licensed for subsoil use at the Elga coal field was carried out, and three centers of human-induced impact, corresponding to various factors of human-induced impact, were identified [11].

We carried out a component analysis of the current state of the natural environment of North-Eastern Yakutia and an assessment of the resilience of natural landscapes to human-induced impact as a necessary basis for developing ways to reduce the consequences of environmental impact during the mineral resource development of the investigated area.

We identified the directions for improvement of the area. They include the integrated use of geoecological research methods based on landscape analysis, which is necessary for assessing the current state, its monitoring, and predicting changes in the natural environment. Another component is the use of geoinformation methods and aerial surveying in order to obtain operational information and do environmental mapping.

Furthermore, we identified the main directions to be pursued for environmental protection in the use of fuel and energy resources in Yakutia.

III. Conclusion

The development prospects of the energy industry in the Republic of Sakha (Yakutia) are related to improving the reliability of energy and fuel supply and making energy consumption more efficient, including through:

- elaboration and timely updating of strategic planning documents for energy development, drawn up so as to take into account the unique features of the Russian Far North;
- development and timely implementation in the energy sector of the products of technological change;
- development of integrated heating and cooling systems;
- application of new cold- and corrosion-resistant materials;
- development of such topologies and operating conditions of power plants that are adequate to the severely continental climate and low temperatures;
- adoption of efficient energy supply schemes based on proper long-view technical and economic comparisons of available options.

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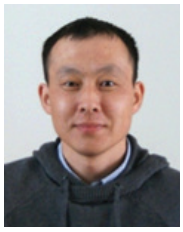

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