Energy conservation challenges and potential in Russia's North-East region

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Abstract. The paper discusses challenges and a potential of fuel and energy savings in one of the republics of the North-Eastern region of the Russian Federation. The authors show the challenges of energy- and heat-saving, with due account too particular features of Sakha Republic (Yakutia), which include: inconsistency of the actual operating conditions of the equipment with the requirements of regulatory documents in force; problems in supplying the consumers in the decentralized zone. The region's goals in the segment of energy saving are determined. A detailed assessment of energy-saving potential in the electricity, thermal and fuel saving sectors is carried out. Energy saving is achieved mainly by reducing the losses in general-purpose utility networks, when switching to energy-saving lighting devices, as well as by reducing electricity consumption rate for water pumping, supply and sewage disposal. Heat energy savings can primarily be achieved only by reducing losses in heating services' networks. Considerable fuel savings can be obtained by reducing the fuel consumption rate in boiler houses and diesel-run power plants. The results show high potential for energy savings in the region. Energy- and fuel-intensive activities alone could save the estimated 1 million TOE every year.

1 Introduction

In terms of energy intensity, Russia, regrettably, lags behind many developed and even developing countries [1]. According to Russia's Ministry of Economic Development, by 2018, the energy intensity of Russian GDP has decreased by only 12% (over the past 10 years – by only 9%, in the last 4 years the energy intensity does not change) [2]. Moreover, in line with prepared by the Ministry of Economic Development forecast of a prospective reduction in GDP energy intensity, the earliest Russia could reach the 2018 global average level of GDP energy intensity is in 2035, and only on the condition that the Russian economy is fully based on the best global technologies [3]. The dynamics of electricity production, energy structure and carbon intensity in the world in 2010 and 2018 are presented on Fig. 1 [4].

According to 2018 report on operation of Russia's National Grid, the South Yakut energy region of the power grid of the Sakha Republic (Yakutia) reached a historic 2018 peak of power consumption on 19.02.2018 – 344 MW, up 8% on the previous figure, in one go.

The energy efficiency of the economy is defined by energy intensity, electricity intensity, per capita electricity consumption and electric intensity of labour [5].

The high energy intensity of the republic's economy is conditioned by its climatic features [6]. The complexity of life support of the population of the republic is due to not only the long and frosty winter period, but also a large area. The distances between settlements in separate ulus sometimes reach 600-700 km. Poor transport infrastructure, seasonal delivery of basic goods, petroleum products impose additional costs and create difficulties in the energy supply of the republic.

Dynamics of the key energy efficiency indicators, Sakha Republic (Yakutia), 2012-2016.Table 1 [7].

The level of electricity intensity of gross regional product in the republic as a whole grew by 10.8% over the period 2012-2016. Significant growth occurred in 2016 (to 14.58 kWh per 1000 roubles), which was associated with the expansion of activities and services in such power-intensive industries as oil transportation, heat production by using electric heating, housing and utilities, etc.

The energy costs of production are largely determined by the ever-increasing share of obsolete production funds, the deterioration of equipment, and the lack of qualified personnel in the field of energy conservation [8]. The population is uneducated in this respect, there is no promotion of effective methods for saving energy resources. The state-financed organisations are less than 50% equipped with the means of accounting for thermal energy, which, of course, affects the republic's budget, first of all [9].

Sakha Republic (Yakutia) spends formidable amounts in order to meet its fuel and energy needs [10].

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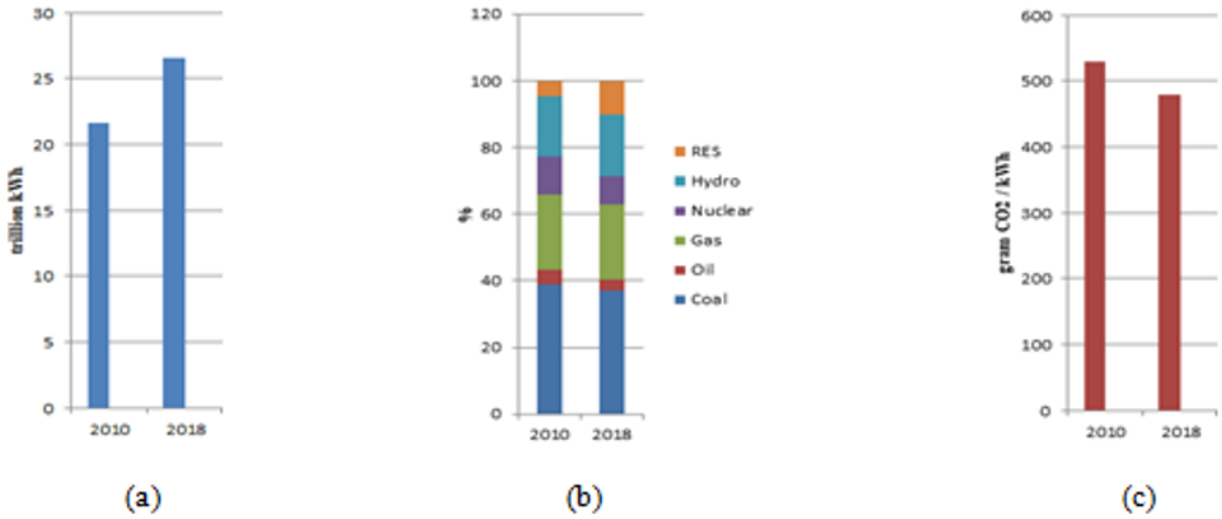

Fig. 1. Electricity production (a), Energy structure (b) and Carbon intensity (c) in the world.

The republic spends about a third of its budget on energy supply, which conditions one of the main tasks of energy conservation – to reduce budgetary expenses for energy resources and subsidy payments from the budget [11].

2 Goals and objectives of the study

Due to the above, the purpose of this work will be to study the problems and to assess the potential for saving fuel and energy in the Sakha Republic (Yakutia), the largest republic in the North-East of Russia. In order to achieve this goal, the following tasks will be solved: analysis of regulatory and technical documentation on energy conservation in the republic; defining the problems for energy and fuel savings; determining energy-saving goals; assessing the potential for saving electricity, thermal energy and fuel.

3 Results of the study

To solve the problems of energy saving from 2008 to 2018, the Government of Sakha Republic (Yakutia) adopted a number of official documents, including the Decree of the President of the Sakha Republic (Yakutia) No. 1464 dated June 8, 2012 on the program of Sakha Republic (Yakutia) "Energy saving and increasing energy efficiency for 2012-2016 and for the period up to 2020." The main goal of the program – to ensure the transition of the republic's economy to an energy-saving trajectory to reduce budgetary expenditure and improve the social and living conditions of the population – corresponds to the federal goals of improving energy security, ensuring macroeconomic stability and balanced development. The program includes five sub-programmes: energy conservation in housing and utility sector, power sector, construction and industrial segments, in the budget sphere and housing stock [12].

In the Sakha Republic (Yakutia), just as in the Russian Federation overall, energy-saving is yet to receive a comprehensive development. Therefore, at the current stage, development of proposals for economic incentives for consumers and producers of energy resources is considered as crucial [13].

The key principles of energy-saving policy are: prioritising fuel and energy efficiency over increased production and output; mandatory accounting and control of the energy acquired and used by legal entities, as well as accounting of by individuals for the received energy resources; matching the energy-saving interests

Table 1. Republic's key energy efficiency indicators.

Indicator	Units	Year					Average annual growth rate, %
		2012	2013	2014	2015	2016	
Energy consumption	'000 TOE	8,007	7,948	7,970	8,117	8,462	101.4
Electricity consumption	mln. kWh	7,126	7,183	7,378	8,104	8,694	105.2
Energy intensity of GRP	kgoe/'000 RUB	14.79	14.55	14.14	14.16	14.16	99.0
Electricity intensity of GRP	kWh/'000 RUB	13.17	13.15	13.09	14.14	14.58	102.6
Per capita electricity consumption	'000 kWh/pers.	7.46	7.52	7.71	8.44	9.03	105.0
Electric intensity of labour	'000 kWh/pers.	14.76	14.90	15.30	16.79	17.98	105.1

of consumers, suppliers and producers of fuel and energy; providing a governmental financial support for programmes on energy efficiency and non-traditional energy; engaging energy producers in the projects related to improving energy efficiency and developing non-traditional energy.

3.1 Energy-saving challenges

Particular features and challenges of the power grid in the Sakha Republic (Yakutia) include: lack of capacity of 35-220 kV electrical networks; mismatch between equipment rupturing capacity and the calculated short-circuit currents; non-compliance of relay protection and emergency automatics to the requirements of the existing regulations; non-compliance of the actual operating conditions of the equipment to the requirements of the existing regulations; problems in the energy supply to the consumers of the decentralized zone [14-16].

The results of 2017 winter check measurement of the load flow identified large load nodes running on one power transformer (or two power transformers with one being turned off), with an overload of the power transformer, which cannot be eliminated neither by redundancy measures from other power centres, nor by any other other grid-mode measures.

To determine whether the equipment's rupturing capacity is consistent with calculated short-circuit (SC) currents, comparisons have been made between existing SC values in the 110 kV grid and above and the nominal switch parameters. Excess of rupturing capacity over the SC value has been identified in the following cases: less than 2 times – 2 electric substations (1.79%); 2 to 5 times – 25 electric substations (22.32%); 5 to 10 times – 8 electric substations (11.61%); more than 10 times – 79 electric substations (64.28%).

On the territory of the Sakha Republic (Yakutia) there are power grid facilities of 110 kV and above, where the actual operating conditions of the equipment do not meet the requirements of regulatory documentation, according to the information of the energy suppliers and producers (PJSC Yakutskenergo, JSC “DRSK”, JSC “Neryungrinskaya GRES”). Operation on outdated electrical equipment is the most common reason for non-compliance with requirements of regulatory documents [17].

Much of the territory of the Sakha Republic (Yakutia) is outside the grid, mainly the northern ulus areas, where electricity consumers get electricity from numerous autonomous power plants of JSC “Sakhaenergo”. All diesel power plants operate for their respective distribution grids, covering the territory of a separate village or settlement. A significant part of the equipment has been commissioned more than 30-40 years ago and its fleet life already run out. The operation of power equipment is carried out in difficult climatic conditions, which leads to considerable expenses for maintaining the electricity grids, as well as accelerated depreciation and additional costs [18-20].

3.2 Heat saving challenges

The accumulated technical problems are largely related to the fact that the development of heat supply systems, both in the republic and in the country, was focused for many years on simplified and cheapest solutions: aggregate linkage of heating load, exposed water intake, dead-end arrangements of thermal networks, unreliable heat lines and fittings, manually run boiler houses. There is no local automatic control in consumer installations and no measurement of the heat consumed [21].

The current situation in heating sector of the Sakha Republic (Yakutia) is marked by serious problems, such as deteriorated equipment, low efficiency and reliability, poor level of comfort in buildings; low technical level and low economic efficiency of heating systems and facilities; huge thermal energy overheads.

The key challenges in the field of heating and heat consumption: unsatisfactory technical level, due to insufficient automation, accounting and control systems, depreciation of fixed assets; low level of centralised heat supply infrastructure; low efficiency of boiler houses; significant deterioration of equipment and heating services due to their delayed repair and replacement; large losses of thermal energy in pipeline networks; a high degree of depreciation of the housing stock.

3.3 Energy-saving tasks

The key goals in the field of energy conservation in the Sakha Republic (Yakutia) are [22]: reduction of budgetary payments for energy resources and subsidy payments from the budget; improving the efficiency of existing power plants; reducing the republic's energy dependence on imported fuel resources; improving the heat protection of buildings, structures, utility networks; reducing consumption rate of fuel and energy resources in power plants and utility sector; reducing specific energy consumption per produced unit in industry, housing and communal sector, domestically, in agriculture, etc.; expanding the use of measuring, accounting and controlling instruments for energy resources; improving metrological control, supervision and time-independent monitoring of energy consumption; formation of effective economic and financial energy-saving mechanisms; improving real incomes and corporate profits by reducing energy bills; boosting the scientific engineering potential of the republic.

The key goals of energy conservation in the electricity sector are: boosting the efficiency of power generation by reducing the cost of energy production and transfer; meeting the needs of the republic's economy in electric and thermal energy; reducing the amount of financial resources leaving the republic as payment for imported fuel resources; reducing the environmental impact of energy companies [23-25].

Table 2. Provision of electric power, natural gas and steam; dynamics of electricity consumption per employee in industrial production.

Year	Electric power, mln. kWh	Heat power, '000 Gcal	Electricity consumption per employee in, kWh		
			Industrial production	Mining	Manufacturing
2012	8,452.8	14,560.9	43,089	40,079	18,635
2013	8,509.2	14,412.8	50,819	45,088	19,650
2014	8,578.0	14,581.7	45,197	46,308	20,332
2015	9,006.1	14,236.4	53,265	51,141	19,976
2016	9,326.8	14,447.0	58,222	59,945	19,273
2017	9,225.8	14,118.6	53,243	56,541	21,930
2018	9,727.2	14,391.5	47,762	47,356	23,017

3.4 Assessment of energy-saving potential

Improving the efficiency of fuel and energy consumption is one of the top priorities of the republic's economic and energy development strategy. An analysis of energy consumption shows that there are currently reserves of energy conservation in various types of economic activity.

3.4.1 Electricity savings potential

In the structure of electricity consumption, the bulk – 40% – is spent on mining commercial minerals [26-28]. The losses in the transfer of electricity over the public networks are fairly large, their share tops 13%. Also, population consumes a significant share of electricity in the production and distribution of electricity for natural gas and water – respectively, 11% and 15%. The dynamics of electricity and heat supply, and electricity consumption per employee in industrial production in the republic in the Sakha Republic (Yakutia) for 2012-2018 is presented in Table 2.

Analysis of the specific indicators of electricity consumption in mining shows that in the republic the averages are lower than the indicators for the Far Eastern Federal District (DFO) and the Russian Federation, both for coal mining and for oil production[29]. Consequently, there is currently no significant potential for electricity conservation in this sector of the economy.

The dynamics of electricity losses in public grid in recent years shows their certain unevenness, while hinting at a general upward trend. Comparative data indicate that although the values of losses in the republic are not the worst, yet their decline to guideline values (about 10%) would create the prerequisites for energy savings.

In the republic, the amount of specific electricity consumption for lighting and household needs per head per year is lower than in neighbouring regions, statistics show. This indicates insufficient electric coverage of the population. In this regard, the specific consumption of electricity in this sector is likely to increase in the near future. At the same time, the use of modern technologies in the field of electricity consumption for lighting can reduce electricity consumption. Thus, the use of modern energy-saving lamps of European and domestic manufacturers instead of incandescent bulbs will reduce five-fold the electricity consumption for lighting purposes, on average. It is estimated that about 20% of the electricity consumed by the population is used for lighting (total 2018 consumption reached 984 mln. kWh per annum). Thus, in 2018 the republic's population consumed the estimated almost 200 million kWh of electricity for lighting purposes. Even with partial replacement of incandescent bulbs (15-20%) with energy-saving bulbs gives the estimated electric savings at 30-40 mln. kWh pa.

In the sector of electricity, gas and water production and distribution, the largest excess of specific indicators over the average values is observed in pumping up and supply of water (excluding utility needs) and its purification. Reducing the electricity consumption rate for pumping up and supply of water, as well as for water purification to DFO average levels provides a significant potential for electricity savings – more than 50% of total consumption. The total potential of electricity saving in the considered usage areas is estimated at 310-375 mln. kWh pa.

3.4.2Thermal energy savings potential

Total 2017 thermal energy consumption in the Sakha Republic (Yakutia) amounted to 15.2 mln. Gcal. More than 50% of this volume is in the heating sector (population and household consumption). Losses in thermal networks amount to 16.6%. Industry and others account for 30% of allocated total.

The low engineering level of many facilities and interfaces of the republic's heating systems – heating services, user installations, the lack therein of the necessary automatic control and measurement systems, unsatisfactory thermal characteristics of buildings lead to large excess heat losses. These losses create the potential of energy-saving, which, if implemented, could significantly improve the efficiency of transport and the use of thermal energy, reducing its consumption [30].

The total potential for thermal energy savings in the republic's heating supply (excessive heat loss) reaches 2.450-2.91 mln. Gcal per annum, or 16-19% of annual heat provision. In the structure of the entire potential of thermal energy savings in the heating sector, the buildings account for 70%, the thermal networks – 30%. Reducing losses in thermal networks to the guideline (8-10%) will save 0.91-1.21 mln. Gcal pa of heat energy.

The studies revealed a high thermal energy consumption rate for natural gas transportation, as this energy carrier needs to be heated up prior to transporting in the harsh climatic conditions of the republic. There is no energy-saving potential here, so far.

It should be noted that in other heat-intensive industries, such as oil processing and coal enrichment, lumber drying, bread and bakery production, oxygen and meat production (including Category 1 by-products), the thermal energy consumption rate is no higher than the regional average.

Thus, the main potential of thermal energy savings is concentrated in the heating sector. The total potential of thermal energy savings is estimated at some 2.5-2.9 mln. Gcal pa.

3.4.3 Fuel savings potential

The republic's main consumers of fuel are power industry and transport. Power plants and boiler houses consume more than 84% of total boiler and furnace fuel (mainly coal) [31]. Oil products are used on the transport. According to the statistics, the average 2018 fuel consumption rate for production of electric and thermal energy in power plants operating on boiler-furnace fuel amounted to 363 goe/kWh and 160 kgoe/Gcal, respectively. These figures are at the average level for Far Eastern Federal District.

However, for individual power plants, fuel consumption exceeds the average. Thus, at the Yakutskaya GRES the fuel consumption rate for electricity production was 380 goe/kWh, and at the Yakutskaya CHP – 491 goe/kWh. Reducing consumption rate at these plants, even to the republic's average values, would ensure more efficient use of fuel resources, saving about 22,000-32,000 TOE annually.

Fuel efficiency in boiler houses is much lower, with an average consumption rate of 221 kgoe/Gcal in 2018. Excess consumption of fuel in thermal energy production reaches 385,000-480,000 TOE annually, which is 22-28% of the amount of fuel used by the republic's boiler houses for heat production; this creates a significant fuel-saving potential.

Diesel power plants also have the potential for fuel saving – by reduction of fuel consumption rate, as the republic's average is higher than the guideline figure or the respective indicators for the DFO and the nearby subjects of the Russian Federation.

Analysis of fuel efficiency indicators in transport and industries shows that the fuel consumption rate in the republic does not exceed the DFO averages. Thus, the fuel-saving potential of the Sakha Republic (Yakutia) is focused on energy sources and estimated at 436,000-552,000 TOE annually.

4 Conclusion

An assessment of the current state of energy consumption in the North-Eastern regions of Russia (case study: the Sakha Republic (Yakutia)) shows that there is a considerable energy saving potential [32]. The savings in energy- and fuel-intensive activities alone are estimated at:

- in electricity consumption – 310-375 mln. kWh;
- in heat consumption – 2.5-2.9 mln. Gcal;
- in fuel consumption – 0.43-0.55 million TOE

Thus, the total potential of fuel and energy savings is estimated at 0.9-1.1 million TOE every year.

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