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Energy consumption and CO2 emissions in the northern cities (case of Yakutia)

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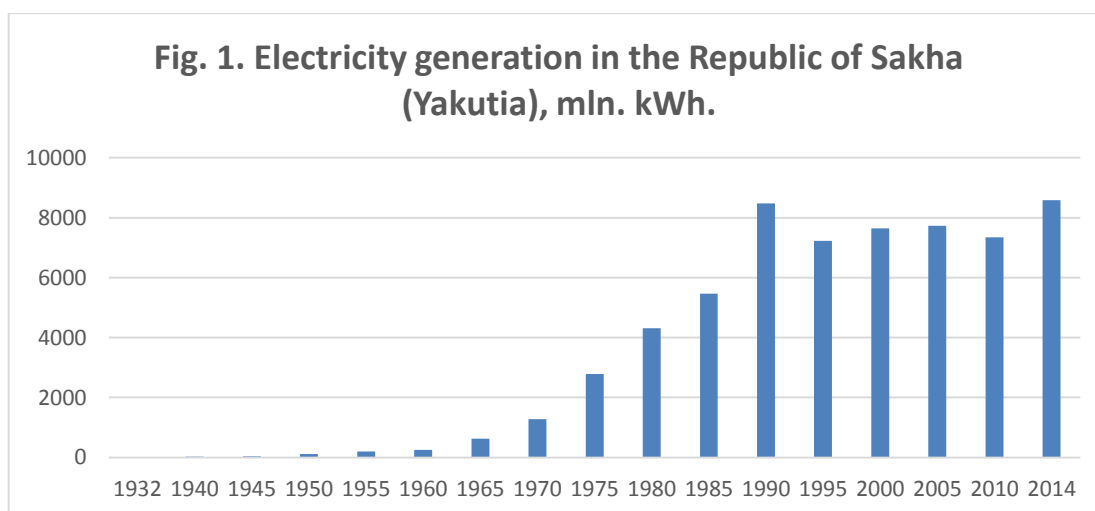
Key words: North, energy system, net cost, energy consumption, heat energy, cross-subsidization, Arctic settlements, population, territorial disparities

The Republic of Sakha (Yakutia) is one of the most challenging regions of Russia in maintenance of accessibility of heating and electricity for the population and industries. The Republic is located in the North-Eastern Asia and territorially is the largest region of Russian Federation. The total area of the continental and insular territory of Yakutia is 3.1 million sq.km, where more than 40% of the territory is located within the Arctic Circle.

The vast territory and the dispersion of population settlement, where the distance between the settlements in some areas reach 600-700 km, predetermine the complex structure of the region's power grid, which is one of the most expensive in the country nowadays. On average, duration of the heating season in Yakutia is 8-9 months in a year, and it is 12 months in the Arctic. In terms of conservation of isolation and inaccessibility in which 90% of the territory does not have a year-round transportation system, the main expenses of the budget system, population and businesses of the region are still electricity and heating costs.

COPERA project ("C budget of ecosystems and cities and villages on permafrost") carried out by a group of scientists of North-Eastern Federal University together with Japanese and American specialists by grant of RFBR №15-54-71003 under the Belmond forum. It is aim not only at assessment of greenhouse gas emissions, but also to study socio-economics problems in the sphere of life support of the population in the North.

The production of electricity in Yakutia started to develop on a large scale only since mid-1960s during the active development of mineral deposits. (Fig. 1) Thus, the priority of the development of electric power has always support an industry, rather than the household sector or the social services.



Source: Data of SSC of Republic of Sakha (Yakutia), <http://sakha.gks.ru>

By the end of 80th electricity generation reached a maximum, after there was a slight drop. One of the reasons is the elimination of a number of industrial enterprises, which have become unprofitable in the market economy. This decline was overcome only in 2014, both due to the strong growth of new industries, such as oil production and due to active housing construction.

There are four power districts in Yakutia. All districts are fundamentally different from each other by a source of energy production (coal, natural gas, hydro, diesel fuel), and by other parameters – consumer structure, costs, pricing (Table 1).

Totally there are 120 power plants of total capacity of 187 GW. For electricity generation almost 85% of the fuel raw materials imported from outside of the country (diesel power). Seasonal nature of the delivery connected with the navigation system and sophisticated transport delivery scheme. However, delivery terms for some regions can reach up to 1.5 to 2.5 years. These factors determine the need to attract credit resources for seasonal importation for energy companies to the amount of 5 billion rubles per year. There are problems with high unit costs for the purchase and delivery of diesel fuel. There is also the problem of the length of power lines in the whole country that amounts to 5 thousand km., where only 3 thousand km. belong to the range of the central power system. Furthermore, mostly all the power lines are worn out.

The largest amount of CO₂ emissions in power generation accounts to the territory in which the concentrated power of the region's major generating capacity, in such human settlements as Serebryany Bor (Neryungri District), Svetly (Mirny District) and also in the

Table 1.

The structure of power generation in the Republic of Sakha (Yakutia) in 2014

Power Districts	Regions of Republic	Human settlement	Value of generation, MW	The structure, %	Raw material
Central	Yakutsk city	Yakutsk city	420,4	17,1%	Natural gas, oil
Western	Mirny District	Svetly	1228,3	50,1%	Hydro-generation etc.
Southern	Neryungri District	Serebryany Bor	618	25,2%	Coal
Northern Power District	Northern and Eastern Yakutia, Arctic	Various northern settlements	187,2	7,6%	Diesel fuel, coal
Total			2453,9	100,0%	

Source: Report of Marinychev P.A "Development of the electricity of the Sakha Republic (Yakutia)", 27.06.2013, <http://www.rushydro.ru/upload/iblock/adc/Pavel-Marinychev-Gov-of-Yakutia.pdf>

capital of the Republic – Yakutsk city. These settlements are the heart of intensive anthropogenic impact of energy facilities to the environment, while, in the area of decentralized energy system anthropogenic impact is dispersed due to low power of energy generating enterprises.

Production of electricity in the Republic is partially redundant, partly in short supply, and the electricity are supplied and purchased to other regions of Russia in the wholesale electricity and capacity market within the framework of the United Energy System of Russia. According to the fuel and energy balance of the Republic of Sakha (Yakutia), in 2007, the ratio of "imported" in the area of electricity estimated at 2.4% of its own generation volume and the share of "exported" electricity is 13% [Energy Strategy, 2010, p. 24].

In 2015, the integration of the Western, Central and Southern Yakutia power districts was completed. It will lead to a significant change of the situation in the area of pricing. Previously, large industrial companies, including JSC "ALROSA" which subsidized consumers decentralized energy zones. There was used so called an "boiler" pricing principle, which meant the establishment of uniform tariffs for electricity in the territory of the Republic, respectively, the tariffs for consumers in Central, South and West power were 33-35% higher than economically justified level (Table. 2).

Table 2.

The differentiation of tariffs for electric energy in the context of power districts of the Republic of Sakha (Yakutia)

	2010	2011	2012	2013	2014	2014/2010
Economically justified tariff (central+southern+western), rub./KWh.	2,37	2,89	2,98	3,37	3,6	152%
Economically justified tariff (decentralized power supply area), rub. / KWh.	17,56	21,5	22,84	28,45	30,54	174%
The average tariff on Republic, rub. / KWh.	3,21	3,75	3,95	4,55	5,10	174%
The ratio of areas of decentralized and centralized energy	7,41	7,44	7,66	8,44	8,48	114%
The average tariff to the economically justified tariffs (central + southern + western)	135%	130%	133%	135%	135%	
The average tariff to the economically justified tariffs (zone of decentralized power supply)	18%	17%	17%	16%	16%	

Source: Data of OJSC «Yakutskenergo», <https://yakutskenergo.ru>

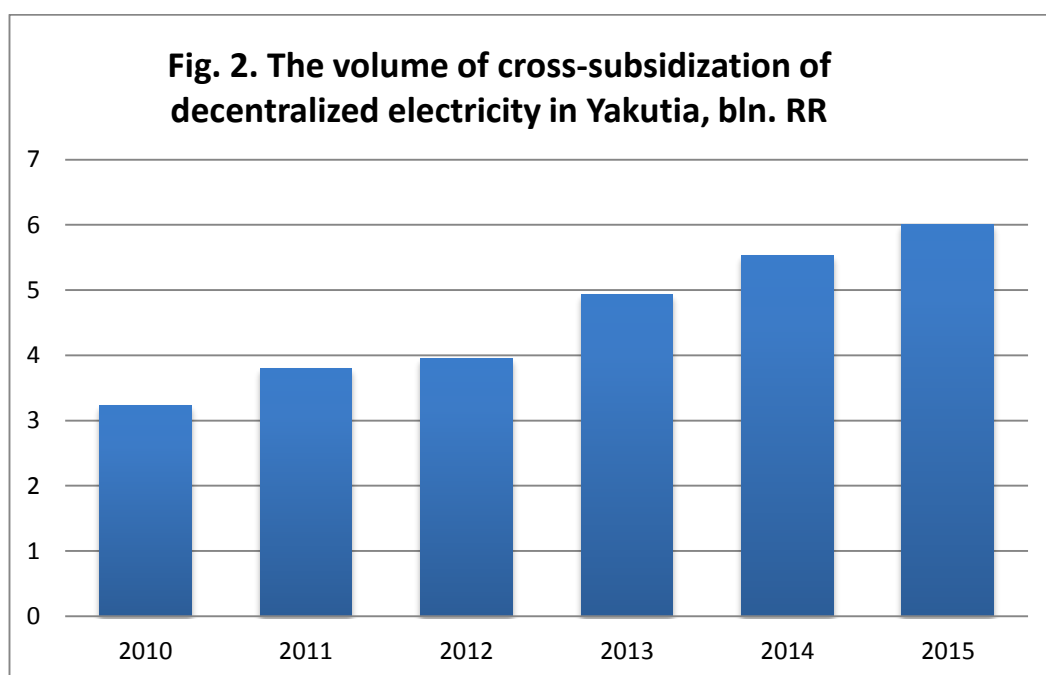
Due to the withdrawal from OJSC “Yakutskenergo” in wholesale electricity and capacity market of such large consumers as JCS “Yakutugol” and PJSC “Zoloto Seligdara”, an increase in electricity tariffs in 2015 amounted to 15% (of which 9% - is a loss of customers), while in 2014 it was 4.4%. The refusal of the cross-subsidies would lead to higher costs of economic entities (the budget system, population and businesses) in the areas of decentralized power supply for 6 billion rubles per year (in terms of 2015). (Fig. 2).

Currently, the government of the republic and the federal government have not formulated coordinated decisions with regard to compensation for these costs yet. In addition, the elimination of cross-subsidies was supported by the President of the Russian Federation and on 3 November 2015 were given special instructions. The situation is exacerbated by the current financial crisis that imposes severe restrictions including to the budget system.

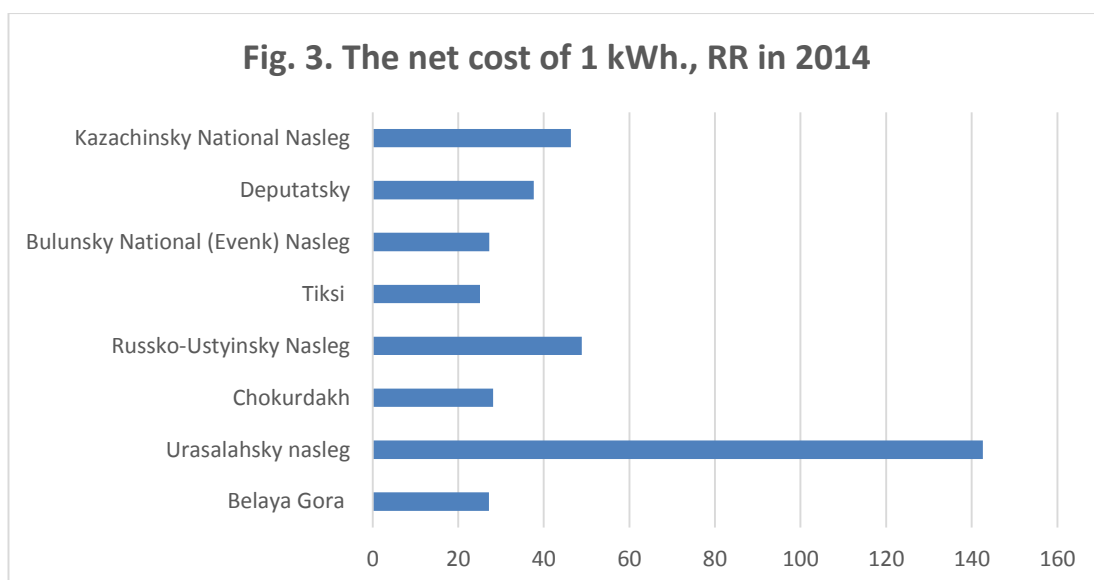
Human settlements selected for analysis in COPERA project belong to the central and northern power districts of Yakutia (Table 3). Within the project were began the formation of a database based on official statistics, the data of energy companies as well as certifications of settlements.

Electricity production in the settlements of the zone of decentralized power generation is carried out by low-power boilers that uses as a fuel coal and diesel. The main electricity supplier in this area is “Sakhaenergo”. As Fig. 3 shows, the net cost of electricity generation in remote settlements in the Northern Power District is higher than in Central in 7-40 times. Diesel fuel is not used in the settlements of the Central Power District, but it is only available in case of emergency. In settlements of the Central energy district as Zhatay, Pokrovsk, Nizhniy Bestyakh et al., do not have their own generation.

The mechanism of cross-subsidies until 2015 had no effect to the certain diesel power plants in isolated load centers, for example in Chersky, Ugol’ny, Orto-Nakhara, Saskylakh, Morkoka. Consumers of these plants have paid by actual tariffs for electricity (12,54 – 25,62 rub/kWh in 2014). High tariffs did not reflect to the population, as lifeline tariffs were fixed. In addition, there were fixed also mechanism of housing allowance.



Source: OJSC “Yakutskenergo», <https://yakutskenergo.ru>



Source: Database of research

Table 3.

Energy generating capacities and fuel consumption in the settlements of the Republic of Sakha (Yakutia)

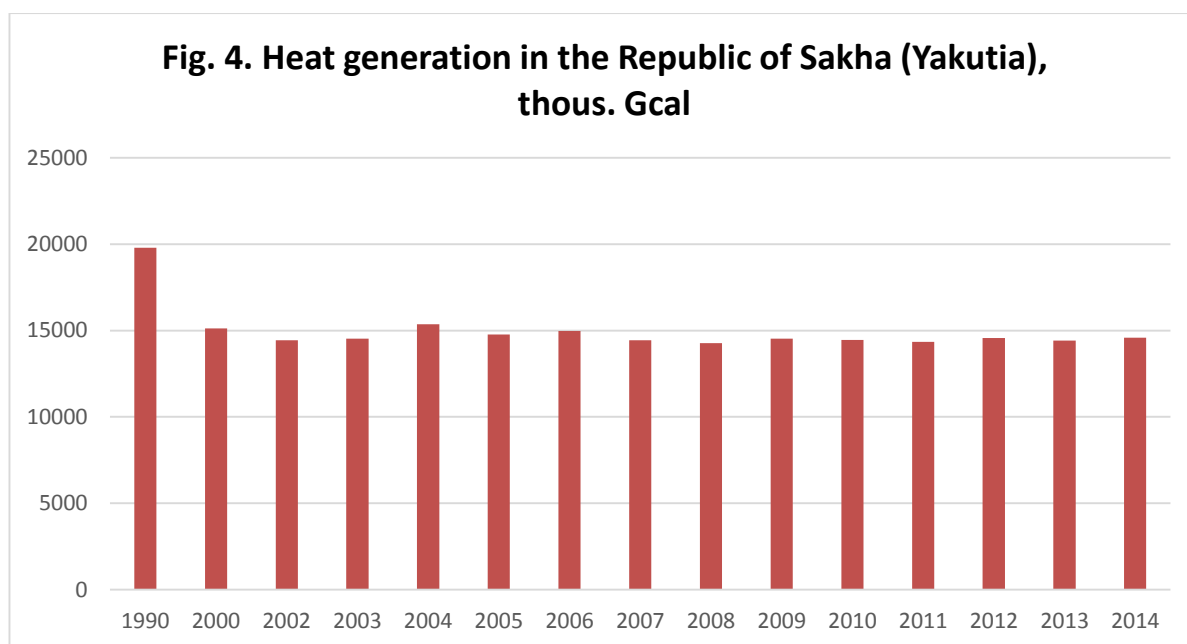
Settlements	Districts	The number of production units (boilers)	Fuel	Power (thousand kW)	Adjoint load, total (thousand kW)
Belaya Gora	Abyysky Ulus	1	Diesel fuel	4,945	1620,00
Urasalakhsky	Abyysky Ulus	1	Diesel fuel	0,260	0,10
Chokurdakh	Allaykhovsky Ulus	1	Diesel fuel	7,765	1900,00
Russko-Ustinsky	Allaykhovsky Ulus	1	Diesel fuel	0,4921	0,10
Tiksi	Bulunsky Ulus	1	Diesel fuel	10,065	3,90
Kusur	Bulunsky Ulus	1	Diesel fuel	2,500	600,00
Nizhny Bestyakh	Megino-Kangalassky Ulus	4	Diesel fuel	1,700	1,45
Tabaga	Megino-Kangalassky Ulus	3	Diesel fuel	0,120	126,63

Ust-Maya	Ust-Maysky Ulus	1	Diesel fuel	3,000	2,50
Petropavlovsky	Ust-Maysky Ulus	1	Diesel fuel	0,100	90,00
Deputatsky	Ust-Yansky Ulus	2	Diesel fuel	11,564	5557,34
			Coal	7,500	3286,75
Kazachinsky	Ust-Yansky Ulus	1	Diesel fuel	3,035	1892,16
Pokrovsk	Khangalassky Ulus	1	-	16,3 (substation)	450,00
Sinsk	Khangalassky Ulus	1	Diesel fuel	1,13	0,50
Yakutsk	Yakutsk	2	Natural Gas	12000,000	
			Natural Gas	368,000	1113,2
Zhatay	Zhatay	17	Natural Gas	-	-

Source: Database of research

According to this mechanism, the government compensated expenses exceeding more than 15% of household incomes. Only small and medium-sized businesses faced with this problem. To eliminate this kind of "inequality tariffs", the government of Yakutia has adopted a law "On preferential tariffs for liquefied gas, electricity and thermal energy (power), water supply and sanitation." The law allowed to approve a reduced rate for entities that previously paid at the rate greater than the size of the basic tariff guaranteeing supplier in the territory of Yakutia (OJSC "Yakutskenergo») [<http://regnum.ru/news/1873525.html>].

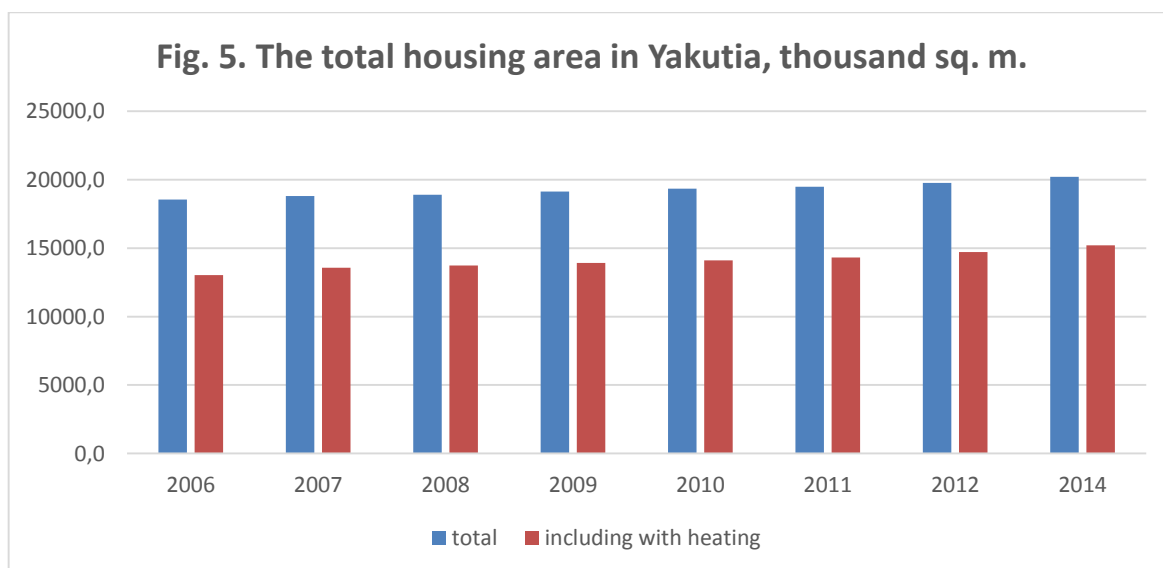
A significant territorial differentiation in net costs forms in the field of heat generation. In settlements and cities of the Republic operates 1355 boilers, of which 1031 belong to the State Unitary Enterprise "Housing of the Republic of Sakha (Yakutia)", 109 boiler served by JSC "Teploenergосervіs" (OJSC "Yakutskenergo"), the rest are departmental, municipal or belong to small and medium-sized businesses. Almost in all districts and cities there is a high level of wear of heating services, which does not allow the normal functioning of heating systems. According to the State Program of Yakutia "Providing quality housing and communal services and the development of electric power industry for 2012-2016" approved by the Decree of the President of Sakha (Yakutia) dated October 12, 2011 № 970, the average level of depreciation of heat supply systems reached 56.9% in 2011.



Source: Data of SSC of Republic of Sakha (Yakutia), <http://sakha.gks.ru>

Fig. 4 shows the dynamics of heat generation in the Republic of Sakha (Yakutia) in 1990-2014. The data shows that the volume of production is quite stable, as well as in the power downturn in 1990 - 2000. The construction boom (Fig. 5) has accompanied stable volumes of thermal energy generation in recent years. The total area of dwellings in Yakutia has grown from 2006 to 2014 by 9%, and dwellings with a central area or central heating - by 17%, while heat production decreased by 2.6%. It testifies that the republic has a stable effect from optimization the local power plants and energy-saving programs.

Thus, according to state statistics (table 4), since 2000 the number of heat sources has decreased by 37%, respectively, in the total number of sources by 16% decreased the proportion of heat sources with a capacity of up to 3 Gcal-h. From 27% to 21% decreased the proportion of heat and steam networks that need to be replaced. At the same time, by load growth, the share of heat losses it networks, from 13.3% in 2000 to 25.3% in 2014.



Source: Data of SSC of Republic of Sakha (Yakutia), <http://sakha.gks.ru>

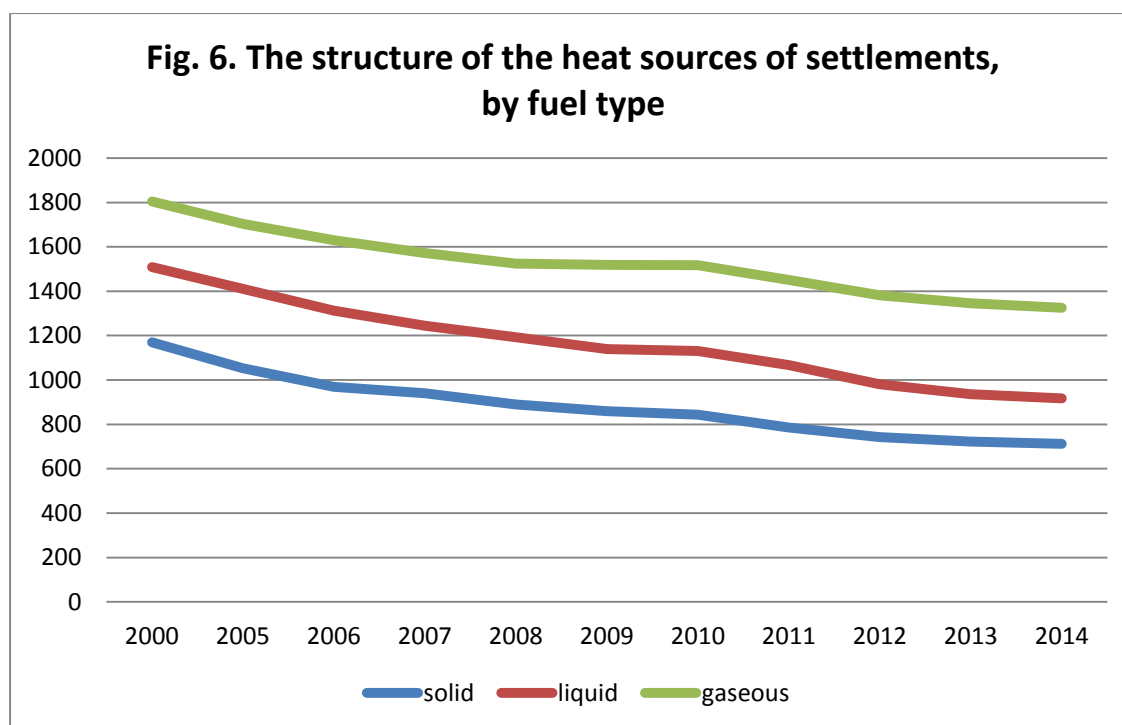
Table 4.**Specifications of the heating supply in the Republic of Sakha (Yakutia)**

	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
The number of heat supply sources	1865	1752	1670	1612	1562	1567	1552	1490	1422	1375	1355
The proportion of sources of heat supply capacity up to 3 Gcal-h of the total number, %	77,9	74,5	72,6	73,4	69,9	69,2	68,7	67,7	66,9	65,8	65,6
Total power supply sources, Gcal-h	7589,2	8042,5	8112,9	7815,4	8476,6	8364,2	8430,6	8387	8665,1	8698,2	8853,3
The length of heat and steam networks in two-pipe basis, km	3657,6	4081,3	4011,2	4109,1	4136,2	3937,6	3770,2	3502,6	3615,3	3547,3	3770,6
of them need to be replaced	992,9	808,4	933,6	1435,5	1165,3	1262,7	1233,7	933,9	809,6	731,5	796,9
Proportion of heat losses in the total amount of heat filed into the network, %	13,3	17,8	17,9	16	19,1	21,3	21,6	20,6	23,3	24,1	25,3

Source: Data of SSC of Republic of Sakha (Yakutia), <http://sakha.gks.ru>

A significant effect was achieved in the field of gasification of settlements, which allowed to significant change of heat sources on the structure of fuels (Fig. 6). The share of boilers running on gas, in 2000-2014 increased by almost in 2 times from 16% to 31%. Nevertheless, the share of boiler operating on solid fuel (coal) is still high, in 2000 – 65%, in 2014 - 54%.

The settlements of Yakutia are not compact because of the specific agricultural specialization. The content of cattle requires a large area of territory. As a result, in the settlements the construction of new social facilities increases the number of low sources of heating power and coverage of apartment buildings with central heating strongly differentiated. Therefore, housing area with central heating in the villages selected for analysis - Urasalahskom, Taragayskom and Sinskaya is relatively low, there is a high proportion of housing with stove heating (Table 5, Fig. 7). In the settlements, located in the Central power district, the availability of pipeline gas leads to stock of individual heating in the housing, also there is an effect of economies to scale.



Source: Data of SSC of Republic of Sakha (Yakutia), <http://sakha.gks.ru>

Table 5.

Heating supply to settlements of Republic of Sakha (Yakutia)

Human settlement	Districts	Power District	Supply agency	The number of heat supply sources
Belaya Gora	Abyysky Ulus	Northern	The Ministry of Housing and Energy, OJSC "Sakhaneftegazsbyt", The Ministry of Healthcare of Republic of Sakha (Yakutia)	11
Urasalakhsky	Abyysky Ulus	Northern	SUE "Housing and Communal services of Yakutia"	1
Chokurdakh	Allaikhovsky Ulus	Northern	SUE "Housing and Communal services of Yakutia"	8
Russko-Ustyinsky	Allaikhovsky Ulus	Northern	SUE "Housing and Communal services of Yakutia"	1

Tiksi	Bulunsky Ulus	Northern	SUE "Housing and Communal services of Yakutia"	3
Kusur	Bulunsky Ulus	Northern	SUE "Housing and Communal services of Yakutia"	5
Nizhny Bestyakh	Megino-Kangalasky Ulus	Central	SUE "Housing and Communal services of Yakutia", OOO "Kommunteploservice", SO Dyakonov Kh.A.	10
Tabaga	Megino-Kangalasky Ulus	Central	SUE "Housing and Communal services of Yakutia"	3
Ust-Maya	Ust-Maysky Ulus	Central	JSC "Teploenergoservis"	6
Petropavlovsky	Ust-Maysky Ulus	Central	FTE "Aeroporty Severa"	1
Deputatsky	Ust-Yansky Ulus	Northern	OJSC "Sakhaenergo	3
			OJSC "Sakhaenergo	
			FTE "Aeroporty Severa"	
Kazachinsky	Ust-Yansky Ulus	Northern	OJSC "TES"	1
Pokrovsk	Khangalasky Ulus	Central	SUE "Housing and Communal services of Yakutia", Pokrovsk city	17
Sinsk	Khangalasky Ulus	Central	SUE "Housing and Communal services of Yakutia", Yuzhnoe settlement	5
Yakutsk	Yakutsk	Central		235
Zhatay	Zhatay	Central	MUE "Zhataiteploset", OJSC "JSSZ"	3

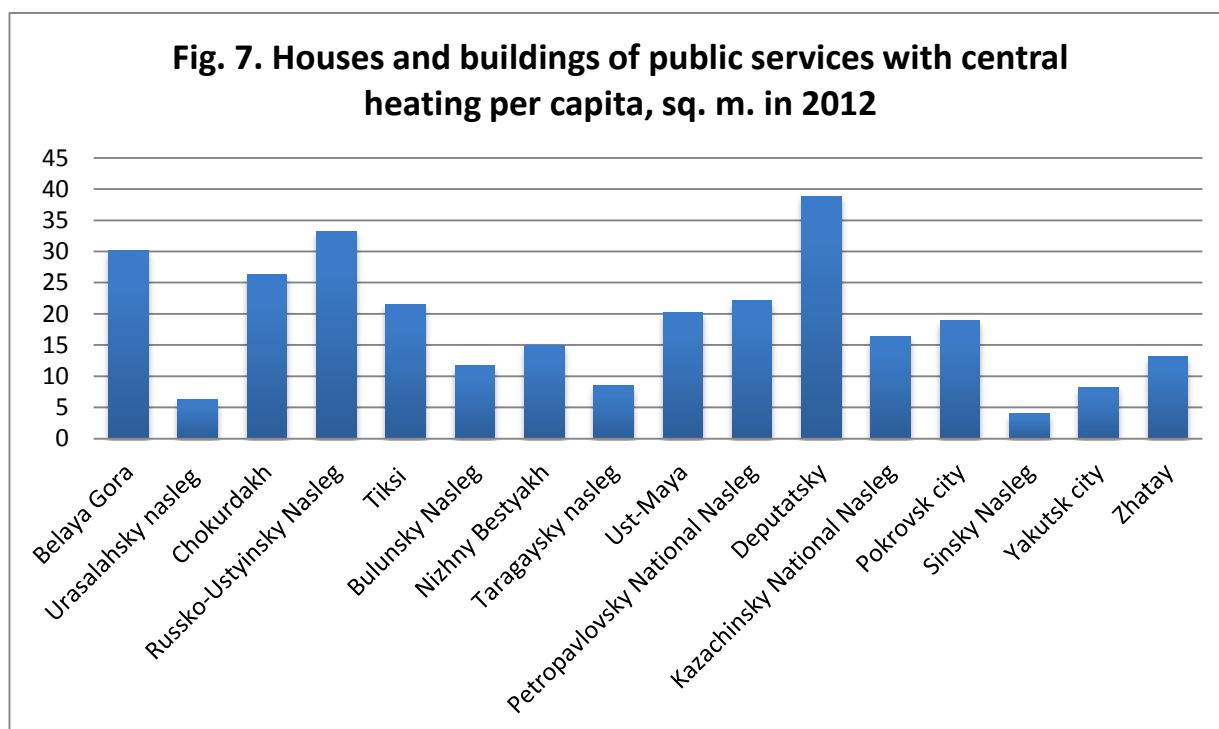
Source: Database of research

Many units of public services were built in the Soviet time, since these times many of rural settlements lost their population due to internal migration. Social infrastructure in the area of some settlements is redundant (Fig. 7). All this causes the growth of the spending from the budget of Yakutia, taking into account the various mechanisms of compensation of utility services to the population.

One of these mechanisms is the cross-subsidization, which is in contrast to the system of subsidies in the power sector, carried out at the level of municipal districts. Establishment of a horizontal tariff for heating for the district led to benefits for consumers of small, isolated settlements, the losers were the subjects of the regional centers. This system does not provide an incentive to the saving of heating, to adoption of new technologies and transition to energy service agreements.

"Starting from July 2016 the tariffs will be approved for each settlement. Taking into account the energy consumption and the cost of generation of heat power, the transition will significantly reduce heating costs by more than 60% for consumers. Reduced tariffs for heating will affect also all business categories. The rest of the consumers (less than 40%) are mostly in remote settlements, where a low level of boiler efficiency costs low sales volume due to high production. National budgetary institutions in rural area will be provided by funds for compensation through intergovernmental transfers, as there will be the increase of the tariffs for heating due to changes in tariff scheme. As for rates for socially oriented and life sustaining businesses, it will be on the level of operating with indexation. » [http://nvk-online.ru/news/] According to some estimates, the sharp increase in tariffs for heat could affect 196 enterprises in remote settlements, including shops, bakeries, etc.

Thus, in the Arctic zone part of the costs of all economic entities including businesses will continue to be borne by the budget system of the republic. As shown by the data in Table 8, nowadays in the Republic of Sakha (Yakutia) population reimburses at its own expense only 25.5% of the cost of central heating, 51.7% - in water supply, 78.2% - in electricity, in general - 38.2% the cost of housing and communal services, which is significantly lower than in Russia and the Far Eastern federal district.



Source: Data of SSC of Republic of Sakha (Yakutia), <http://sakha.gks.ru>

At this stage of the development of sustainment technologies, complex organization of energy system, existing territorial differentiation and social problems cannot completely abandon from this practice. The problem of subsidizing of decentralized energy system can be fully solved by eliminating the Arctic settlements, what is objectively impossible in a view of national security interests and because of the needs to preserve the historical and cultural traditions of the indigenous people of the North. Rapid transition to tariffs based on real costs will lead to further loss of population living in Arctic and the elimination of remote settlements. To various extents, the mechanisms of subsidizing of the expenses for energy exist in all Nordic countries. The support of Arctic is expensive around the world, as well as in Russia. We need to search new mechanisms of resettlement, also technological, financial and social organization of life in the Arctic.

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