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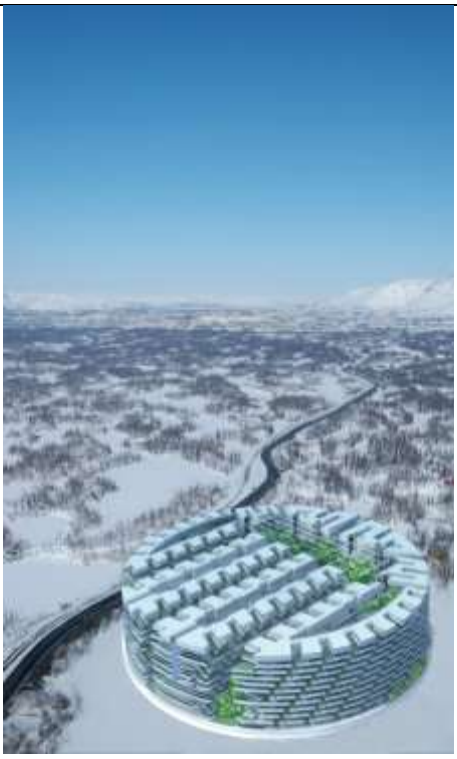
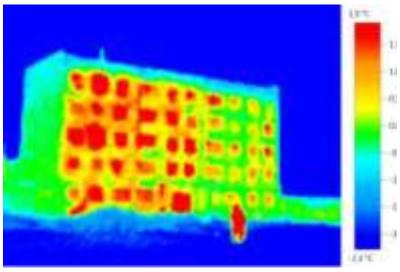
(CENEf)



Low-Carbon Solutions for Russian Off-Grid Regions with High Energy Costs



Project: ***Dialogue and analysis to drive low-carbon development in remote Russian regions***

March 2017

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Background

The project *'Dialogue and analysis to drive low-carbon development in remote Russian regions'* seeks to identify typical packages of low-carbon solutions and to assess their cost-effectiveness, potentials, and implementation schedules (energy efficiency improvements and renewable energy development), to develop a pilot programme of providing reliable and affordable energy services to remote Russian regions with currently very high prices for energy supplied by small off-grid sources (including to regions with limited summer-time navigation period, *'severny zavoz'*) to lay the basis for the development of the federal target (sub)programme which may include not only northern territories, but be expanded to small off-grid settlements across the whole country (nearly 100 thousand in all, according to the RF Ministry of Energy), where it is very costly to ensure access to central energy infrastructure.

Five to ten million people in Russia live in such remote localities with extremely costly energy supply from small fuel fossil-fired off-grid energy sources (where end-use energy supply costs amount to 50% of the municipal product and energy supply is only possible with huge federal subsidies (more than 150 billion rubles per year) and involve financial losses of energy utilities). With current electricity and heat tariffs in Russian Extreme North, energy efficiency improvements and renewable energy deployment are economically attractive, albeit there are a few barriers to investing in such technologies. One such barrier is poor problem visibility determined by the small size of each individual energy supply system.

This project initiated by CENEf aims to develop packages of typical low-carbon solutions to substantially reduce operational costs in integrated (heat, electricity, fuel) energy supply systems to ensure reliable energy services by applying an integrated approach that combines energy efficiency improvements, deployment of renewable energy technologies, the use of local fuels and fossil fuel-fired equipment (to serve as elements of hybrid systems at the beginning and as a standby source at later stages) based on low-carbon solutions that can be replicated in the programme for the whole region or the entire country in order to: (a) improve the visibility of cost reduction (including subsidies decrease) and of other benefits; (b) use such programme as a basis for low-carbon technologies accelerators; and (c) launch market-based mechanisms to accumulate experience and subsequently replicate low-carbon solutions across the country.

Even with existing currency exchange rates, the cost of energy supplied by small fossil fuel-fired sources amounts to 20-50 US¢/kWh or more, whereas the cost of heat generation is 3 to 10 times higher, than in large Russian cities. Therefore, energy efficiency improvements and deployment of renewable energy are quite attractive, though the application scale in such regions is currently not up to the expectations. Today, no systemic effort is taken on the federal level to address issues related to the extremely high energy costs and huge subsidy demand through low-carbon solutions. Individual measures are taken regionally and are limited to fragmented energy efficiency improvements or renewable energy development, whereas integrated efforts could yield multiple and tangible synergistic effects.

Reliability of energy supply is an acute problem not only for remote localities with energy supply from small off-grid sources. Remote inhabited locations with access to the central energy infrastructure and small electricity loads also need autonomous energy supply to obtain maintenance cost savings for power transmission lines and roads, as well as fuel delivery cost savings. The RF Government is currently developing a concept that would allow it to sustain small settlements scattered across the whole country (nearly 100 thousand in all) by providing decentralized services to such regions, including reliable energy supply. This proposed project can become a test field for this concept. A.V. Dvorkovich, Vice-Prime Minister of the Russian Federation, required that methods to ensure fuel switch for heat supply services from liquid fuels to local fuels and renewable energy sources be identified. This mostly refers to regions that are in the focus of our project. Therefore, our project can contribute to addressing this issue.

CENEf estimates, that the national budget spends nearly 150 billion rubles per year to provide energy subsidies to off-grid regions and to pay energy bills of local public organizations. The analytical center of the RF Government assessed total public spending and cross-subsidies provided to cover heat supply costs in Russia at more than 70 billion rubles, with the large part forwarded to the northern territories. This proposed project can substantially decrease this subsidy demand at no impact on the cost-effectiveness or reliability of energy services.

This paper provides an analysis of the current situation in off-grid energy systems with high energy costs and describes pilot low-carbon projects for Russian off-grid regions with high energy costs for six pilot settlements, differing in size and parameters of energy supply. It aims to lay the ground for the discussion by the expert community of how 'Low-carbon solutions for off-grid Russian regions with high energy costs' programme can be best developed and launched.

On December 27, 2016, a meeting of the Federal Council titled 'Russia's environmental development in the interests of future generations' took place. For this meeting, a Report 'Russia's environmental development in the interests of future generations' was prepared.[1] It substantiated the need to develop and launch federal programme 'Low-carbon solutions for off-grid Russian regions with high energy costs'. The programme should be developed from packages of typical low-carbon solutions with estimated cost-effectiveness, potentials, and implementation schedules for energy efficiency improvements and renewable energy deployment. A series of pilot projects can be launched first to lay the grounds for the development of regional and federal target programmes. Like stated above, this programme may include small off-grid settlements across the territory of Russia (where it is very costly to maintain grid energy supply), rather than be limited only to the northern localities. The experience accumulated in Alaska, Norway, and the Arctic part of Canada proves the economic viability of such solutions even in the absence of subsidies to deploy renewable energy technologies in these regions. Implementation of these programmes will help substantially reduce public subsidy demand to cover fuel delivery costs.

The paper includes 4 sections. The first section presents an analysis of the current situation in off-grid energy systems with high energy costs. The second section provides the results obtained for current financial pressure on regions with costly off-grid energy supply. The third section describes foreign experience in low-carbon transformation of off-grid energy systems, whereas the last section deals with pilot low-carbon projects for Russian off-grid regions with high energy costs for six pilot settlements and provides recommendations in terms of how to launch and finance federal and regional programmes 'Low-carbon solutions for off-grid regions with high energy costs'.

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[1] CENEf-XXI was responsible for the coordination of preparation of this Report.

1 Analysis of current situation in off-grid energy supply in regions with high energy costs

1.1 Extreme North with a large number of off-grid energy supply systems and high energy costs covers much of Russia's territory

Russia's economic well-being is to a large degree determined by the development of vast, yet scarcely populated and hard-to-reach territories of Extreme North with severe climate. While these territories only account for 8% of Russia's population, they are responsible for 76% of national oil production, 93% of natural gas, 95% of coal, 95% of gold, 100% of diamonds, 100% of salmon roe, and plenty of other valuable resources. These territories are the place where most of nickel, copper, and aluminium are smelted. They directly contribute 15-16% to the national GDP, while the indirect contribution, with an account of revenues obtained through resource transportation, industrial construction, financial and insurance services to resource production companies, and resource price markup, equals 25-30%. Extreme North contributes more than a half to overall national budget revenues and nearly 70% to export revenues. On the other hand, these territories have a 9-11 months-long heat supply season, construction is very difficult for permafrost, and cargo (including fuel) deliveries are only possible during the short summer navigation period, because there is no permanent ground transportation. Successful deployment of energy efficiency and renewables technologies would address the strategic goal of Arctic territories' recovery and active development.

Reliable and good-quality energy supply to remote and scarcely populated locations scattered across the huge part of Russia that is called Extreme North (Fig. 1.1), remains an acute problem in social, technical, and economic aspects. The number of off-grid energy supply systems with high energy costs is estimated above several thousand; these are maintained to serve more than 11 million people.

Figure 1.1 Distribution of local off-grid energy supply systems

Sources: V.E. Fortov, O.S. Popel, *Power in the modern world.* (2011).

In all, 30 thousand settlements are served by local off-grid energy systems. Of these, more than 6 thousand have population above 500 people, 1 thousand have population above 2,000 people, and 580 have population above 3,000 people. Therefore, replication potential for a successful model programme *'Low-carbon solutions for off-grid Russia's territories with high energy costs'* may run into thousands.

Scarcity of energy resources and high energy costs hinder local economic development and hopes for comfortable living conditions and consequently reduce the attractiveness of northern territories. Extreme North is characterized with a number of special conditions such as economic isolation of territories; limited transport availability; seasonal navigation and complex multistage fuel delivery schemes (up to 7,000 km) that include multiple transshipments and the costs of rent, cargo protection, load and reload, and ice roads maintenance, and sometimes suggest fuel delivery only a year after shipment for changes in the water content or ice conditions in northern rivers (sometimes this determines the need to have a 1.5-2 years' fuel stock); long (9-11 months) heating season; polar night, snow storms, low air temperatures and high wind loads; risk of permafrost degradation induced by climate change; relatively small power and heat loads. In 2017, the costs of summer fuel delivery to the Extreme North may exceed 100 billion rubles. Whereas diesel fuel end-use cost in the central part of Russia is around 46 thousand rubles/ton, in many off-grid territories it is nearly 70-90 thousand rubles/ton. In many instances fuel transportation costs are fully or partially covered through public subsidies to make energy resources affordable. Coal price in locations with summer shipping period is up to 5-8 thousand rubles/ton. In Nenets Autonomous Region, the price of coal is 7.6 thousand rubles/ton and the price of firewood is 4.3 thousand rubles/m^3, but households purchase coal and firewood at 2.1 thousand rubles/ton and 1.26 thousand rubles/m^3 respectively.

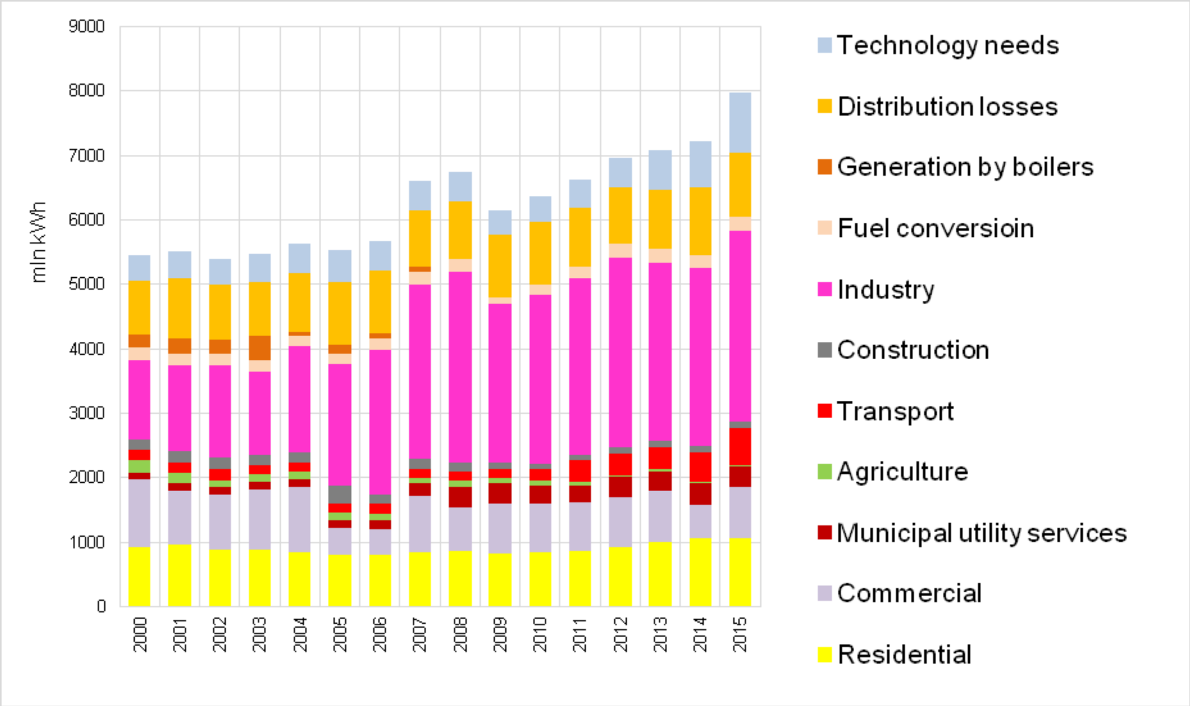
1.2 Problems related to off-grid energy systems maintenance

Overall costs (including delivery) of diesel fuel for power generation in off-grid energy supply systems in 2015 can be estimated close to 60-80 billion rubles. This should be added up with nearly 4 billion rubles in lubricants cost. Low-capacity power sources used for distributed power supply typically have poor technical and economic parameters, and insufficient fuel delivery results in long energy breakdowns or regular outages up to 12 hours a day. Specific fuel consumption by many obsolete diesel power plants (DPP) may be up to 600 goe/kWh.

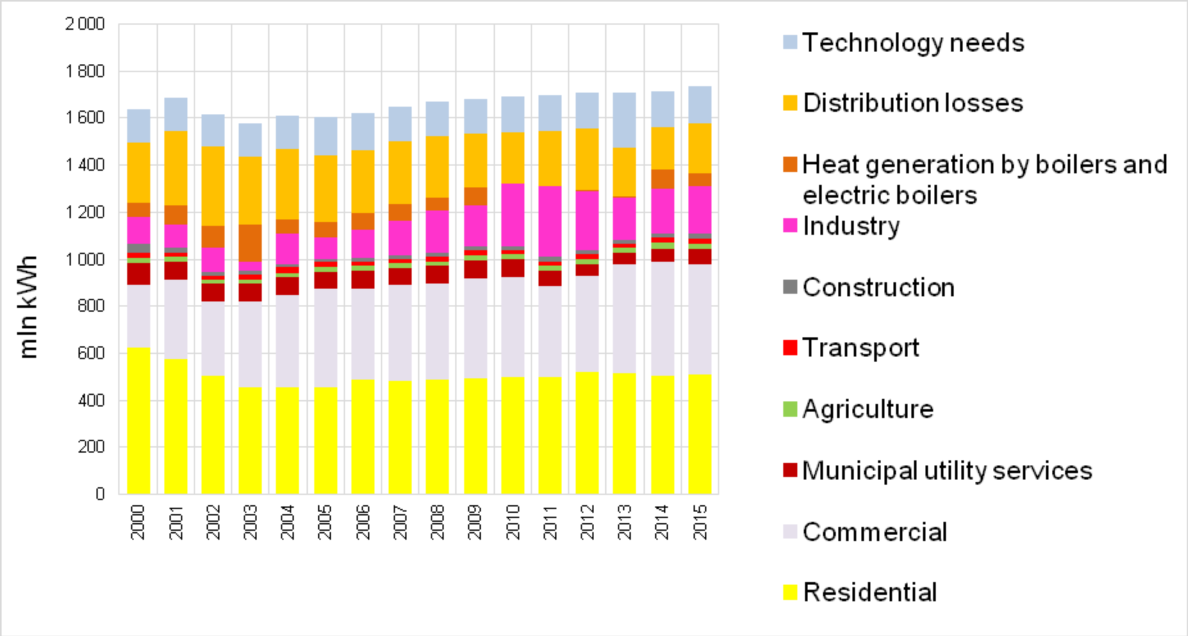
In most northern regions, power consumption was growing between 2000 and 2015 (Fig. 1.2). Power consumption structure is largely determined by a region's specialization. Some regions have a relatively large share of industry. In others, buildings are responsible for nearly half of power consumption. The same situation is typical of settlements powered by off-grid electricity supply.

No matter what industrial to household consumption ratio is, life support systems (such as DPP's operation needs, boilers, water supply and sewage) consume one fourth of total electricity supply. Therefore, water and heat savings yield electricity savings as a side-effect. Around 15-20% of extremely costly electricity generated by DPP are used for space heating purposes to make up for the deficiency of thermal comfort. Another 18-20% are used for lighting purposes. This is unaffordable luxury. In many localities, boiler-houses do not provide good quality heat to buildings, and so electric heaters need to be used. Electricity savings of 35-45% can be yielded by addressing space heating problems and through lighting upgrades alone. Energy efficiency programmes in power supply include measures such as installation of variable speed drives; replacement of uninsulated power lines with insulated ones; upgrades of lighting systems and replacement of appliances with more efficient models; installation of efficient motors and replacement of industrial equipment with more efficient models. In some regions, energy efficiency programmes only include a very limited list of measures. Instead of implementing the electricity saving potential, many localities are planning to build (or have already built) new DPP to make up for the deficiency of thermal comfort.

Figure 1.2 Electricity consumption evolution and structure in some northern regions



Sakha (Yakutia) Republic



Kamchatsky Krai

Source: CENEf

Subsidies that will be provided in 2017 to heat supply systems of remote municipalities of Extreme North can be estimated at 18-24 billion rubles. Overall heat consumption in more than 1,000 localities with total population of around 5 million people is 100 million GCal. If we assume that average heat price is 3-4 thousand rubles (and in some settlements it exceeds 10 thousand rubles), then the cost of heat supply to these territories is 300-400 billion rubles. Fuel costs equal 150-200 billion rubles. Reduction in subsidies for fossil fuel-based energy along with the modernization of energy supply systems in off-grid localities ought to become a key national goal.

Analysis of problems faced by boiler-houses in off-grid localities allows for the following diagnosis: poor technical inventory and certification of boilers; few fuel meters and heat supply meters installed; short remaining lifetime and poor shape of equipment; lack of boilers maintenance in many boiler-houses; poor fuel quality and subsequent burner failures; poor automation / lack of automation; high specific fuel consumption for heat production; lack / poor quality of water treatment; incompliance with air temperature curves; high fuel costs; shortage and poor qualification of boiler-house personnel.

Many local heat supply systems have substantially excessive heat production capacities. Overall inefficiencies of heat supply systems (and of boilers in particular) are determined by nearly absolute lack of meters and controls, which makes it impossible to effectively and rapidly adjust the equipment operation. Typical distribution loss standards for small heat supply systems may reach or exceed 20%, whereas actual losses can be up to 50-80%. Basic problems related to the operation of small-scale heat distribution systems include: high distribution losses; high operation costs of heat distribution networks (on average, nearly 50% of overall heat supply costs); excessive centralization which adds 5-10% to even permitted distribution losses; high wear of heat distribution networks and failure rates above the critical level; unsatisfactory shape of heat distribution networks, poor insulation and high heat losses; violation of hydraulic regimes of heat distribution networks and consequent under- or overheating of individual buildings. Boilers, distribution networks, and in-house heating and DHW systems are in poor shape and further degrading. Many heat supply systems do not practice heat carrier treatment, and so the service life of boilers, heat pipes and in-house systems is substantially shorter, than nameplate parameters. In such systems equipment repair and maintenance costs are 3-4 times higher than normal.

The role of district heating in northern settlements varies a lot. In some localities it may account to just 15-20%, with other buildings using firewood or gas-fired boilers (where natural gas is available – for example, in Yakutia). In other areas it may reach 40-50% and even 100%. To a large degree this share is determined by the parameters of the housing stock. For example, one-storey housing dominates in Verkhnevilyuisky ulus (region) of Yakutia (97% of buildings), while multi-storey housing is typical of Evensk (Magadanskaya Oblast) (Fig. 1.3). The share of public organizations in buildings with district heat supply is much larger.

Buildings clearly dominate in the heat consumption structure. Added up with heat distribution losses, they account for up to three fourths of overall heat use. In some off-grid localities, this share may account for 85%. Specific heat consumption for residential space heating is 0.25-0.9 Gcal/m^2/year, while Russia's average is 0.18 Gcal/m^2/year. In many northern settlements population keeps stable, so residential construction is mostly substitutive. Stricter requirements to new buildings may yield just a limited effect, and it is important to focus on capital repairs of the buildings stock. Very few or no households have heat meters. Therefore, heat production and heat consumption are not metered, but mostly estimated, and heat bills are based on normative consumption, rather than on the actual use.

Figure 1.3 Examples of housing stock in Extreme North

Verkhnevilyuisky ulus (region) of Yakutia

Evensk, Magadanskaya Oblast

Potential heat savings in many Extreme North settlements can be estimated at 40%. With additional weatherization they may scale up to 60-70%. Potential heat savings in buildings in Kobyaisky ulus (region) of Yakutia to 2020 alone are estimated at 35%, in Oimyakonsky ulus at 34%, and in Aikhal settlement at 37%. Heat supply efficiency programmes include projects dealing with boilers upgrades; replacement of heat distribution networks with pre-insulated pipes; installation of individual automated heat controls in residential and public buildings; housing weatherization; and installation of in-house and individual heat meters. Optimization of the housing stock (phasing out partially inhabited buildings along with the relocation of people and subsequent capital repair) is an important measure. Where there is heat supply shortage, the primary goal would be to improve energy efficiency and thus eliminate this shortage, rather than to reduce heat consumption. Unsatisfied end-use heat demand may be completely met through improved heat efficiency and reduced heat losses to comply with heat supply requirements and avoid the use of electric heaters.

High energy intensity hampers the economic development of Extreme North territories and reduces the opportunities for additional tax revenues. Energy efficiency policies in northern territories have yielded relatively scarce fruits, and additional energy demand in many regions was determined not only by GDP growth, but also by growing GDP energy intensity.

1.3 Examples of renewables development in off-grid energy systems

For many off-grid energy supply systems, alternative technical solutions for energy source upgrades are quite practical, yet applied on a very small scale. Renewable energy resources are abundant in Extreme North, so solar and wind are a feasible alternative that can replace a substantial part (40-50% at the beginning and even more at a later stage) of diesel fuel. High solar radiation is typical even of a number of areas beyond the Polar Circle, particularly in summer. Regions with the highest average wind velocities are located in the north and east of Extreme North.

Development of renewables can build on huge cross-subsidies to diesel energy, which in Yakutia alone amounted to 5.5 billion rubles in 2014, 6 billion rubles in 2015, and 6.8 billion rubles in 2016. Cross-subsidies place a substantial additional price pressure on industrial customers. Each kWh used by industrial customers involves 2.48 rubles in cross-subsidies to diesel energy. Cross-subsidies (i) encourage large customers to enter wholesale electricity and capacity markets; (ii) send a message to large industrial customers that they need to establish on-site power generation;

(iii) impair the attractiveness of investment projects dealing with the development of deposits and establishment of processing plants.

Figure 1.4 Examples of solar and wind plants in Extreme North

Joint Russian-Japanese pilot project for wind energy development in cold climates (Ust'-Kamchatsk settlement)

10 kW automatic solar tracker in Yuchugei, Oimyakon ulus

Data analysis for Extreme North shows, that overall installed solar and wind capacity does not exceed the load in any one of more than 1,000 settlements with more than 1,000 people each (7-8 MW) connected to off-grid energy supply systems with fuel delivered during summer navigation period. This means, that less than 1% of the potential is used today. Like correctly highlighted by Surzhikova, despite numerous resolutions and extensive programme development, practical implementation of electricity supply to off-grid customers, including from renewable energy sources, is only small-scale and does not allow it to address problems related to power- and fuel supply.

Fuel shift of boilers to renewable energy is only possible with guaranteed stable renewables availability over many years to come. Renewable resources are abundant in the north of Russia's European part and beyond the Urals, yet much scarcer in many Arctic regions. The latter may focus more on using local coals along with drastic improvements in boilers efficiency, construction of cogeneration plants, reduction of heat distribution losses, identification of the optimal scale for district heating, radical weatherization of buildings, reduction of heat loads, and drastic improvement of individual boilers efficiency.

1.4 Barriers

Implementation of the fuel saving potential (which is estimated at least at 40% in the beginning and more than 50% at a later stage) through energy efficiency improvements and renewables deployment is hindered by a number of various barriers: price and financial; related to the economy and market structure; institutional; social; cultural; behavioural; etc. In other words, any factor that directly or indirectly affects decision-making regarding energy generation and energy use can potentially become a barrier to energy supply cost reduction in off-grid localities.

So far, energy efficiency improvement and renewable energy development in Extreme North has not been realized by the national and regional governments, local administrations, companies' management teams as a practical method of addressing a variety of social and economic problems. Energy efficiency and renewables development programmes can substantially reduce fuel delivery costs and the interest paid on fuel delivery loans; reduce the costs (including public expenses) of energy supply to residential and public customers; improve the reliability of heat- and power supply systems; improve the competitiveness of industrial companies through reduced energy costs, including through the reduction in cross-subsidies. Resulting monetary savings can then be used to give momentum to social and economic development of Extreme North territories. Today, only scarce institutional and economic resources are allocated to reduce the costs of energy supply to off-grid localities.

Mentality of 'economy of deficiency' persists. In the economy of deficiency, the government's entire institutional and economic resources are used to cover the shortage: ensure fuel delivery, develop and comply with the power outage schedule, etc. Shortage of funds results in fuel shortage against the background of inefficient heat- and power supply. Heat shortage leads to excessive power consumption for space heating and ultimately to fuel and funding shortage. The circle is closed, yet needs to be broken.

After 2014, there has clearly been a downtrend in the activities that encourage energy efficiency efforts. On the national level, between 2013 and 2016 public energy efficiency spending under the 'Energy efficiency and energy sector development' programme dropped 50-fold (from 7,110 to 140 million rubles). Data obtained from 22 regions that used to benefit from national subsidies for energy efficiency programmes show, that each ruble of subsidies reduction in 2014-2016 brought along 5.4 rubles in overall reduction of energy efficiency financing from all other sources. In 60 RF regions, investment in energy efficiency programmes from all sources halved in 2014-2016 (or dropped 2.5 times in comparable prices). Elimination of national subsidies (nearly 6 billion rubles per year) resulted in at least 55 billion rubles reduction in regional and local public and private financing and in a shortfall of annual additional tax revenues of at least 10-12 billion rubles. In fact, could be much more: according to the RF Ministry of Energy,[2] investment in energy efficiency measures in 2013-2016 dropped by 178 billion rubles (from 233 billion rubles in 2013 to 55 billion rubles in 2016, or 4-fold), while national funding for the 'Energy efficiency and energy sector development' programme was down by nearly 7 billion rubles.

Lack of financial support from regional and local budgets. Many regions have no energy efficiency or renewables programmes under way. Without financial support energy efficiency activities are very dull. Programmes that are formally existent receive very limited financing. In 2016, public financing to energy efficiency programmes in Kamchatka dropped more than 2-fold; in Murmanskaya Oblast, they dropped 3-fold, while overall financing 4-fold. In Sakhalin, public financing to these activities decreased by nearly 2.5 times, in Khabarovsky Krai by 39 times. 13% growth was expected in 2016 only in Yakutia. In many of the regions with energy efficiency programmes or programmes related to municipal utilities sector, too little attention is given to off-grid settlements.

There are no mechanisms to stimulate the construction of renewable energy facilities in off-grid energy supply systems, including for microgeneration, or to promote renewable energy heat generation (such as setting long-term tariffs (price formula) for renewables-based power over the payback period; dispatch control to ensure priority load of renewables-based power generation capacities; compensation of technical integration costs; etc. The key purpose of renewable energy generation facilities construction in off-grid localities is to obtain fuel savings. Even with higher specific capital costs extremely high power tariffs make them economically viable (5-8 years paybacks) and they do not require federal subsidies (providing long-term tariffs are set). Setting long-term power tariffs for the whole payback period of a renewable energy project will help make renewables part of energy supply mix. If such projects are combined with energy efficiency programmes that include buildings weatherization, space heating temperature curve compliance control, and replacement of appliances with more efficient models, then from the very beginning customers can start obtaining savings even if tariffs are kept at the same level, whereas capital costs of solar or wind plants can be substantially reduced. The national

[2] The RF Ministry of Energy. 2016. State report on state-of-the-art energy conservation and energy efficiency in the Russian Federation in 2015.

government may want to finance some of the housing weatherization measures in hard-to-reach northern areas. This can be done similarly to the scheme outlined in the RF Government's Resolution No. 18 dated 17.01.2017 'On approval of the Rules for providing financial support from the budget of the federal corporation – Fund for the promotion of municipal utility sector reform to finance capital repairs of multifamily houses'. This scheme suggests that the national government buys out 2-4 years' energy cost savings from housing owners, providing these savings exceed 10% of municipal utility services payments baseline.

Instability of overall economic situation determines a bunch of problems. Spikes in prices, ruble/USD exchange rates, interest rates, etc. make it difficult to assess the cost-effectiveness of investment in energy efficiency and renewable energy, or to monitor the results. Reduced incomes of energy customers and growing debts, as well as huge energy losses, discourage mobilization of finance for energy efficiency measures.

Insufficient information support to energy efficiency and renewable energy policies. Poor information support has adverse impacts on the personnel's qualifications and is a serious barrier to the development and implementation of energy efficiency measures. It is important to ensure local training in energy efficiency and renewable energy.

Energy pricing. Energy prices are very high. However, the pressure is mostly on industrial plants and organizations, whereas residential sector benefits from substantial cross-subsidies. Elimination of subsidies is hardly feasible due to low households' incomes and substantial use of power for space heating, as district heating is only very poor quality. This is one factor driving households' energy efficiency motivation down and other customers' motivation up. It is important to shift cross-subsidies mostly to purchasing energy efficient and renewable energy equipment, so residential tariffs could grow without increasing the pressure of energy bills (primarily through reduced energy consumption for lighting and space heating). Reduced cross-subsidies could give a new lease of life to the industry and so give momentum to the development of Extreme North territories.

Lack of mechanisms to finance small-size projects and to incentivize customers and investors to invest in energy efficiency improvements and renewable energy development. It is important to develop and codify such incentives. Households and many organizations cannot afford to purchase energy efficient equipment and materials. Lack of financial schemes, such as microloans or 'white' or 'green' certificates, is a barrier to many cost-effective projects. It is crucial to deploy new financial mechanisms for energy efficiency projects: set up energy efficiency fund; leasing, etc.; microloans with repayment from municipal utility payments. Interesting experience in tuning ESCO mechanisms to energy efficiency and RE projects is being accumulated in Yakutia Republic.

Weak mechanisms to attract 'green' financing. It is important that the government initiate and participate in the discussions of perspectives and possible directions for 'green' development and that it support the development of 'green' projects, as well as assist in searching for funding for energy efficiency and renewable energy projects in Extreme North, including through setting up a guarantee fund for projects that have a potential to obtain financing through 'green' financial products (bonds; special products designed by international development banks; private investors interested in 'green' projects). This would require that two problems be addressed: development of bankable projects that may be classified as 'green' and development of a market for 'green' financing in Russia.

Intricate logistics and weak local markets for energy efficient and RE equipment. Market infrastructure for EE and RE equipment and services is not existent in remote locations. It is possible to assign providers of municipal utility services with ESCO responsibilities and to launch delivery and sales of energy efficient equipment with repayment from municipal utility bills.

1.5 Project 'Dialogue and analysis to drive low-carbon development in remote Russian regions'

Energy efficiency and renewables projects in off-grid localities are economically viable. They are widely supported. However, the work is moving too slowly. In Russia, real management decision-making is done by top officials. Therefore, while preparing Report 'Russia's environmental development in the interests of future generations' for the Federal Council, which met on December 27, 2016, CENEf initially included the following wording into the draft list of the RF President's instructions:

- The RF Government shall develop Federal Programme 'Energy Efficient Russia' that shall be comprehensive, take account of BAT deployment perspectives, and include:
  - energy efficiency targets for the whole economy and by sectors;
  - mechanisms to incentivize, manage, and coordinate the implementation efforts;
  - plan to improve the energy efficiency legislation and to update earlier regulations;
  - energy efficiency and renewable energy subprogramme for remote localities with high energy supply costs to lay the basis for the modernization of local energy supply systems and ensure cost-effective, sustainable, and reliable energy supply at minimal cost to all-levels budgets;
- The RF Government shall submit proposals on amending the RF legislation so as to ensure the most favourable conditions for renewable energy-based microgeneration with the intended goal to:
  - ensure integration of renewables and energy recovery in the energy supply mix of buildings, constructions, and facilities and to provide incentives for the development of RE-based microgeneration:
    - ✓ oblige power distribution companies develop technical specifications for integrating RE-based microgeneration in the grid;
    - ✓ oblige power distribution companies and default suppliers to:
      - sign contracts for the purchase of excess power generated by RE-based microgeneration facilities, including with physical persons, individual entrepreneurs, and legal entities, whose principal activity is not power generation or sale;
      - develop an accounting system for power consumption to allow for offsets of excess power supplied to the grid by 'super-small' RE-based power generation sources, including for physical persons, individual entrepreneurs, and legal entities, whose principal activity is not power generation or sale.

The final version of the List of the RF President's instructions following the meeting of the Federal Council 'Russia's environmental development in the interests of future generations' did not include part of these proposals and has the following wording:

- develop strategic planning documents and a comprehensive 2017-2025 action plan for the RF Government for 2017-2025 for the main purpose of ensuring Russia's transition to a sustainable development model that will allow for long-term efficient use of national natural resources and at the same time remove environmental threats to human health with a particular focus on:
  - setting energy efficiency targets for the whole economy and by sectors, and on the implementation of energy efficiency improvements, including the development and deployment of renewables and development of RE-based microgeneration;

- with the involvement of the leading entrepreneur associations develop and submit proposals:
    - on the deployment of ‘green’ financial instruments by Russian development institutions and public companies.

Draft regulation on energy efficiency targets for the whole economy and by sectors, as well as on the implementation of energy efficiency improvements, including the development and deployment of renewable energy and development of RE-based microgeneration, shall be submitted by the RF Government before July 1, 2017. There is still some time left to convince the RF Government to integrate the development and implementation of an EE/RE programme for off-grid localities with high energy costs in the ‘set of energy efficiency measures, including the development and deployment of renewable energy sources’ as a basis for the modernization of energy supply in these areas and to ensure economically and environmentally sustainable energy supply at minimal cost to all-level budgets.

It is exactly for this purpose that CENEf is implementing the project *‘Dialogue and analysis to drive low-carbon development in remote Russian regions’.* The project purpose is to push inter-regional cooperation to develop regional and municipal programmes *‘Low-carbon solutions for off-grid Russian regions with high energy costs’* based on the development of standard packages of low-carbon solutions, including cost-efficiency assessments, potential, and implementation schedules (energy efficiency improvements and renewable energy supply), to be integrated in a pilot programme to provide reliable and affordable energy services to remote Russian regions with currently very high costs of energy supply from off-grid small sources (including to the regions with a short summer navigation period – *‘severny zavoz’*), which will then lay the grounds for a federal target (sub)programme that may include not only northern territories, but also small off-grid Russian settlements (nearly 100,000 in all, as estimated by the RF Ministry of Energy), where it is too costly to provide centralized energy supply.

In order to attain this purpose it is important to do the following:

- analyze current situation in off-grid energy supply and small energy sources and discuss it by the Stakeholder committee of the Interregional agreement and by the expert community;
- analyze current financial pressure on regions with costly off-grid energy supply and small energy sources and discuss it by the Stakeholder committee and the expert community;
- set up Stakeholder committee and get its work started;
- develop a library of success stories and useful contacts based on low-carbon best practices in off-grid energy supply (with a focus on regions with severe climate) in Russia and abroad. Case studies;
- develop a model programme *‘Low-carbon solutions for off-grid Russian regions with high energy costs’* to assess the costs and benefits of the transition to low-carbon ‘smart’ and comprehensive energy supply systems; calibrate the model programme for two pilot regions;
- replicate energy efficiency and renewable energy practices and experiences in off-grid localities with high energy costs. Develop three issues of quarterly electronic newsletter *‘Low-carbon solutions for regions with high energy costs’*;
- organize a workshop and a meeting of the Stakeholder Committee in Moscow to discuss the project results that are expected to lay the grounds for a federal programme.

CENEf invites any and all stakeholders and experts to provide their comments and/or suggestions as to what and how needs to be done to develop and implement national energy efficiency and renewable energy programme for remote localities with high energy supply costs to ensure cost-effective and sustainable energy supply at minimal cost to all-level budgets.

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2 Analysis of current financial pressure on regions with costly off-grid energy supply

Overall costs of energy supply to all customers in 15 regions of Extreme North is 1.7 trillion rubles. Such huge costs are determined by both poor energy efficiency in these regions with costly off-grid energy supply and high energy price. Fuel, power, and heat prices in Russian off-grid energy supply systems are nearly the highest in the world. Electricity prices amount to 20-237 rubles/kWh, which is 5-55 times above Russia's average, and heat prices are 3-20 thousand rubles/Gcal (with peaks far above the range), which is 3-17 times higher, than Russia's average. A large part (two thirds) of energy costs are attributed to large industry and distribution systems. The income of providers of municipal utility services from power, heat, and natural gas sales amounts to 464 billion rubles. Of these, total spending from all-level budgets for energy supply to Extreme North regions amounted to more than 150 billion rubles in 2016. The share of public spending in the costs of energy supply to many regions of Extreme North exceeds 30%, occasionally even 60%, whereas Russia's average is about 20%. Cross-subsidies and the loss suffered by energy utilities in Extreme North amount to 40 billion rubles or more. About half of this amount is attributed to subsidies provided to customers in off-grid energy supply territories.

Nearly in all regions of Extreme North (except for those with oil and gas production) the share of energy supply costs in gross regional product (GRP) amounts to 20-37% and is several times beyond energy affordability thresholds, hampering economic development. In off-grid inhabited localities, the ratio of energy supply costs to municipal product is often above 40%. Energy efficiency improvements and renewable energy development can yield nearly 100 billion rubles in annual savings from reduced subsidies demand and cut down energy bills of public organizations. This is 14 times the maximum subsidies for energy efficiency improvements under the 'Energy Efficiency and Energy Sector Development' Programme allocated in 2013, and 714 times the amount allocated in subsidies in 2016. The question is, how to best use these 100 billion rubles: keep plugging the holes in the financial discipline of customers in the North and the Russian Far East or make energy affordable through more efficient use and 'greener' production? The first option is not feasible without continuously increasing public spending, whereas the second one is very feasible. All it takes is to start thinking in the terms of 'green', 'low-carbon' development instead of in the terms of 'economy of deficit' or 'summer navigation period delivery'.

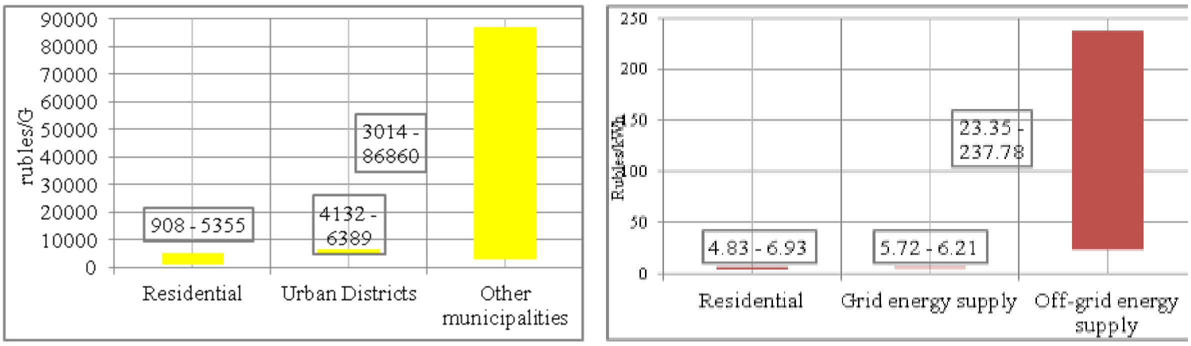
2.1 Energy prices and tariffs in regions with costly off-grid energy supply

Fuel, power, and heat prices in Russian off-grid energy supply systems are nearly the highest in the world. For this reason, if there is one location where energy efficiency or renewable energy solutions pay off, it is exactly off-grid areas of the Russian Extreme North. The mathematics is as follows. The price of diesel fuel is 50-100 thousand rubles/ton, specific consumption for electricity generation is 320-500 gce/kWh; therefore, fuel cost (net of diesel oil cost) amounts to 11-34 rubles/kWh (it normally amounts to nearly half of the costs of power generation). Then the full costs would vary between 22 and 68 rubles/kWh. It will be shown later, that it is possible to go beyond the upper value of this range. Speaking about coal-fired heat production, the price of 1 ton of coal (including delivery costs) in these regions is 3-8 thousand rubles. With 180-240 kgce/Gcal specific fuel consumption, 50% of other costs in overall heat supply costs, and with 20% heat distribution losses, heat tariff is 2-7 thousand rubles/Gcal, which is below the real heat tariff cap though.

Below we provide information on the current power and heat tariffs in Extreme North territories, including in off-grid energy supply areas. For the purpose of setting the scale, here are the tariffs that will be average for Russia in 2017, as expected by the RF Ministry of Economy: power (residential) – 3.86 rubles/kWh (for users without electric ranges), power (industrial) – 2.53 rubles/kWh; heat (residential) – 1,184 rubles/Gcal, heat (industrial) – 1,806 rubles/Gcal.

Flat rate residential electricity tariff in **Arkhangelskaya Oblast,** as of the first half of 2017, was set at 4.41 rubles/kWh. Residential heat tariffs vary by municipalities between 725 and 2,276 rubles/Gcal. Residential electricity tariff set for 2017 in **Vologodskaya Oblast** is 4.05 rubles/kWh. Heat tariffs are set between 802 and 16,476 rubles/Gcal.[3] In **Kamchatsky Krai,** tariffs for electricity supplied to residential customers from the central energy knot and from off-grid energy knots are 6.69 rubles/kWh. Economically justified tariffs for off-grid customers are between 17.04 and 30.57 rubles/kWh. Residential heat tariffs vary between 904 and 4,835 rubles/Gcal. Economically justified tariffs in off-grid electricity supply areas in **Magadanskaya Oblast** are much higher than those set for residential customers (6.93 rubles/kWh) and vary between 23.35 and 237.78 rubles/kWh (Fig. 2.1). Residential heat tariffs vary by municipalities between 9% and 72% of the economically justified level, which is between 3,014 and 86,860 rubles/Gcal.

Figure 2.1 Residential heat tariff range and economically justified tariffs for urban districts and other municipalities in Magadanskaya Oblast in 2016



Residential heat tariffs and economically justified tariffs for urban districts and other municipalities

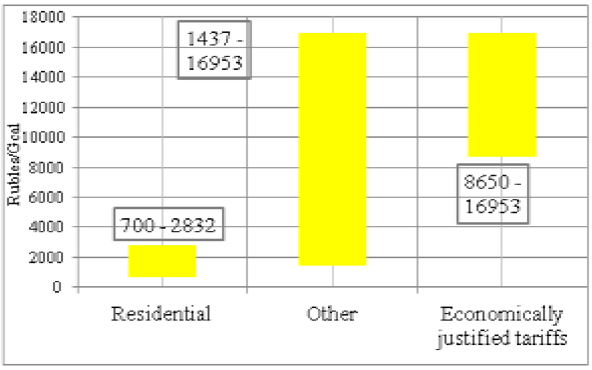
Residential electricity tariffs and economically justified tariffs for centralized and off-grid electricity supply areas

Source: Department for prices and tariffs, Magadanskaya Oblast Administration

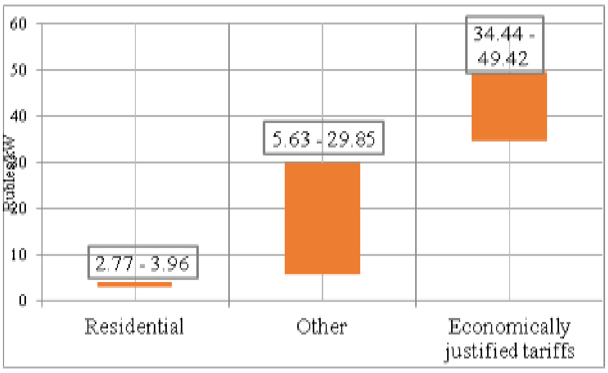
Economically justified tariff for electricity from diesel power plants in Chavan'ga, Chapoma, Tetrino, and Pyalitsa (Tersky region of **Murmanskaya Oblast**) is 20.53 rubles/kWh versus 7.95 rubles/kWh current customer tariff. Residential heat tariffs vary across the Oblast between 910 and 6,021 rubles/Gcal. In off-grid electricity supply areas of Nenets Autonomous District, tariff for residential customers is 3.96 rubles/kWh versus 5.63-29.85 rubles/kWh for other customers. Economically justified tariffs are several times higher: 34.44-49.42 rubles/kWh. Residential heat tariffs are only 8-19% of the economically justified levels, which vary between 8,650 and 16,953 rubles/Gcal.

[3] Vologodskaya Oblast has experience in setting tariffs for electricity (capacity) from renewable energy sources and purchased to compensate distribution losses of Bely Ruchei industrial mini-CHP. Capacity charge is set at 1,916.71 rubles/kWh, and electricity tariff at 0.873 rubles/kWh.

Figure 2.2 Residential heat tariff range and economically justified tariffs for urban districts and other municipalities in Nenets Autonomous District in 2014



Heat tariffs for residential and other customers and economically justified tariffs

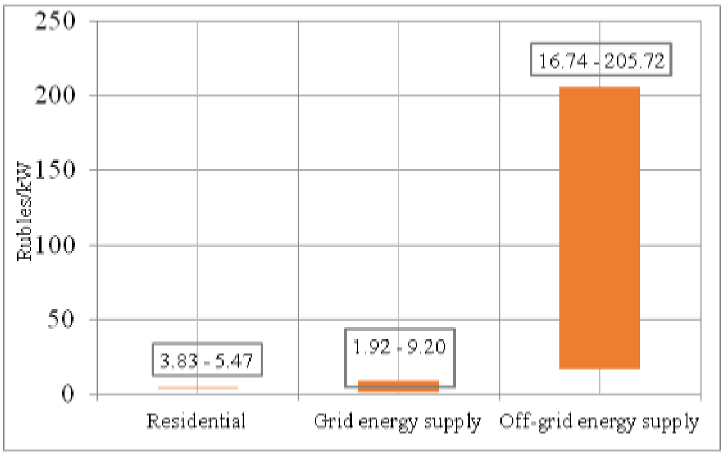


Electricity tariffs for residential and other customers and economically justified tariffs

Source: Department for federal price/tariff regulation, Nenets Autonomous District.

Residential heat tariffs in **Komi Republic** vary between 875 and 3,354 rubles/Gcal. Residential tariffs are only 7-88% of the economically justified level, which varies between 1,598 and 18,949 rubles/Gcal. Electricity tariff in off-grid energy supply systems of **Sakha Republic (Yakutia)** is set at 3.83-5.47 rubles/kWh for residential customers and at 7.80 rubles/kWh for individual entrepreneurs and agricultural producers. Economically justified tariffs vary between 16 and 206 rubles/kWh (Fig. 2.3). Heat tariffs vary widely between 803 and 45,574 rubles/Gcal.

Figure 2.3 Residential electricity tariff range for centralized and off-grid energy supply systems in Sakha Republic (Yakutia) in 2017



Source: Federal Committee for pricing policies – Regional public utility commission of Sakha Republic (Yakutia).

In off-grid energy supply areas of **Yamalo-Nenets Autonomous District**, economically justified tariffs amount to 30 rubles/kWh, and heat tariffs in some municipalities are above 5,200 rubles/Gcal. Residential heat tariffs in **Sakhalinskaya Oblast** vary between 1,023 and 2,096 rubles/Gcal, and heat tariffs for public and other customers vary between 386 and 14,481 rubles/Gcal. Heat tariffs for residential and other customers in **Tomskaya Oblast** vary between 687 and 14,341 rubles/Gcal; and in **Khanty-Mansiysky Autonomous District** between 249 and 11,946 rubles/Gcal. In **Chukotka**, residential heat tariffs are 400-1,425 rubles/Gcal, whereas economically justified tariffs are 2,956-99,219 rubles/Gcal. In other words, **economically justified electricity tariffs in off-grid energy systems in Extreme North are 22-237 rubles/kWh, i.e. 5-55 times higher, than Russia's average, and heat tariffs are 3-20**

thousand rubles/Gcal (with spikes even beyond this range), i.e. 3-17 times higher, than Russia's average.

2.2 Public spending for energy supply to customers in Extreme North

Customer incomes vary substantially across the regions of Extreme North. In oil and gas production regions, as well as in those where valuable natural resources are produced (including Nenets Autonomous District, Khanty-Mansiysky Autonomous District, Yamalo-Nenets Autonomous District, Magadanskaya and Sakhalinskaya Oblasts), they are higher, than Russia's average, whereas in other regions they are below or close to Russia's average. In off-grid areas with dominating conventional indigenous occupations (such as hunting, fishing, deer-breeding) incomes are often below Russia's average. Therefore, energy prices 5-20 times higher, than 'on the continent', are unaffordable and so subsidized using a variety of schemes.

Assessments of public spending to finance energy supply to customers in Extreme North are based on the information from statistical form '22-ZhKH' (2015), data on subsidies provided to residential customers to pay their energy bills, and information on privileges to certain categories of residential customers in terms of housing and municipal utility bills. Two latter elements are financed from the public budget to residential customers so they can pay their energy bills. Statistical form '22-ZhKH' helps assess (i) payments to public organizations to pay their municipal utility bills; (ii) public spending to compensate the difference between economically justified tariffs and actual residential tariffs (i.e. to cover the loss generated by energy price regulation); (iii) public spending to maintain municipal utility facilities that used to be in ownership other than municipal; public allocations to replace worn out fixed assets (including networks), to renovate and develop municipal utility facilities (see Box 2.1).

Box 2.1. How public spending for organizations that provide municipal utility services is shown in statistical form '22-ZhKH'

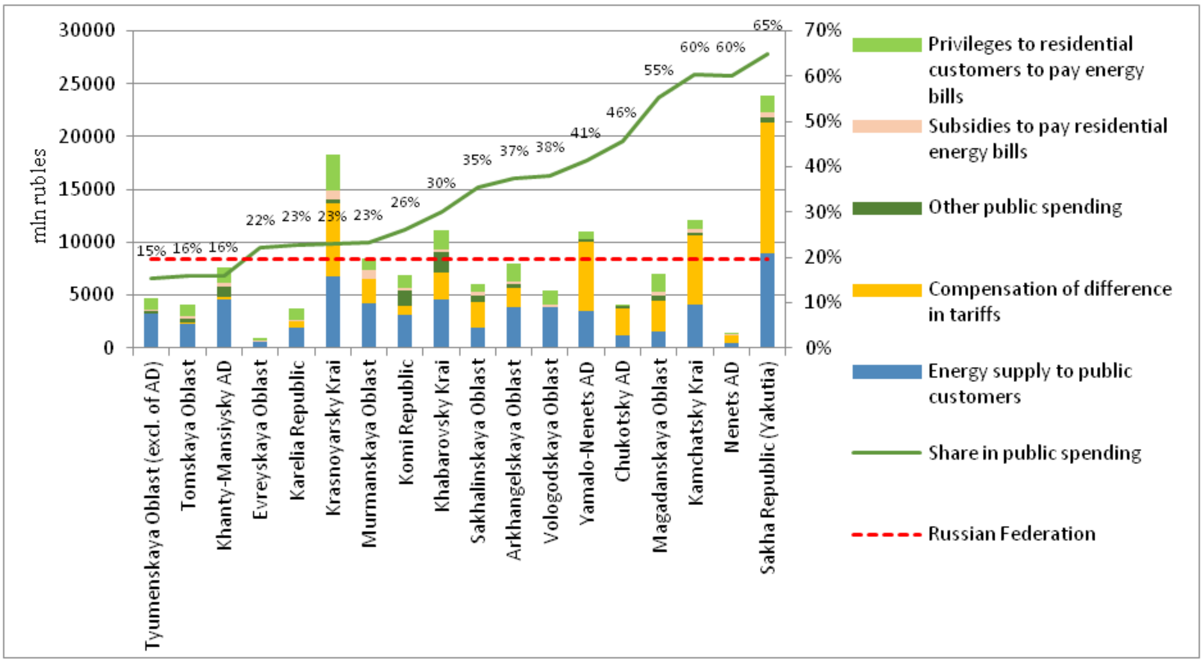
Statistical form '22-ZhKH' shows actual funding provided from all-level budgets to municipal utility services providers, including debts from previous years. They *do not include* financing for winterization or for target programmes (anticrisis programme, installation of meters, handling weather events, etc.). However, they *include* public spending for capital repairs of multifamily buildings; allocations to compensate the difference between economically justified tariffs and actual residential tariffs (i.e. the loss of municipal utility providers generated through energy price regulation); public allocations to maintain municipal utility facilities that used to be in ownership other than municipal; public allocations to replace worn out fixed assets (including networks), to renovate and develop municipal utility facilities. Public allocations for capital repairs of energy supply systems are not included.

Source: Rosstat

Total spending from all-level budgets for energy supply to the regions of Extreme North equaled nearly 145 billion rubles in 2015 and more than 150 billion rubles in 2016. Of these amounts, 60 billion rubles are spent to pay energy bills of public organizations; nearly 50 billion rubles are used to compensate the tariff difference; more than 8 billion rubles are spent for other needs (replacement of worn out fixed assets, renovation and development of municipal utility facilities, etc.); more than 5 billion rubles are used for residential subsidies; and finally more than 21 billion rubles go for social energy 'privileges'. It is hard to say, how much of public energy spending is used in off-grid energy systems alone. It should be around 70-80 billion rubles per year. This estimate is based on approximately 100 billion rubles fuel delivery costs during summer navigation period, which amount to nearly half of heat and power generation costs. Then total costs of energy supply to municipal utility providers amount to nearly 200 billion rubles, of which public spending is around 35-40%.

Public spending amounts to more than 30% in the costs of energy supply to many regions of Extreme North (excluding large industrial customers); in three regions it is more than 60%, whereas Russia's average is 19.5% (Fig. 2.4). This share is the largest (65%) in Sakha Republic (Yakutia); in Kamchatsky Krai and Nenets AD it is above 60%; and in Yamalo-Nenets AD, Chukotsky AD, and Magadanskaya Oblast it is above 40%.

Figure 2.4 Share of public spending in revenues of energy utilities in Extreme North



Source: estimated by CENEf

In many off-grid inhabited localities, little information is available to assess the share of public spending in the revenues of energy utilities. Since the share of public/residential sector energy consumption in these areas is higher, and so are energy tariffs, it may be assessed at 40-80% of total energy bills.

2.3 Cross-subsidies in the regions of Extreme North

Subsidies from the budget are not the only kind of energy subsidies provided to the residential sector. There are also cross-subsidies, which imply that residential energy tariffs in the regions of Extreme North, and primarily in off-grid areas, are reduced through the increase in tariffs for other customer groups, including industrial customers. Increased tariffs are also set for public organizations, and so the costs of energy supply to households are partially shifted to the public budget.

Cross subsidies and the loss of energy utilities in Extreme North amount to more than 40 billion rubles. Subsidies to customers in off-grid localities are responsible for nearly half of this amount. In Sakha Republic (Yakutia), cross-subsidies to diesel energy amounted to 5.5 billion rubles in 2014, 6 billion rubles in 2015, and 6.8 billion rubles in 2016. They are a substantial additional pressure on industrial customers.[4] Cross-subsidies result in the increase in average tariffs from 4.31 rubles/kWh to 6.15 rubles/kWh, because average tariff in off-grid areas is 35.8 rubles/kWh. Each kilowatt-hour used by industrial customers includes 2.48 rubles (or 38% of tariff) in cross-subsidies to diesel energy. This urges customers to go to the wholesale

[4] Sanachev, A. 2016. Local energy sector optimization programme of Sakha Republic (Yakutia). IV International Conference 'Renewable energy development in the Russian Far East'. June, 9, 2016. Yakutsk, 2016.

electricity and capacity market and gives a message to large industrial customers that it is worth investing in their own generation facilities. It also reduces the economic attractiveness of investments in deposits development and construction of processing industries. Total cross-subsidies in the Russian Far East are estimated at nearly 30 billion rubles. These should be summed up with cross-subsidies in Komi and Karelia Republics (2.3 and 1.6 billion rubles respectively), in Arkhangelskaya and Murmanskaya Oblasts (1.4 billion rubles each), and in Vologodskaya Oblast (0.3 billion rubles).[5] So the total is 37 billion rubles, excluding Tyumenskaya and Tomskaya Oblasts and Krasnoyarsky Krai. With an account of the latter three regions, cross-subsidies for power supply alone may be estimated at 40 billion rubles.

Russian State Duma reduced electricity tariffs for industrial customers in the Russian Far East. Draft law "On the amendments to the Federal Law 'On the electricity sector'" passed the second and the third readings. This law No. 508-FZ, passed on December 16, 2016, and approved by the Federation Council on December 23, 2016, will ensure that electricity tariffs in the RFE are brought down to Russia's average level. The law requires, that a special markup on capacity charge be introduced gradually over the next three years (from January 1, 2017, through January 1, 2020) across the whole country to compensate electricity tariff reduction to Russia's average level. Beyond 2020, tariffs are expected to drop to Russia's average level due to the increasing number of customers, which is currently hampered by high electricity costs. Related growth in end-use tariffs in the rest of Russia is estimated by the RF Antimonopoly Service at maximum 1.8%.

Yet even this is not the whole story. Cross-subsidies exist in heat and gas prices, too (Yakutia and Kamchatka). For example, in Kamchatka, the price of natural gas was 5,416 rubles/1000 m^3 in 2016. Gasprom reported commercial loss of 8,330 rubles/1000 m^3 from natural gas sales. In other words, actual costs of gas supply equaled 13,716 rubles/m^3, and total loss in gas supply system amounted to 3.3 billion rubles.

2.4 Total costs of energy supply and their share in gross regional products (GRP) of Extreme North regions

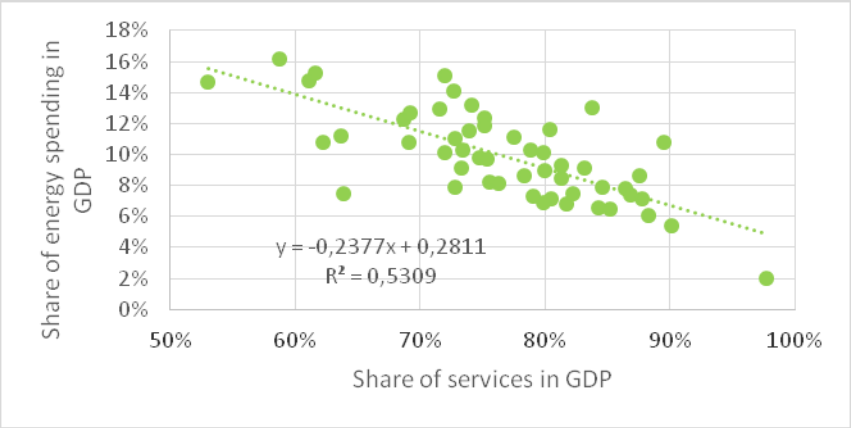
Cross-country analysis shows, that the 'share' of energy costs in GDP or GRP[6] fluctuates around pretty similar levels (8-12%) and is determined by the structure of economy, yet very little depends on the energy costs. The reason is, because, according to the 'minus one' rule, higher energy prices in the long run are gradually compensated by low energy intensity.[7] When the share of energy costs in GRP goes above 12%, it is beyond the affordability threshold and hampers economic growth. In some regions, this share may occasionally amount to 14-16%, but normally only for a short while. Data across some U.S. states show, that the ratio of energy costs to GRP is basically between 7 and 14%, with very few exceptions. The ratio of energy costs to GDP is mostly determined by the contribution of commercial sector to GDP (Fig. 2.5).

[5] Bazanova E.A. Cross-subsidies in the electricity sector of the Russian Federation are an inefficient institute. Magister thesis. Petrozavodsk State University. Petrozavodsk, 2016.

[6] Literally, the ratio of energy costs to GDP is not a share, because a substantial part of energy costs are part of intermediate commodity, rather than of added value or final product. Indeed, energy costs can be defined as a share in the gross product. Therefore, the term 'share of energy costs in GDP' is hereinafter put in quote marks.

[7] I. Bashmakov. 'Economics of constants' and long cycles of energy price dynamics. Voprosy ekonomiki (Issues of Economy). No. 7, 2016.

Figure 2.5 Relationship between the share of commercial sector in GRP and the ratio of energy costs/GRP for some of the U.S. states in 2012



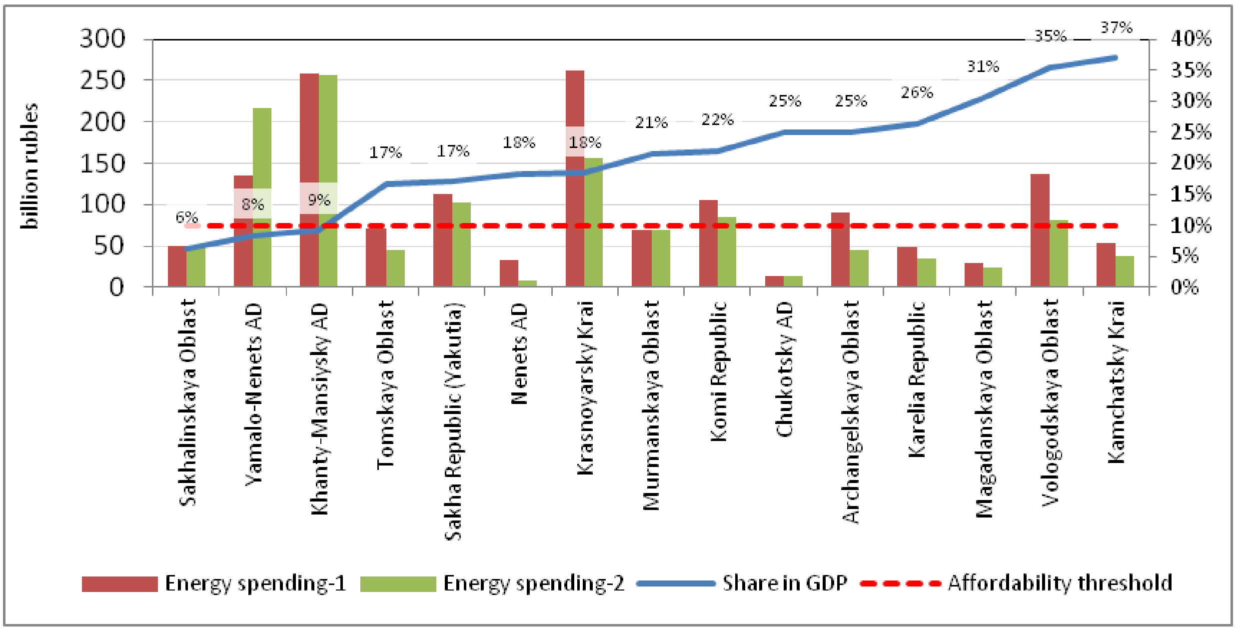
Source: EIA, 2014. US Regional Energy Data – Energy Consumption, Prices, Expenditures, and Production Estimates, July 2014.

Total costs of fuel and energy resources purchased in 2014 in the above 15 regions were estimated at 1,470 billion rubles. In 2016, they amounted to more than 1.7 trillion rubles. This is nearly 22% of total energy spending in Russia. No attempt has been made before to estimate the 'share' of energy costs in GRP of Extreme North regions. Below are the results of the first ever assessment experience. Two energy cost accounting approaches were used. The first approach estimates energy costs by multiplying end-use consumption of various energy carriers by different consumer groups by corresponding prices and tariffs. 2014 end-use fuel and energy consumption was estimated using integrated fuel-and-energy balances developed by CENEf for these regions. Fuel prices were taken from 2014 Rosstat data, and economically justified heat and electricity tariffs were taken from statistical form '22-ZhKH'. The second approach relies on the energy costs by sectors as reported by statistical form '4-TER', which includes fuel and energy spending by various companies and organizations. In order to avoid double counting, spending under 'electricity, gas, and water production and distribution' was not considered, because it is included in end-use prices. Statistical form '4-TER' does not include energy spending by small businesses and households, so these two sectors were added: energy spending by small businesses was estimated by CENEf, and that by households was taken from statistical form '22-ZhKH'. The analysis shows, that the first method better reflects real energy costs and provides more reliable estimates.[8]

Practically in all regions of Extreme North (except oil and gas production regions) the share of energy costs to GRP is substantially above the affordability thresholds (8-12%) and the Russia's average level (10.7%). The highest share of energy costs in GRP is in Kamchatsky Krai (37%) (Fig. 2.6). In eight regions this share is above 20%. In most regions of Extreme North it is 1.8-3.7 times above the energy affordability threshold. If this threshold is set at 10%, then energy affordability can be ensured only if energy subsidies of all types to customers of all groups equal 163 billion rubles in 2016. This is quite close to the above estimate of total public spending for energy supply to regions of Extreme North (more than 150 billion rubles).

[8] Total costs of fuel and energy resources purchased in 2014 in the 15 regions are estimated (using the second method) at 1,228 billion rubles.

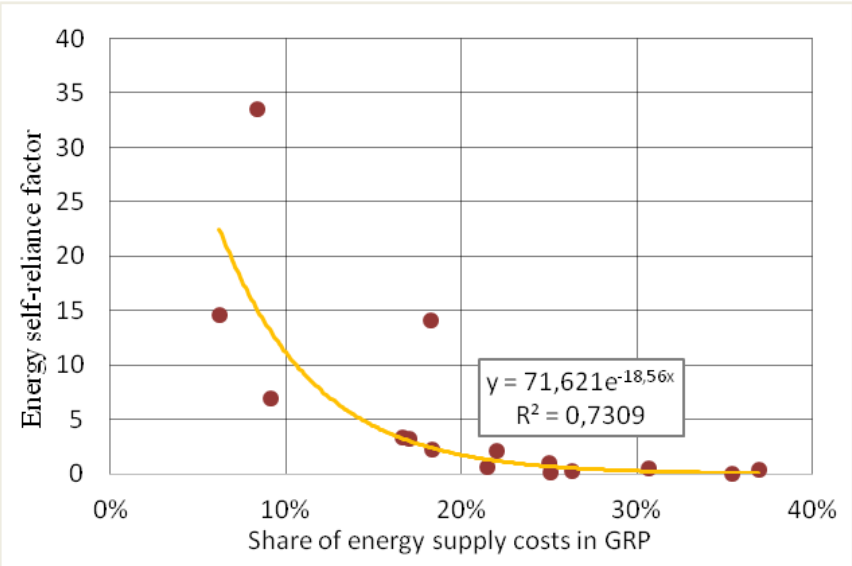
Figure 2.6 15 Russian regions ranked by share of energy supply costs in GRP



Source: estimated by CENEf.

In off-grid inhabited localities, the 'share' of energy supply costs in the municipal product should be above 40% and may reach 50-60%. Energy subsidies demand in such localities amounts to 40-50% of municipal product. There is an obvious correlation between a region's fuel and energy self-sufficiency factor[9] and the 'share' of energy supply costs in GRP (Fig. 2.7). Self-sufficiency factor is inverse to the region's reliance on fuel imports. In other words, the higher the share of fuel imports, the higher the share of energy supply costs in GRP (reaching up to 25-37% in regions that completely rely on fuel imports).

Figure 2.7 Correlation between the share of fuel and energy supply costs in GRP and the energy self-sufficiency factor

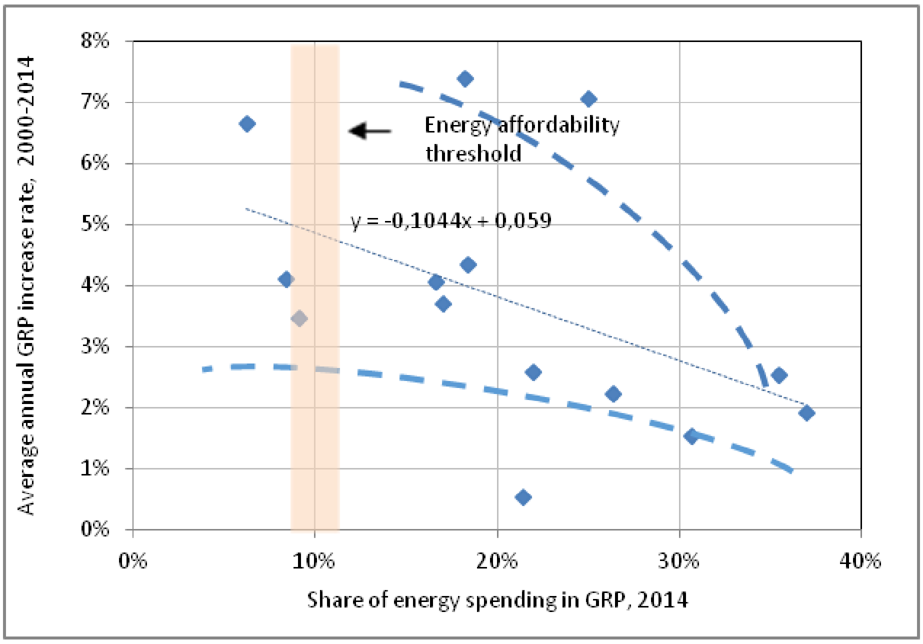


Source: estimated by CENEf.

[9] Fuel and energy self-sufficiency factor is defined as the ratio of fuel and energy resource production to primary consumption.

Research papers that look into the economic effects of high energy prices rarely explore energy affordability thresholds. Whenever the 'share' of energy costs in GRP is below the energy affordability threshold, there is no correlation between the energy cost pressure, energy efficiency, and economic activity. The latter is hampered by energy cost exceeding the upper threshold, but is spurred when the ratio is below the lower threshold. Correlation between GDP growth and the 'share of energy cost in GDP' can be described with the 'wing' function (Fig. 2.8).

Figure 2.8 Correlation between the 'share' of energy cost in GRP and average GRP increase rates* for regions of Extreme North (the 'wing' function)



* For Khanty-Mansiysky AD (Yugra), Yamalo-Nenets AD and Nenets AD average annual rates are given for 2001-2014

Source: estimated by CENEf

As long as the 'share' of energy costs in GDP is below the energy affordability threshold, energy availability and affordability put no 'limits to growth', and economic growth rates are determined by other factors. Therefore, the range of the 'wing' function is quite large, while correlation in this zone is pretty uncertain. This period is dominated by the "ignore/satisfice" behaviour. All key energy use decision-making is based on existing stereotypes, while energy cost optimization opportunities are not considered, because the cost pressure is relatively modest and allows for the purchase of other resources or for meeting other needs. As the upper threshold is approached, the decision-making scheme is replaced with "compensate/optimize". In this case, if the old trends are followed, too little resource would be available to address other problems, so resource use optimization is important. This is the only zone where decision-making is governed by neoclassic theory approaches. When the 'share' of energy costs in GRP goes beyond the upper threshold, reduced affordability of energy neutralizes the impacts of other factors that could potentially spur economic activities, and thus hampers these activities preventing full-scale implementation of the economic growth potential. When the upper threshold is exceeded substantially, the need for substitution of energy exceeds opportunities available in the short-term, hampering economic growth and focusing on the economic and energy security issues. This situation requires a new decision-making model ("secure/transform"), while medium-term optimization problems take a back seat losing it out to strategic problems. **For the regions of Extreme North, ensuring energy affordability by implementing energy efficiency measures**

and replacing diesel-fired generation with 'green' (RE) generation is a strategic priority and the basic means of ensuring their economic and energy security. It is impossible to ensure high economic growth rates with high pressure of energy costs. Going beyond the upper threshold is the beginning of dramatically hampered growth or stagnation. Fig. 2.8 shows, that each percent of going beyond the upper threshold reduces average annual GRP increase rate by 0.1%. The 'wing' function range keeps narrowing with distance from the threshold. This leads to decreased energy demand and economic growth rates and to the complete block of the impacts of other factors that might promote economic growth.

2.5 Energy efficiency improvements and renewable energy development to ensure energy affordability in Extreme North

Energy efficiency improvements and renewable energy development in the regions of Extreme North can yield nearly 100 billion rubles in annual savings from reduced subsidies demand and cut down energy bills of local public organizations. This is 14 times the maximum subsidies for energy efficiency improvements allocated under the "Energy Efficiency and Energy Sector Development" programme in 2013, and 714 times the amount allocated in subsidies in 2016. Energy saving potential in Extreme North is above 40%. Renewable energy development potential is also substantial. If both are fully implemented, energy supply costs can be reduced by 40-45%, while subsidies demand and energy bills of local customers can be reduced from 150-163 to 45-50 billion rubles per year, or by nearly 100 billion rubles. Approximately half of these savings can be obtained by implementing energy saving and renewable energy development measures in off-grid localities of Extreme North. The question is, how to best use these 100 billion rubles: keep plugging the holes in the financial discipline of customers in the North and the Russian Far East or make energy affordable through more efficient use and 'greener' production? The first option is not feasible without continuously increasing public spending, whereas the second one is very feasible. All that it takes is to start thinking in the terms of 'green', 'low-carbon' development instead of in the terms of 'economy of deficit' or 'summer navigation period delivery'.

Those who argue that energy efficiency and renewable energy technologies do not pay back in Russia ought to look at the regions where electricity price is 30-350 US¢/kWh, and heat price is 50-750 USD/Gcal. If a household gets a 10 W LED lamp for free to replace a 60 W incandescent lamp, it can save more than 100 kWh annually (with 30 rubles/kWh off-grid electricity cost) and bring more than 3,000 rubles in electricity cost savings per year. It is 15 times the lamp price. In other words, the investment pays back within a month. Now that the government provides a 20-25 rubles/kWh subsidy to residential customers by spending 200 rubles to purchase such lamp, the government will save 2,000-2,500 rubles each year. What other investment across the Russian economy is more efficient than this one? If a school in Extreme North uses 2,000 Gcal of heat per year, and installation of a 1-2 million rubles worth individual heating unit can yield 30-40% in savings, then, given 5,000 rubles/Gcal economically justified heat tariff, annual heat savings will be 3-4 million rubles. These two examples illustrate the fact that many energy efficiency improvements have very short paybacks with such energy tariffs. As to renewable energy, electricity tariffs of more than 20 rubles/kWh make virtually all renewable energy technologies competitive, even with additional costs required to make them operable in the Arctic climate.

3 Foreign experience in low-carbon off-grid energy supply transformation

High costs of diesel energy in remote regions hamper business development. Diesel energy generation units produce harmful atmospheric emissions, noise pollution, as well as water and soil pollution because of potential fuel leaks. Remote inhabited off-grid locations can hardly use natural gas to 'bridge the road' to the low-carbon future. They can rather use fuel savings yielded by energy efficiency improvements and renewable energy for this purpose. Because renewable energy generation costs are continuously going down, and diesel fuel price is sustainably growing, a shift from fossil fuels to a stronger focus on local and renewable energy resources offers substantial economic, financial, and environmental benefits.

Renewable energy development in remote regions may provide many useful lessons for large-scale RE use 'on the continent'. This is particularly true, if we take account of the distributed energy and mini-networks trend, which is increasingly viewed as an option to improve energy security, quality, and reliability of energy supply, and a method to cut energy costs. Reduced costs of renewable energy make it attractive for households and small communities, so the latter tend to cut themselves from centralized heat supply and launch their own energy generation.

Renewable energy development in off-grid energy systems has three decades' history. Analysis of foreign experience presented in this paper is mostly based on publications by IEA, IRENA, and individual researchers. All of them view off-grid energy systems as inhabited localities that are not connected to the central heat/power infrastructure, with 10 buildings or more, and 10 thousand people or less. For such localities, even with 30-60 rubles/kWh electricity generation costs, electricity transmission for more than 110 km is economically unpractical; and for settlements with less than 1,000 people the economic viability distance is limited to 20 km (Ziegler, 2015). IEA (2012) defines economic remoteness as regions where households cannot afford to pay the full costs of basic energy services.

By a variety of estimates, in Canada there are 175-300 off-grid energy systems with diesel electricity generation.[10] Everything is pretty much the same there, as in Russia. Average electricity price in off-grid systems is 1.12 USD/kWh (67 rubles/kWh) varying between 24 and 72 rubles/kWh; the price of diesel fuel depends on the transportation costs and is above 60 thousand rubles/t reaching 90 thousand rubles/t in the most remote areas (Advanced energy centre, 2015; Bhattarai, 2013). Specific electricity consumption per person (5,400 kWh) is also similar to the average consumption in Russian off-grid localities, and so is specific fuel consumption by diesel plants (approximately 330 gce/kWh or more); electric efficiency (34% or less); electricity generation cost structure (53% fuel, 28% operation costs, and 19% administrative costs).

What's even a bigger surprise, is that energy supply financing schemes are also similar. Customers pay only 9% of full energy supply costs. The rest is covered through: cross-subsidies by other provincial customers (34%), provincial government (1%), national government (56%) (Advanced energy centre, 2015). Not only northern, but also southern off-grid areas (for example, French or Japanese) use an approach by which local customers pay the same energy price as 'on the continent', rather than cover real generation costs. In Ontario Province alone, annual subsidies for diesel electricity generation equaled CAD 90 million in 2011. In such scheme, there is no obvious beneficiary from reduced energy subsidies. There is a 'disruption of incentives': those who can generate energy savings have little interest, and those who would like to obtain the savings have no physical opportunity.

[10] 292, according to the latest data. http://www.theglobeandmail.com/report-on-business/breakthrough/remote-communities-struggle-to-finance-wind-power/article15741016/

The basic strategy to improve the reliability of energy supply to remote regions includes energy efficiency improvements and energy demand management. These can reduce energy and fuel demand and so reduce energy supply costs and demand for renewable energy capacity to replace diesel energy units and boilers. Access of remote customers to the most efficient technologies is often limited by delivery difficulties. For example, in Scotland, only 13% of households in remote regions are classified as energy efficient versus 55% in the remaining part of the country. In fact, poor transport accessibility can be an advantage. If only highly efficient equipment were delivered to remote areas (with possible compensation of the price difference with medium-efficient models), then there would be no chance for the customers to buy inefficient models. This can partially address the problem of poor price motivation for energy savings that results from energy subsidies. Serious attention should be paid to electricity distribution losses, which can amount to 20% or more. Programme implementation should include renovation of power distribution networks.

A windpark in Kodiak, Alaska, USA (6 thousand people) is a success story of renewable energy deployment in remote regions with long winter season. In 2009, a hybrid wind/diesel system was installed there to include three 1.5 MW wind turbines and a 33 MW diesel unit. This system was integrated with the existing 20 MW hydropower plant. The effort resulted in the reduction of diesel fuel consumption by 3.4 million l and yielded USD 2.3 million in energy cost savings over the first year. In 2011, another hydro turbine was installed (10 MW), followed in 2012 with 3 more wind units of 4.5 MW total capacity and a 3 MW energy accumulation system. This allowed it to meet nearly 99.7% of local electricity demand with renewable energy and to cut down energy tariffs, rather than increase them.[11] While residential energy price in Alaska is 17.6 ¢/kWh on average, in Kodiak it is 13.8 ¢/kWh, which is just a little more, than the average tariff 'on the continent' (12.5 ¢/kWh). In 2016, hydro electricity generation cost was 6.8 ¢/kWh, wind electricity generation cost was 11 ¢/kWh, and diesel energy generation cost was 28.9 ¢/kWh.[12] In addition, wind units are installed in Alaska in the following locations: Kotzebue, Wales, Kasigluk, Pillar Mountain, and in a number of settlements in West Alaska.

Ramea Island in Canada (600 people) is another example. A hybrid wind/diesel unit combined with hydrogen accumulation system was installed there. Wind capacity is 690 kW, hydrogen fuel cell is 250 kW. These are combined with three 925 kW diesel energy units. The cost of the first project stage was CAN 1.4 million, or CAN 3,589 per kW. The national government provided CAN 475 thousand and CAN 112 thousand in technical aid. For the second project stage, Atlantic Canadian Opportunities Agency provided CAN 3 million in addition to CAN 4.5 million from the province government.

In Utsira Island (Norway), the first ever wind/hydrogen plant was installed in 2004. Under the project, 10 households were supplied only with renewable electricity. An electrolyzer is used to produce hydrogen with excess capacity and a fuel cell is used to produce electricity from hydrogen. The project was implemented by Statoil and allowed it to detect problems and figure out how to address them. More efficient electrolyzers and fuel cells were needed.

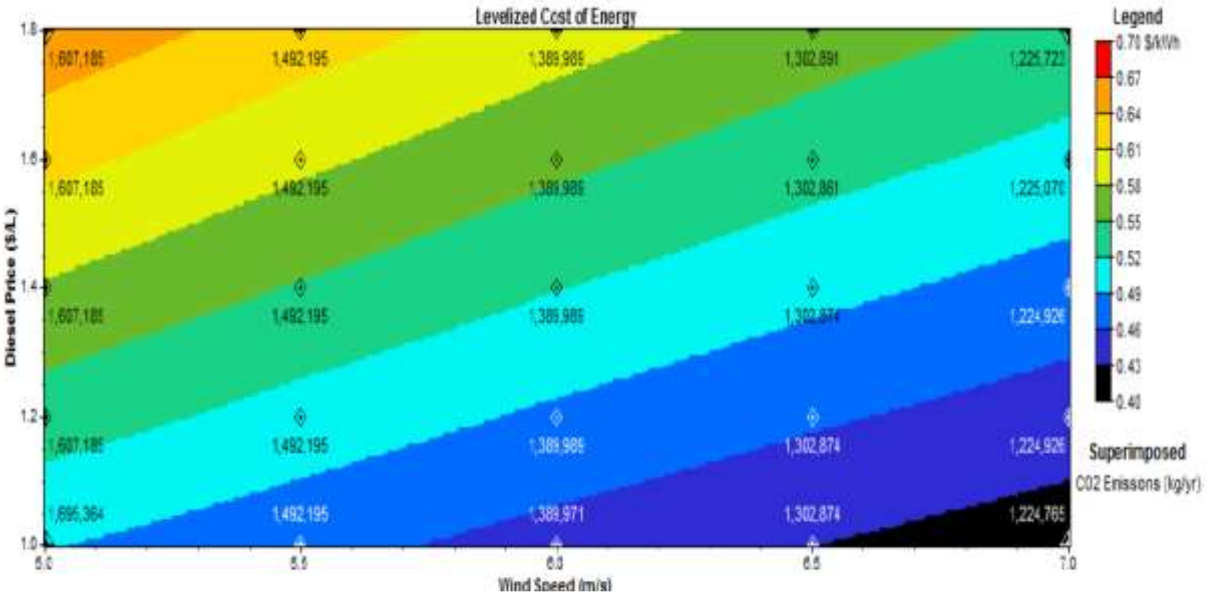
Off-grid energy systems operation experience shows, that renewable electricity generation is more costly (1.5-2 times) in off-grid locations, than in energy systems connected to central energy infrastructure. This is a result of smaller unit capacities and additional costs of transportation and equipment installation. However, electricity generation from renewable energy sources is still much cheaper, than by diesel units.

To identify the optimal configuration for off-grid electricity supply, various countries use HOMER, RETScreen, and other models that allow for a least-cost and highly reliable energy supply system with minimum emissions. HOMER model (www.homerenergy.com) addresses

[11] http://blog.rmi.org/blog_2015_05_19_an_alaskan_island_goes_one_hundred_percent_renewable
[12] http://www.kodiakelectric.com/generation.html

three basic problems: modeling, optimization, and sensitivity analysis. It can model systems with any combinations of PV modules, wind turbines, small hydro, biomass, diesel energy, fuel cells, batteries, and hydrogen storage systems. To make estimates, it requires information on loads, parameters of generators and energy storage systems (PV panels, wind turbines, hydro turbines, diesel units, electric networks, batteries, converters, electrolyzers, etc.); renewable energy (solar, wind) parameters, and economic information: discount rate, project lifetime, unserved load cost, fuel price, fixed operation costs, maintenance costs, carbon tax; parameters of units and accumulation batteries management; systemic limitations: operating reserve, maximum annual capacity shortage. HOMER experience shows, that diesel electricity generation costs can be reduced through the optimization of diesel unit capacity to best fit the load curve, which is often determined mostly by the buildings (residential and other) sector. Such optimization can cut fuel demand by 15-20% (Bhattarai, 2013). Even with a relatively small share of renewable energy in the hybrid unit (7-14%) reduction in electricity generation costs may amount to 20%. With 24-72 rubles/kWh energy tariffs this reduction would yield 4.8-14.4 rubles/kWh. The higher the wind speed, the larger decrease in electricity tariff and GHG emissions can be obtained (Figure 3.1).

Figure 3.1 Example of sensitivity analysis of effects generated by installation of a hybrid energy generation unit using HOMER model



Source: Bhattarai (2013).

There are a number of barriers to renewable energy deployment in off-grid areas. It is important to have data in increments of 10 minutes at least for one year to correctly estimate the wind profile in any location and to identify the optimal location and parameters for a wind unit. These data can be obtained with the help of meters installed at various altitudes. During the project initiation stage, meteorological data of local airports can be used. A variety of organizations explore the potential of various renewable energy sources, yet most of the data obtained are confidential, not meant for other users, and are not accumulated in any central data storage (Bhattarai, 2013). As far as solar energy is concerned, data obtained under one project can be used as a baseline for a nearby other project.

Installation of renewable energy units in remote northern localities also faces technical problems related to equipment reliability requirements, given low loads and early wear. Energy supply reliability is a top priority, particularly in remote inhabited localities. Therefore, hybrid systems including renewable energy sources should be as reliable as diesel units. Renewable energy is often viewed as a new technical solution, whereas diesel energy units are regarded as a proven alternative. Therefore, it is important to collect more renewable energy success stories, disseminate information; accumulate operation experience; train personnel; tune financing schemes for renewable energy projects. High costs of installing renewable energy equipment in remote areas are also an important barrier to large-scale RE technologies deployment. Transportation logistics is an important issue (Advanced energy centre, 2015). Financing for individual renewable energy projects is often provided from a variety of sources and is based on different labor-intense application and assessment procedures. Current mechanisms to assess renewable energy projects in remote areas do not include environmental, social or economic assessments.

There is no adequate understanding yet, as to which renewable energy technologies and under which circumstances it is practical to implement; and reliable data on renewable electricity generation costs are not available. Lifecycle costs are rarely taken into account while making investing decisions, losing it out to the minimization of upfront capital investments. There is no coordination between investment demand and operation costs. Huge subsidies, numerous subsidy sources, intricate diesel fuel procurement process mess up the structure of incentives for energy cost savings in off-grid areas. The existing variety of financial sources often makes it impossible for one organization to justify renewable energy deployment costs. In many instances, organizations that provide financing for renewable energy technologies do not have sufficient incentives to develop a viable project replication system.

Energy efficiency and renewable energy project experience in remote areas in other countries allows for the identification of policy requirements to expand these efforts and improve their effectiveness. National and regional aid is important to optimize subsidy schemes and goals; spur energy efficiency programmes; assist in personnel training and project development and implementation; develop a system of incentives, including by amending the subsidies scheme; tailor the procurement process to address the problems caused by the small size of any one project; set renewable energy targets for off-grid energy supply systems; mitigate project implementation risks.

One possible national policy is to use part of energy subsidies to support renewable energy development in remote inhabited localities, such as Ramea Island in Canada. Sakha Republic (Yakutia) has also accumulated an interesting experience (Box 3.1). Many of early renewable energy projects were financed, in whole or in part, by national governments, including as pilot projects. Replication of such projects would be practical with private financing that will pay off from the savings on heat and electricity subsidies by a scheme similar to that of a performance contract or using other forms of private-public partnership. Relatively small size or remoteness of an individual project may be a problem. In this case, energy utility that serves several settlements may act as an ESCO, orelse it may provide operation management services to a remote ESCO. It is important to consolidate subsidies to make these schemes more efficient. With the fee-for-service model, investor is the owner of the new RE facilities and signs an electricity or heat supply contract with the energy utility for the same or somewhat lower prices. These prices are used until the investor recovers his investment. If the new equipment is leased out, then the owner will be getting lease payments according to the payment schedule that keeps tariffs lower than those for diesel energy (IEA, 2013).

Integrated energy contract (IEC) is a new scheme recently developed to finance installation of PV panels in the U.S. It integrates the fee-for-service model with energy efficiency measures. Under the integrated energy contract, priority is given to energy efficiency measures. Baseline energy costs, which are important to estimate savings, include former energy supply costs (including all subsidies), which can be reduced either through energy efficiency measures or through renewable energy deployment across the whole energy supply system. A ‘one-contract-pack’ of energy efficiency measures and renewable energy deployment allows it to reduce the payback period and can become an attractive instrument for the implementation of such projects in remote areas. The subject of the contract covers the whole energy supply system, including fuel supply. The energy service company decides as to which elements of the system need to be renovated to obtain the maximum effect. This scheme is practically impossible to implement in energy supply systems that are connected to central energy infrastructure, but it perfectly fits off-grid areas. Incentives may also include tax benefits for certain types of equipment used for off-grid energy systems renovation.

Box 3.1

From July 31, 2014, through November 17, 2015, Sakha Republic (Yakutia) was governed by the "Algorithm to provide subsidies from the budget of Sakha Republic (Yakutia) to partially compensate the costs of energy efficiency improvements under energy service contracts" (approved by Decree of SR(Y) government of July 31, 2014). According to this document, those legal entities and individual entrepreneurs that implemented energy efficiency improvements under energy service contracts in the territory of SR(Y) were eligible for a subsidy amounting to 30% of the actual investment in energy efficiency improvements under energy service contracts. The "Algorithm to provide subsidies from the budget of Sakha Republic (Yakutia) to partially compensate the costs of energy efficient equipment purchased by economic entities for the implementation of energy efficiency projects, including to the economic entities who have accomplished energy service contracts" was approved on November 12, 2015 and was in effect through August 8, 2016. Legal entities eligible for the subsidy included legal entities and individual entrepreneurs, who invested in energy efficient equipment for the implementation of energy conservation and energy efficiency projects, including the economic entities who have accomplished energy service contracts. The list of eligible technologies includes solar energy accumulators and wind turbines. The subsidy was not to exceed 30% of the actual investment. Subsidy effectiveness indicators include: reduction in monthly specific heat-, power-, and water consumption and the economic effect yielded by the new equipment. Relevant targets are specified in the agreement to partially compensate the relevant costs signed between the Republican Ministry and the subsidy applicant. The subsidy effectiveness is assessed by the Republican Ministry by comparing actually achieved reductions and those specified in relevant subsidy agreements. The subsidy must be returned if the specified targets are not achieved. The "Algorithm to provide subsidies from the budget of Sakha Republic (Yakutia) to partially compensate lease payments of economic entities for energy efficient equipment leased for the implementation of energy efficiency projects, including lease payments by the economic entities who have accomplished energy service contracts" was approved on November 28, 2015 and was in effect through August 8, 2016. The subsidy was not to exceed 30% of the actually made lease payments.

A Remote Area Energy Service Company (RESCO) is often set up to serve several remote off-grid inhabited localities. It is easier for such company to attract financing. In renewable energy projects RESCO maintains its ownership, ensures installation, operation, maintenance, repair, and additional services. Another direction to address personnel shortage and poor qualification is to develop professional networks to provide technical assistance, training, and technical support (hotlines). Yet another form of support could include training for technical experts in remote areas with the involvement of non-profit organizations, experts from regional universities and colleges, and setting partnerships with academic institutions.

National governments can support and promote energy efficiency and renewable energy programmes in remote areas through aggregation and scaleup. Relatively small programmes can be put together to form larger ones and so obtain scale benefits. The use of standard equipment in regional and federal programmes allows it to benefit from much lower equipment prices, develop effective technical and training support, attract financing from large banks, extend the number of potential lenders, and launch competition to reduce loan interest rates.

The complex issue of distributed institutional and economic responsibility for energy supply to off-grid areas requires effective coordination of action taken by the national government, regional and local governments. It also requires that an energy efficiency and renewable energy subprogramme be developed and implemented for off-grid areas with high energy supply costs to lay the basis for the modernization of local energy supply systems and ensure cost-effective, sustainable, and reliable energy supply at the minimal cost to all-levels budgets. Russia will have to address energy supply problems of its off-grid areas. Relevant, albeit limited, experience has been accumulated abroad. It must be explored. But at the same time it is important to accumulate and export our own experience.

There is a huge market for renewable energy to replace diesel energy generation. Nearly 400 GW diesel energy generation capacity with less than 0.5 MW unit capacity is currently in operation globally. Diesel generators of about 500 GW total capacity are operated in the industrial sector. 50 to 250 GW of total installed capacity can be hybridized with renewable energy sources. Today, solar batteries are installed at more than six million buildings; around 1 million small wind turbines are in operation; a substantial, yet unknown, number of solar street lights, road signs, and more than 10 thousand telecommunication platforms are powered by renewable energy, in particular by PV (IRENA, 2015). It is a market where Russia can become a global leader.

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4 Low-carbon pilot projects for Russian off-grid regions with high energy costs

4.1 General characteristics of pilot settlements

The purpose of CENEf's project 'Low-carbon solutions for Russian off-grid regions with high energy costs' is to develop model pilot programmes *"Low-carbon solutions for regions not connected to central energy infrastructure and with high energy costs"*. While Chapters 1-3 present a 'top-down', i.e. a macroeconomic picture of energy supply problems and costs in off-grid areas, this Chapter aims to present a 'bottom-up view', i.e. to show the current situation in concrete off-grid settlements, including what exactly it takes to ensure energy supply and what can be done to reduce these costs and to use the savings for the purpose of remote areas development.

Six settlements were selected for the pilot programmes development in Magadanskaya Oblast and in Sakha Republic (Yakutia). Their locations are shown in Fig. 4.1. Table 4.1 presents very general characteristics of these territories. Of the six settlements, one (Sangar) is rather large, another (Evensk) is medium-sized, and the other four are small/tiny settlements. Therefore, the pilot territories represent the whole specter of inhabited localities in terms of population. In all pilot territories, electricity generation is diesel fuel-based. Three settlements (Garmanda, Gizhiga, and Verkhny Paren') have no district heating and only rely on furnaces for space heating.

Table 4.1 General characteristics of six pilot settlements

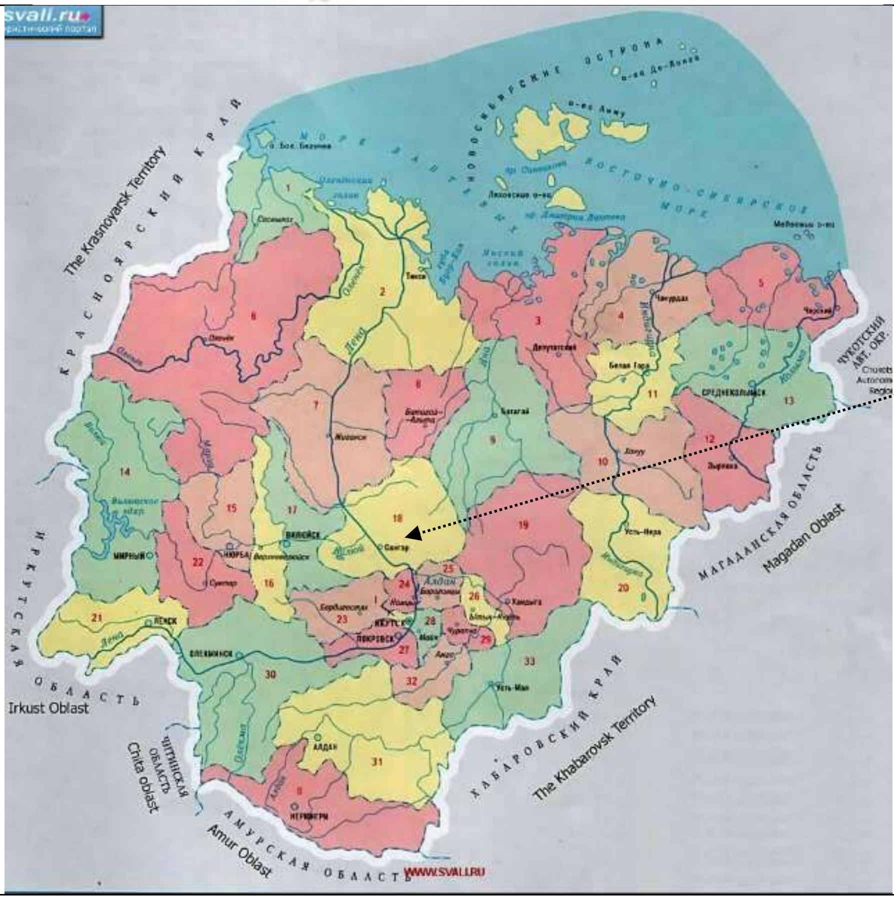
	Units	Sangar	Evensk	Gizhiga	Garmanda	Topolovka	Verkhny Paren'
Population	people	4,657	1,546	241	150	132	64
Diesel fuel and crude oil consumption	t/year	6,400	1,912	192	123	39	37
Coal consumption	t/year	20,177	10,140	2,060	756	387	415
Diesel fuel price	rubles/t	50,137	57,276	61,153	56,980	73,646	64,630
Coal price	rubles/t	8,000	9,750	11,879	9,916	11,879	11,879
Economically justified electricity tariff	rubles/kWh	22.22	28.35	42.13	46.40	80.02	80.06
Economically justified heat tariff	rubles/Gcal	4,869	6,776	19,318	no DHS	no DHS	no DHS
Energy supply costs	mln rubles	654.4	303.4	51.6	21.5	65.7	11.8
Same, per person	thou. rubles	140	198	151.7	145.5	118.4	90.8

Source: CENEf

Figure 4.1 The geographic position of six pilot settlements

Five inhabited localities in Severo-Evensk region (Magadanskaya Oblast)

- Evensk
- Verkhny Paren'
- Gizhiga
- Garmanda
- Topolovka

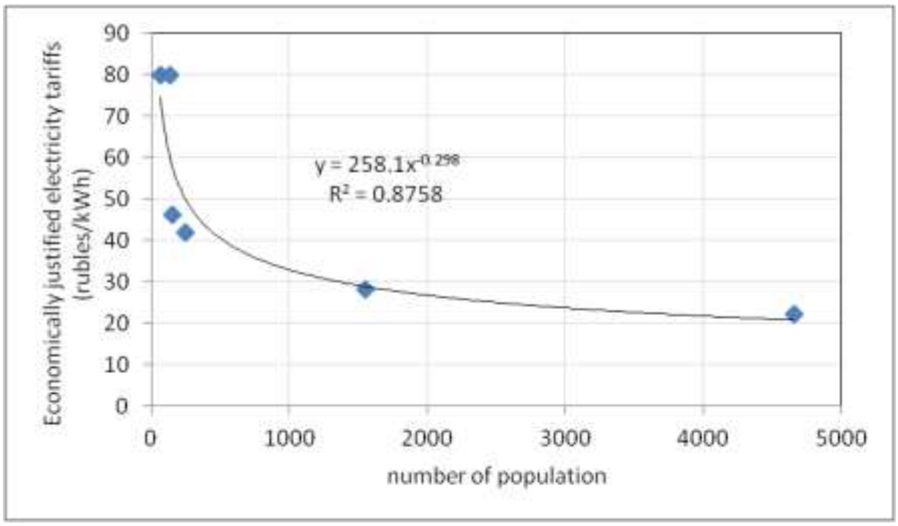


Sangar settlement, Verkhnevilyuisky Ulus, Sakha Republic (Yakutia)

Source: CENEf

Analysis of data in Table 4.1 reveals a few consistent patterns (Fig. 4.2 and 4.3). As diesel fuel price and transportation costs grow, the curve in Fig. 4.2 shifts upwards and the price of electricity grows too. As population drops and electricity sales go down against the background of relatively stable semi-fixed costs of diesel fuel-fired electricity generation, the curve shifts rightwards and the tariff grows. These two parallel processes ensure stable growth in the price of diesel fuel-fired electricity generation.

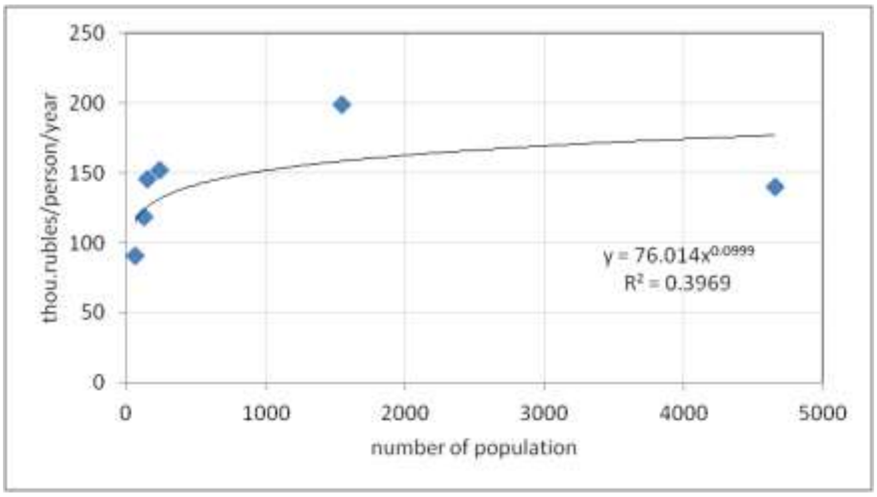
Figure 4.2 Relationship between economically justified electricity tariff and number of population



Source: CENEf

The costs of energy supply to inhabited localities include electricity, heat, and fuel delivery costs as based on the economically justified tariffs. **Total costs of energy supply to six pilot territories are more than 1.1 billion rubles per year, or 100-200 thousand rubles/year per person** (Fig. 4.3). In some settlements (often in large ones) per person costs are higher, because of the social infrastructure and higher level of amenities.

Figure 4.3 Relationship between per person costs of energy supply and number of population



Source: CENEf

Public spending for energy supply to the residential and public sectors in Severo-Evensk region equaled 268 million rubles in 2016. Public spending for fuel and energy subsidies to households and winterization was 204 million rubles, or 93 thousand rubles/person, and for energy supply to public organizations it was 64 million rubles, or 29 thousand rubles/person. At that, the share of tax and non-tax budget revenues is 16%, which is 3.5 times less, than public spending for energy supply alone.

In 2001, CENEf developed an *Energy efficiency programme for Severo-Evensk region of Magadanskaya Oblast.*[13] Therefore, CENEf is now in the position to compare the parameters of energy supply to the settlement as of 2000 and 2016 (Table 4.2).

Table 4.2 Parameters of energy supply to Evensk in 2000 and 2016

	Units	2000	2016/2017	Growth (+) or reduction (-)
Population in region (1990=8.3 thou. people)	thou. people	4,4	2.2	-50%
Evensk	thou. people	2,159	1,546	-28%
Electricity generation	thou. kWh	16500	8228	-50%
Heat generation	thou. Gcal	65	29,6	-54%
Diesel fuel consumption	t	4190	1912	-54%
Fuel delivery costs	mln rubles	123	207	68%
Share of electric space heating in electricity consumption (households)	%	35%	12-18%	-50%
Fuel consumption and heat sales metering at boiler-houses		N/A	N/A	
Heat sales metering	buildings	N/A	1	
Number of flats with DHW meters	flats	N/A	10	
Economically justified electricity tariff*	rubles/kWh	5,14	28,35	452%
Economically justified heat tariff*	rubles/Gcal	633	6776	970%

*Economically justified tariffs are shown for 2017.

Source: CENEf

Analysis of these data shows, that:

- Population of the region is continuously decreasing. It took 10 years – from 1990 through 2000 – for the population to nearly halve for the first time (from 8.3 to 4.4 thousand people) and 16 years to halve for the second time between 2001 and 2016);
- In Evensk, population decrease was slower: by 28% between 2001 and 2016, because population of small settlements was partially concentrating in Evensk;
- Electricity and heat generation, as well as diesel fuel consumption, halved over 16 years;
- While electricity and heat generation and consumption halved, fuel delivery costs showed 68% growth;
- The share of residential electricity consumption for space heating substantially decreased, (from 35% to 12-18%), yet is still substantial;
- There is still no metering of heat sold by heat sources, and practically no building-level metering of heat sold to residential customers, or household-level hot water consumption metering;
- Economically justified electricity tariffs grew up 5.5 times over 16 years, and economically justified heat tariffs grew up 10.7 times.

[13] CENEf. 2001. Energy efficiency programme for Severo-Evensk region of Magadanskaya Oblast. Evensk-Magadan-Moscow. February-April, 2001.

Therefore, **three effects are clearly seen in many settlements of Extreme North**:

- **'frozen time':** the changes that take place 'on the continent', including in energy efficiency and renewable energy, have little impact on these settlements (Fig. 4.4);
- **'shrinking economy':** reduced population, reduced economic activity, growth in subsidy demand, reduced electricity and heat generation and consumption, reduced fuel delivery;
- **reduction in energy affordability:** growth in energy supply costs, both per person (to 100-200 thousand rubles/person/year) and the overall costs per settlement, despite the 'economy of compression' effect.

The latter effect is both the cause and the result of the 'shrinking economy'.

4.2 Electricity balances

In small settlements (such as Gizhiga, Garmanda, Topolovka, Verkhny Paren'), power distribution losses (including commercial) were 40-60% in 2015-2016. Own use by diesel plants amounted to nearly 10%. Therefore, **electricity sales (or, rather, fully paid electricity supply) were just 50% or less**. No accurate data are available on electricity consumption in small settlements. Electricity debts and unauthorized use of diesel fuel used to be camouflaged with overstated specific fuel consumption by diesel plants. This practice was terminated. Electricity debts were then masqueraded with overstated commercial distribution losses. Then Magadanskaya Oblast price department set a 22% cap to distribution losses (although they may amount to 25% in some of the settlements, as estimated by CENEf). So under the new circumstances, electricity affordability can be ensured only through energy efficiency improvements, renewable energy development, and resulting electricity bills reduction.

There is much more certainty in terms of electricity consumption by large settlements (Fig. 4.5 and 4.6). **Own use by diesel plants and distribution losses amount to more than one fourth in total electricity generation.** Because economically justified tariffs are estimated by dividing required gross revenues (RB) by electricity sales, the share of these two elements is very important. The higher the share, the higher the tariff (given specified RB value). If electricity consumption for space heating and water supply is taken into account, it is around 17% of electricity generation. Municipal utilities are responsible for 46% of total electricity consumption in Evensk. In Sangar, own use and distribution losses amount to 22% of overall electricity generation; heat- and water supply to 28%, summing up to 50%.

In other words, **even in large settlements, life sustaining systems and distribution losses amount to approximately half of local electricity generation**. The rest is used by households (30% in Sangar and 36% in Evensk) and public organizations (8% in Sangar and 9.5% in Evensk), as well as by other customers. At least 7-12% of total electricity generation is used for space heating, at least 16% for lighting, 18% by pumps, and the rest by all types of electric equipment.

Figure 4.4 ‘Frozen time’, or visualized “inertia” strategy. Evensk in 2001 and 2017

2001

2017

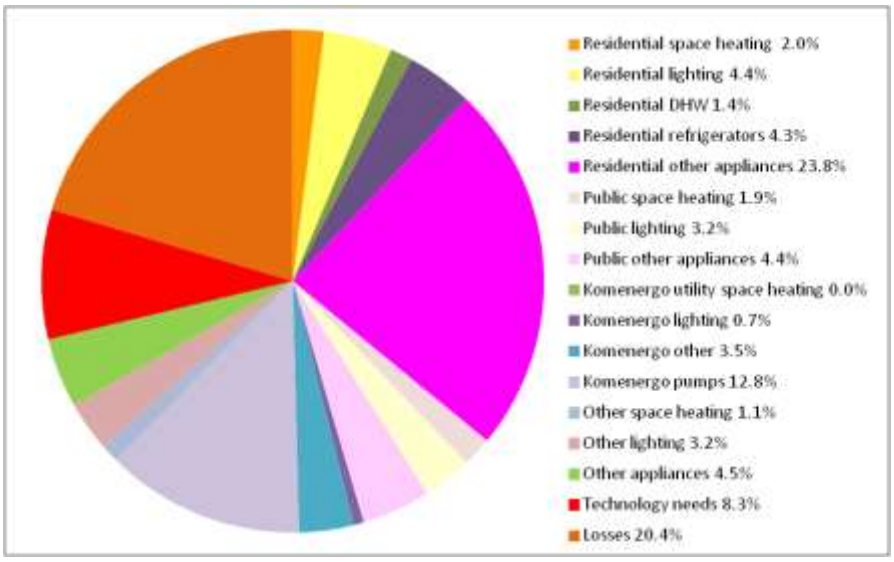
From the Energy efficiency programme for Severo-Evensk region of Magadanskaya Oblast (2001):

‘The local government also implements ‘Wind energy development programme for 2000-2002’, which includes eventual wind energy development in Topolovka, Chaibukha, Gizhiga, Tavatum, and Evensk. A contract was signed with “Severnye Technologii-EKO” and advance payment was made for the installation of two wind turbines (32 kW total installed capacity) in 2001 in Topolovka to be hybridized with a diesel plant.’

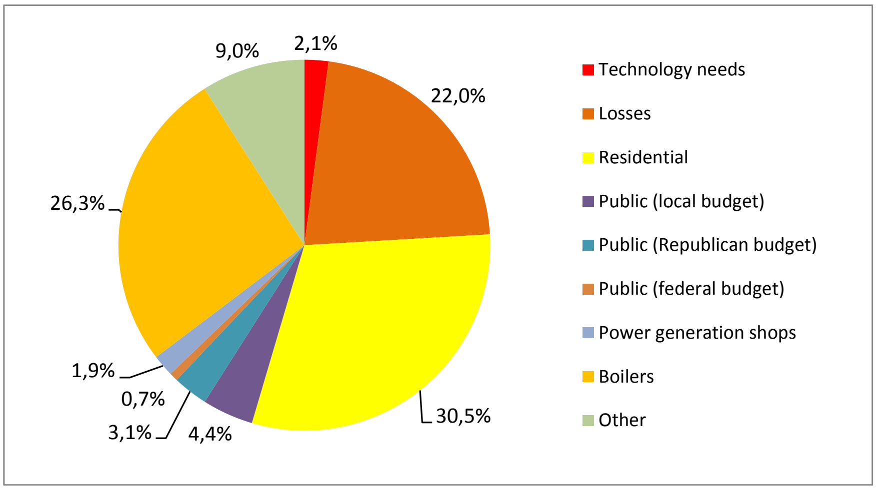
Today (16 years later), these plans have not been implemented.

Sources: CENEf. 2001. Energy efficiency programme for Severo-Evensk region, Magadanskaya Oblast. Evensk-Magadan-Moscow. February-April. 2001. Photo: CENEf during a trip to Evensk in January 2017.

Figure 4.5 Evensk and Sangar: electricity consumption structure



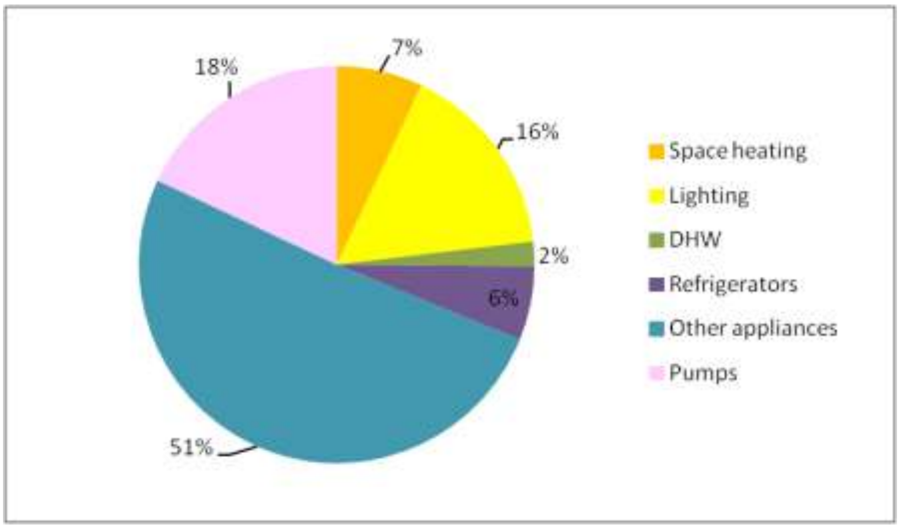
Evensk



Sangar

Source: CENEf based on data from Komenergo and Sakhaenergo utilities

Figure 4.6 Evensk: electricity consumption structure by processes



Source: CENEf based on data from Komenergo utility

Analysis of distribution of households in multifamily buildings in Evensk (around 600 flats) and Sangar (more than 800 flats) by their annual specific electricity consumption per person (Evensk) and per household was conducted. The sample includes only flats with at least some electricity consumption reported over the year. These data are compared with 600 kWh annual per person consumption (the value corresponding to a good, yet not the best, energy efficiency level) and with average consumption across the settlements. Yellow zone (less than 600 kWh/year electricity consumption) may indicate that people either live there only part of the year, or do not pay their electricity bills in full. Red zone shows that paid electricity bills include consumption higher than 600 kWh/person/year. Russia’s average level is 996 kWh/person/year versus 1,751 kWh/person/year average for Evensk. Electricity consumption by some households is even higher than 3,000 kWh/person/year. The highest specific electricity consumption is seen in small households. However, specific electricity consumption varies within a pretty large distribution range across each group of households, and mostly depends on the number and energy efficiency of appliances. The zone above average consumption level indicates that electricity is used for space heating purposes (Fig. 4.7 and 4.8). The share of residential spending for electric space- and water heating is estimated at 18% in Evensk and 16% in Sangar.

Average electricity use subsidy level per person or per household can be assessed by multiplying electricity consumption by the difference between the economically justified tariff and the actual residential tariff. These estimates show, that in Evensk:

- average electricity use subsidy level per person is 37,331 rubles/person/year, and
- in inefficient households it is above 50,000 rubles/person/year and may amount to 175,000 thousand rubles/person/year.

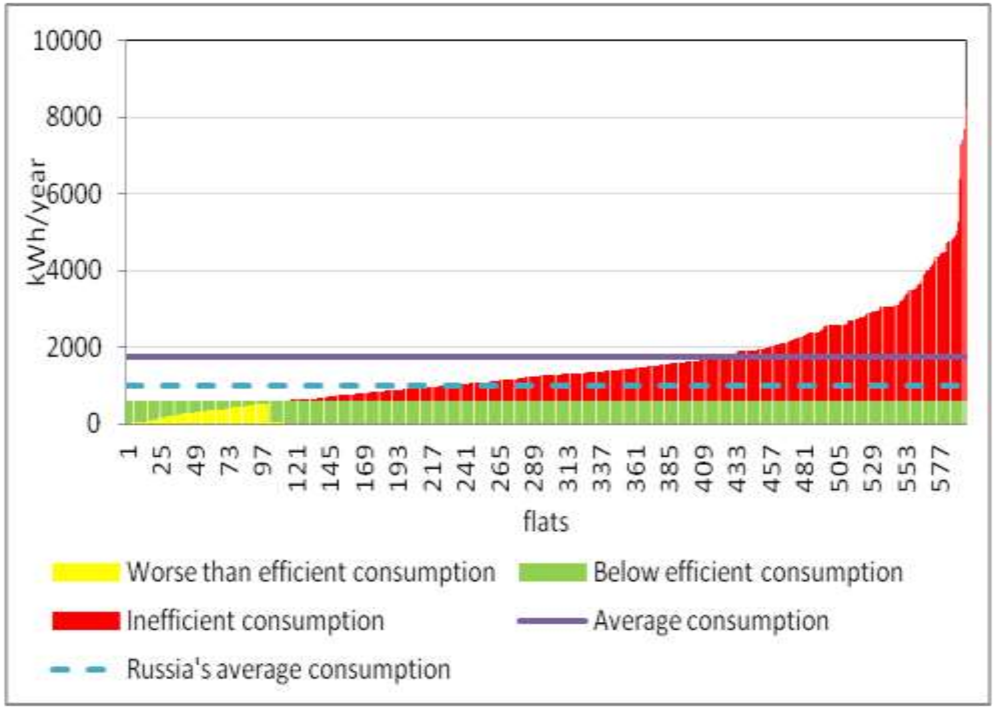
Quite similar result was obtained for Sangar, which is located very far from Evensk:

- average electricity use subsidy level is 69,000 rubles/flat/year, or approximately 31,000 rubles/person/year;
- in inefficient households it is above 100,000 rubles/flat/year and may amount to 200,000 rubles/flat/year.

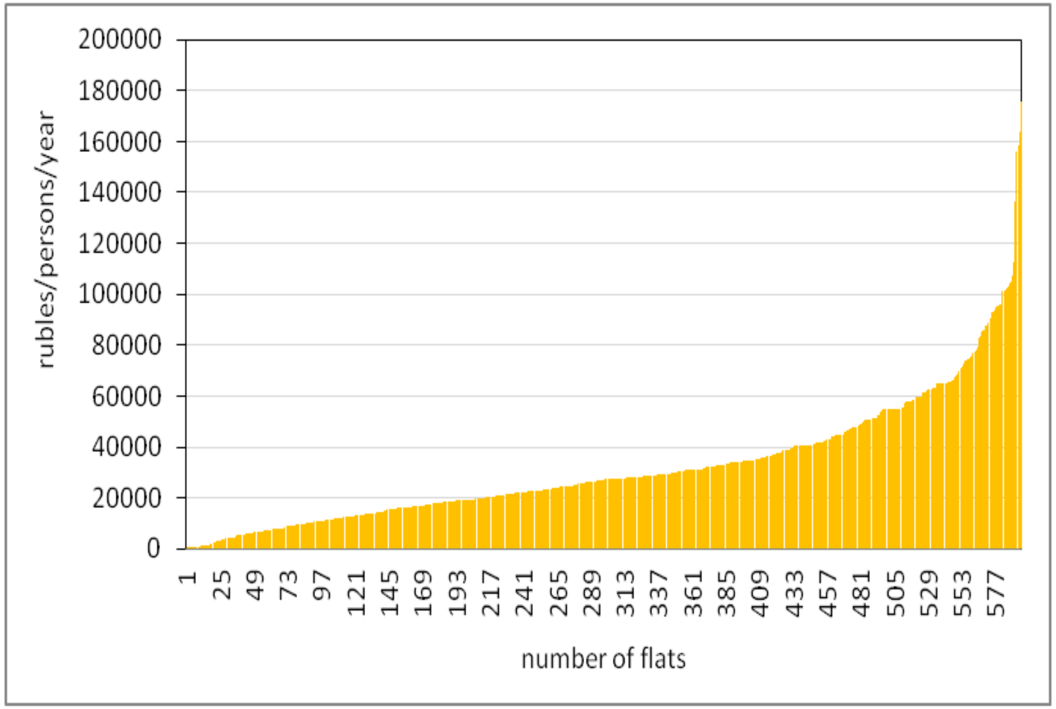
If the electricity saving potential is assessed against the 600 kWh/person/year electricity consumption level, then it is 51%. If it is assessed against the average consumption level, then it equals 18%.

If we take that an average household is slightly larger than 2 people, then **average electricity use subsidy level is 31-38 thousand rubles/person/year and may amount to 100-175 thousand rubles/person/year. The most inefficient users are eligible for the largest electricity subsidies. The national government pays a tangible premium for energy inefficiency. It is time for a change!**

Figure 4.7 Electricity use (per person) distribution and electricity subsidy level (per person) distribution in multifamily buildings (Evensk, 2016)



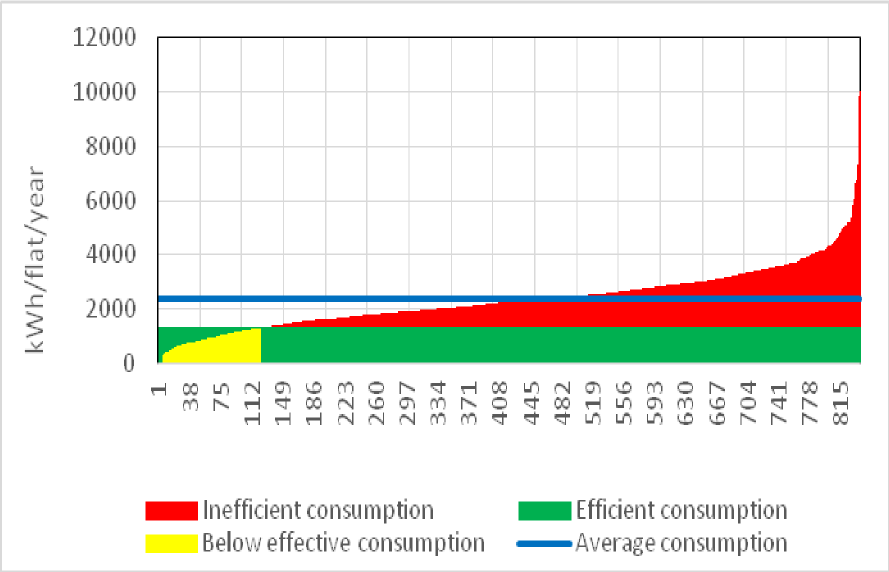
Electricity use per person



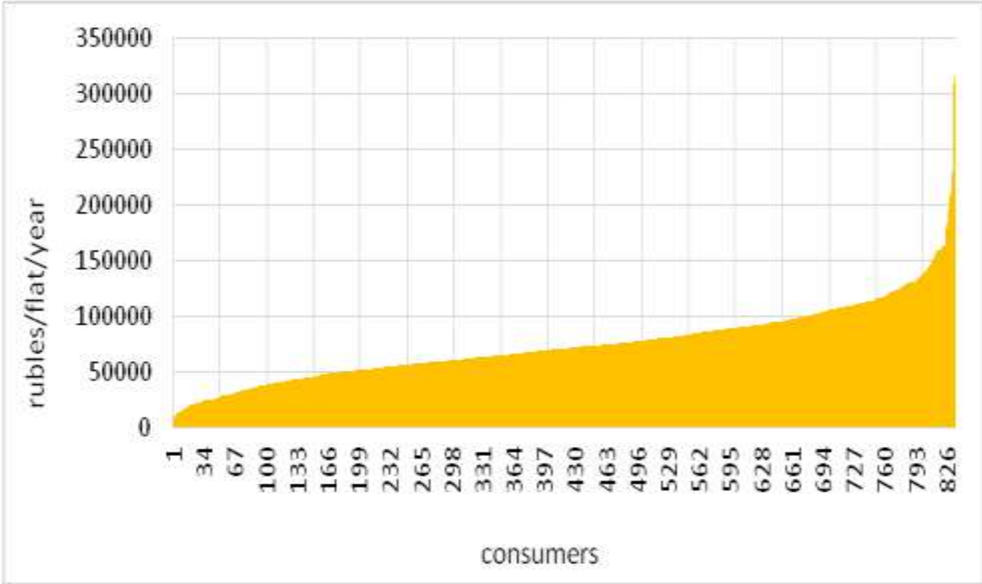
Electricity subsidy level per person

Source: CENEf based on data from Komenergo utility

Figure 4.8 Electricity use (per household) distribution and electricity subsidy level (per household) distribution in multifamily buildings (Sangar, 2016)



Electricity use per household



Electricity subsidy level per household

Source: CENEf based on data from Sakhaenergo utility

This situation can be handled through the following measures:

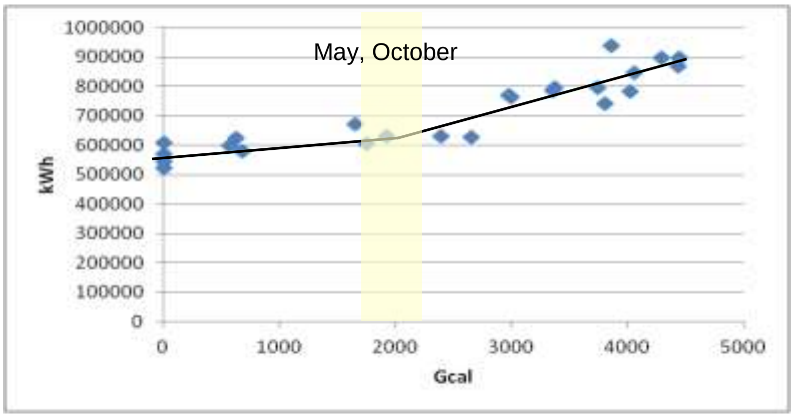
- set limits to subsidized electricity consumption (similarly to the scheme that is used to subsidize coal purchase for furnace space heating in Magadanskaya Oblast);
- eventually bring these limits down to maximum 100 kWh/person/month, or to 1,200 kWh/person/year;
- as soon as the limit is exceeded by more than 50%, increase the tariff incrementally to a level that would cover the full costs of electricity supply (22 rubles/kWh in Sangar or 28-80 rubles/kWh in Evensk or the nearby settlements);
- launch an instrument similar to the 'white certificates' mechanism to incentivize households to purchase highly efficient lighting equipment and appliances and implement weatherization measures in their flats and houses to avoid electric space heating;
- prohibit delivery to remote inhabited localities of incandescent lamps and appliances of energy efficiency classes other than A++.

Funding that is currently used for subsidies (70-200 thousand rubles/household/year) could be used to provide all households with the most efficient appliances or to install windows with the best thermal performance parameters, and over 2 or 3 years end up with highly energy efficient housing.

A larger part of electricity is used for space heating both by households and public and other organizations to improve thermal comfort. With electric space heating and 22-80 rubles/kWh electricity price the cost of heat so generated equals incredible 25,600-93,040 rubles/Gcal. This makes a substantial part (30-50%) of public spending to provide electricity subsidies to households.

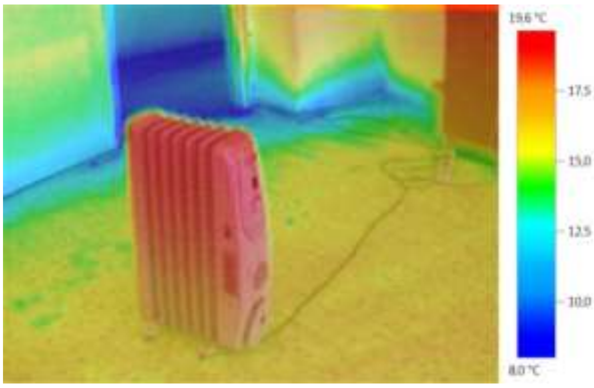
Figure 4.9 shows a correlation between electricity consumption and estimated heat consumption. Because heat supply is not metered, estimated monthly heat consumption is determined entirely based on average monthly outdoor air temperatures. Electricity consumption distribution by months is nothing but a temperature curve. Electricity consumption starts growing with the beginning of the heat supply season. This is partially determined by electricity use for lighting purposes, but mostly by the increasing use of electric heaters. Fig. 4.10 shows, that electric heaters are used to address problems related to the poor quality of buildings envelopes.

Figure 4.9 Correlation between electricity consumption and estimated heat consumption in Evensk



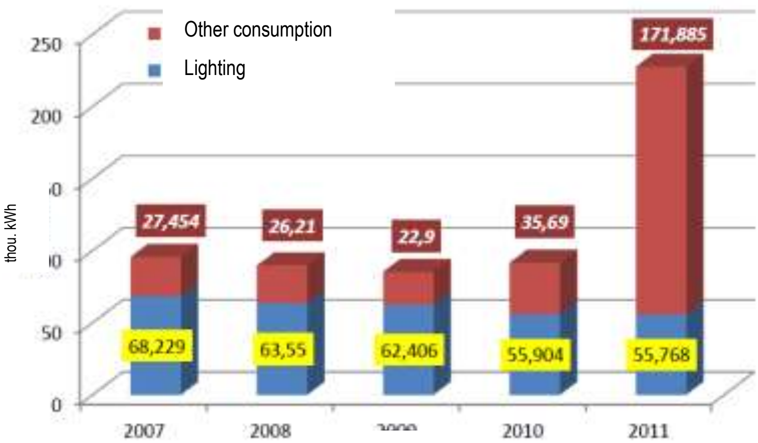
Source: CENEf

Figure 4.10 Electric heaters in the Children's activity centre. Sangar, February 2017



Source: CENEf

Figure 4.11 Evensk. Boarding school. Growth in electricity consumption driven by the use of electric heaters to compensate for poor operation of the district heating system in 2011

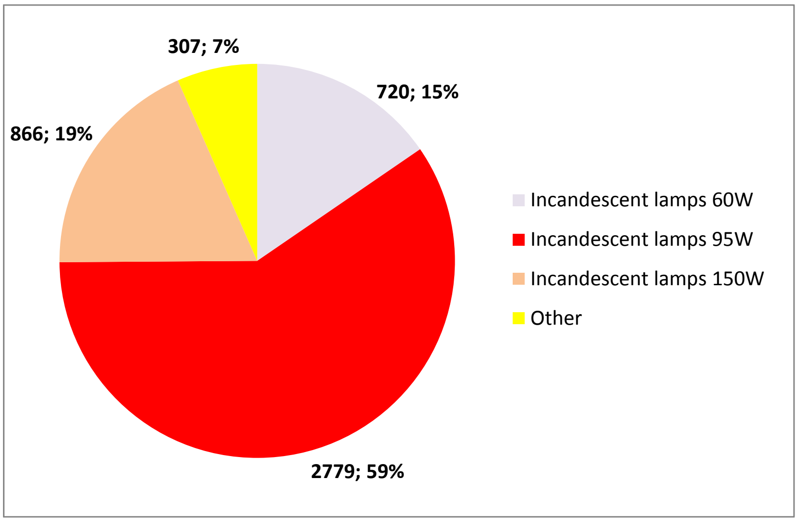


Source: CJSC GARANT-audit. Mandatory energy audit report. Comments to the energy passport of an energy customer "Zakirov Boarding school of general secondary education". Evensk. 2012.

The first thing to do in regions not connected to central energy infrastructure is to provide conditions for avoiding electric space heating, namely to implement weatherization and to improve operation of heat supply systems.

Sales of incandescent lamps keep dominating in the northern localities, while the use of these inefficient lamps keeps exhausting the public budget. Lighting is responsible for approximately 16% of total electricity consumption in all customer groups. Lamps used in off-grid settlements are often inefficient, and so there is a substantial electricity saving potential in this sector. CENEf accomplished an analysis of lamp sales in Evensk for 2016. Incandescent lamps amounted to 93% in total lamp sales (Fig. 4.12) and to 98% in sold capacity. 95 W incandescent lamps amounted to 60% in sold lamp capacity.

Figure 4.12 The structure of lamp sales in Evensk: 2016



Source: CENEf

The government pays at least 2,243-7,313 rubles/year per each 95 W incandescent lamp as compensation for the difference between economically justified electricity tariff and actual residential tariff, assuming such lamp is in operation 1,500 hours/year. Particularly high are these costs in small settlements with high economically justified electricity tariffs. Replacement of a 95 W incandescent lamp with an efficient 15 W lamp in Severo-Evensk region yields 3,360-9,600 rubles in operation cost savings and 2,760-9,000 in public spending savings. If we take that the price of a LED lamp is 300 rubles, and an incandescent lamp with the same luminous flux costs 50 rubles[14], then by providing a 250 rubles/lamp subsidy to incentivize LED lamps purchase the budget can recover the cost within 10-33 days. This can become a most effective programme to cut non-productive public spending in the Russian Federation.

Table 4.3 Incandescent lamps operation costs in off-grid inhabited settlements

Lamp sales in 2016	Share in sales		Operation costs (rubles/year) with 1,500 hours operation		
	%	sold capacity	28 rubles/kWh	40 rubles/kWh	80 rubles/kWh
Total	100%	100%			
Incandescent lamps (IL)	93%	99%			
IL 60 W	15%	10%	2,520	3,600	7,200
IL 95 W	59%	60%	3,990	5,700	11,400
IL 150 W	19%	29%	6,300	9,000	18,000
Efficient lamps	7%	1%	1,260	1,800	3,600
Savings yielded per 95 W IL (rubles/year)*			3,360	4,800	9,600
Monetary savings for the public budget per 95 W IL (rubles/year)*			2,760	4,200	9,000

* Savings estimated as the difference between the operation costs of an IL and an efficient lamp.

Source: CENEf

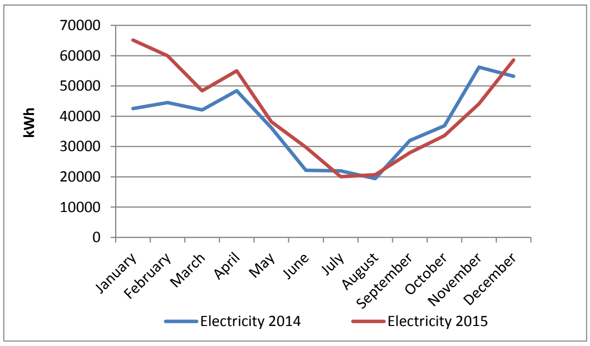
There is also a substantial saving potential in the lighting systems of public and other buildings. Fig. 4.11 shows, that normally lighting is responsible for more than 50% of the boarding school's electricity consumption. CENEf estimates, that lighting is responsible for at least 34% of electricity consumption by public organizations in Evensk and Sangar, or for 42% if space

[14] Average IL price in Evensk was 46 rubles in 2016.

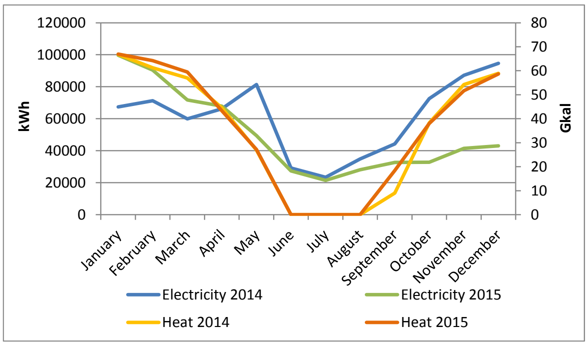
heating is not included. The potential to reduce electricity consumption for lighting purposes by public and other buildings is at least one fourth of current consumption level.

A large share of electricity use for space heating and lighting shapes the electricity load consumption curve (Fig. 4.13). In large settlements, electricity consumption is more even by months, whereas in small locations it is, on the contrary, very uneven and strongly depends on the average monthly outdoor air temperature and on the length of the daylight. In small settlements, electricity consumption in summer drops 3-5-fold compared to the winter maximum. When DHW supply is cut off in large settlements in summer for 2 or 3 months, electricity consumption for water heating grows. Generally, space heating and lighting obviously dominate electricity consumption increase in winter. The share of electric space heating in small settlements may exceed 20%. Buildings weatherization and replacement of lighting systems can substantially reduce both electricity consumption and winter load maximum.

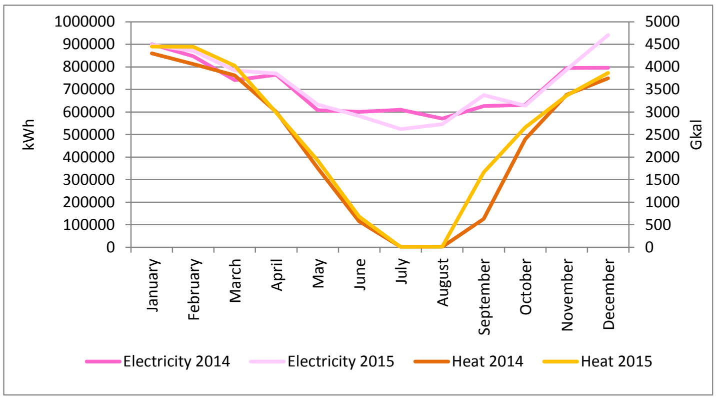
Figure 4.13 Electricity and heat consumption curves



Garmanda



Gizhiga



Evensk

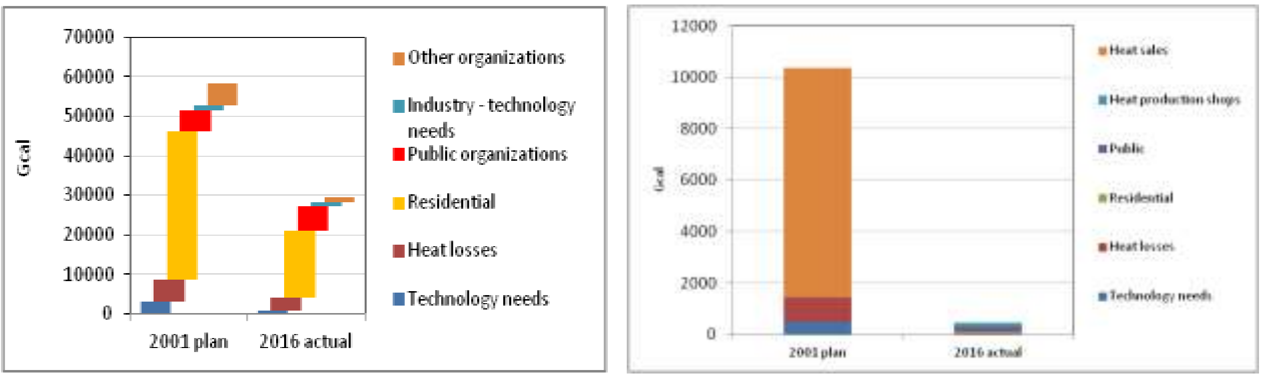
Source: CENEf based on data from Komenergo

4.3 Heat balances

District heat consumption in off-grid localities is continuously falling down (Fig. 4.14). In Evensk, heat consumption halved over 15 recent years. The length of heat distribution networks also halved since 2000. In Gizhiga, heat consumption dropped manifold, and now only 2 buildings are connected to district heating and consume only 56% of heat generated by the boiler-house. Boiler-house in Garmanda closed down. Nine boiler-houses operate in Sangar. Heat is mostly used for space heating. DHW supply is responsible for nearly 10% of heat sales in Evensk and for 14% in Sangar.

Economically justified heat tariff in Sangar is 4,869 rubles/Gcal, in Evensk 6,632 rubles/Gcal, and in Gizhiga 19,318 rubles/Gcal. In Evensk, coal price at point of purchase is 1,980-2,033 rubles/t, plus additional coal delivery costs are 7,769 rubles/t. In Sangar, coal costs 8,000 rubles/t, including delivery. Economically justified heat tariffs above 6,000 rubles/Gcal are seen in small settlements with high semi-fixed costs and low heat sales to end-users. In Kobyaisky ulus of Sakha Republic (Yakutia), heat tariff is 27,288 rubles/Gcal in Lyusyugun and 22,204 rubles/Gcal in Kalnitsa.

Figure 4.14 Heat consumption in Evensk and Gizhiga in 2001 and 2016

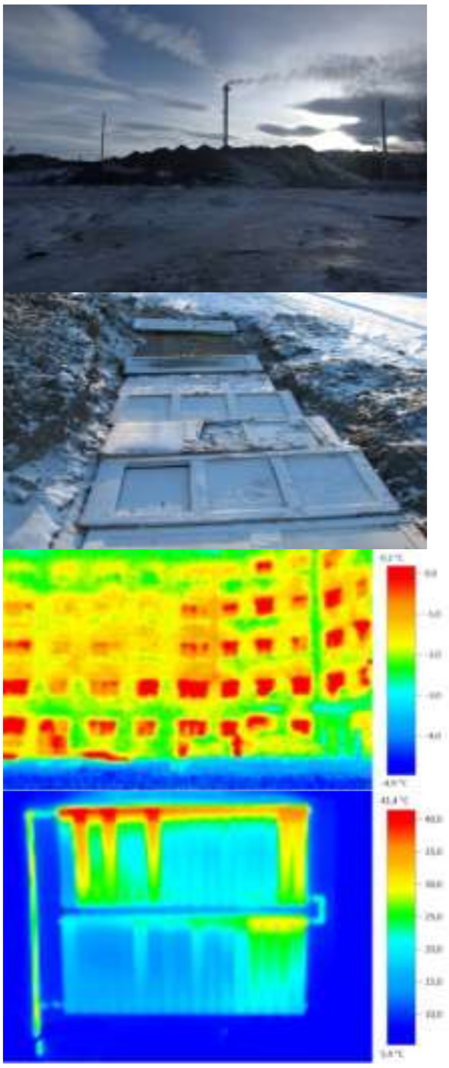


Evensk Gizhiga

Source: CENEf

Basic problems related to heat supply are shown in Table 4.4 and more clearly in Fig. 4.15.

Figure 4.15 Diagnostics of basic heat supply problems



Boilers

- no fuel or heat metering
- coal is stored in the open air; no scales
- no automation or water treatment
- low efficiency (around 65% on average)
- boiler-house in Evensk in a critical condition
- no heat regulation

Heat distribution networks

- large part needs replacement (60-80%)
- large heat distribution losses (11-44%)

Customers

- no pipes insulation in the basement
- large heat losses through entrance units
- no end-use heat metering in Evensk. According to the only meter installed at the local government building, heat consumption is 22% below the estimated level. Less than 2% of customers have DHW meters.
- few buildings have weatherized facades, roofs, and floors above basement
- share of efficient windows is about 20% in residential buildings and nearly 100% in public buildings
- low emissivity of heat radiators in the absence of regular heat pipes flushing

Source: CENEf

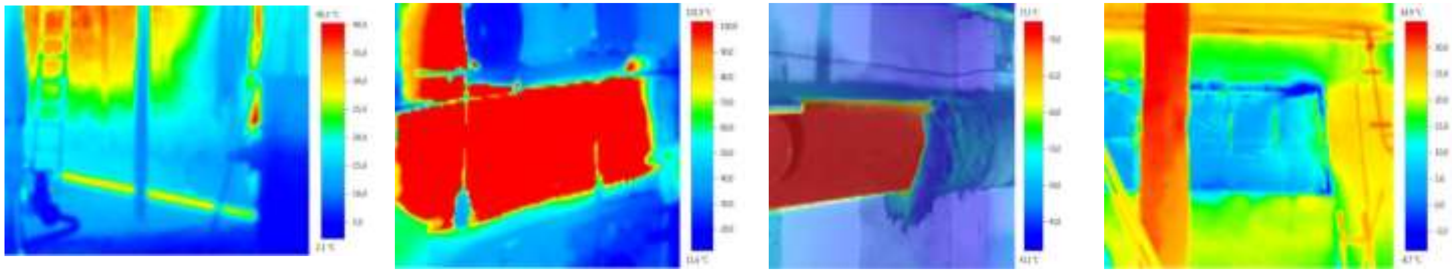
Overall efficiency of local district heating systems is rarely above 50% (Fig. 4.16). It is worse than the efficiency of state-of-the-art individual coal-fired boilers, which is above 75% even in second-rate models.

Furnace space heating dominates in small settlements. In Severo-Evensk region, the price of furnace coal is 11,879 rubles/t. Coal price for households (within the consumption limit) is 3,119 rubles/t. In other words, substantial coal subsidies are provided to households, too (8,760 rubles/t). Total coal subsidies equal 24.6 million rubles/year.

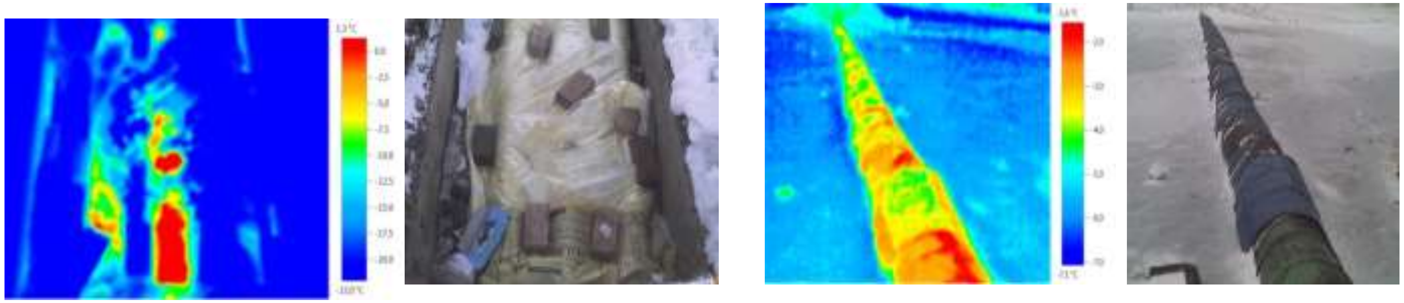
Coal efficiency in furnace space heating is pretty low, not to mention the fact that a large part of produced heat is lost in dilapidated buildings through degraded envelopes (Fig. 4.17). So in this case, too, the government subsidizes the poor coal use efficiency and inefficient heat production and use, yet, unlike electricity, within clearly specified limits.

Figure 4.16 Thermal imagery of individual energy supply systems in Evensk. January 2017

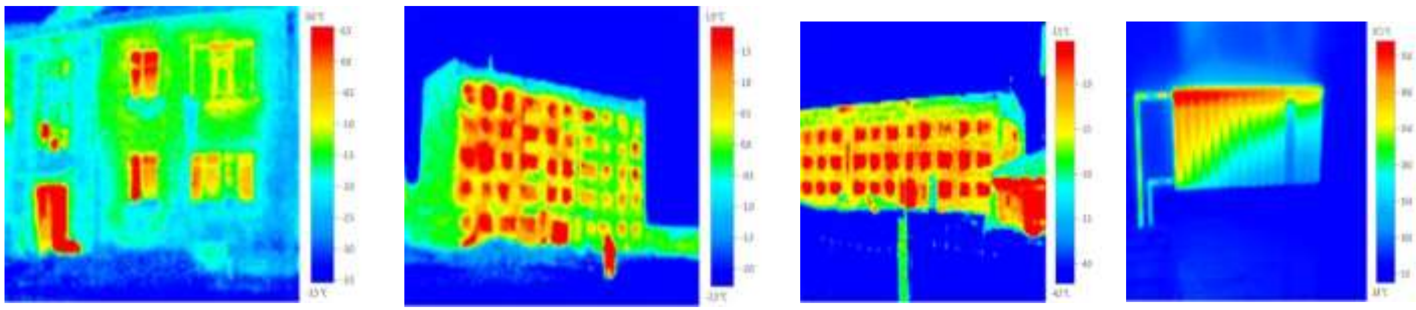
Boilers. Insulation of boilers; heat pipes; windows covered with films



Heating networks. Pipes covered with films and bricks, as well as with fuel barrels cut in two.
Back in 2001 in Gizhiga, they used deer skins for this purpose

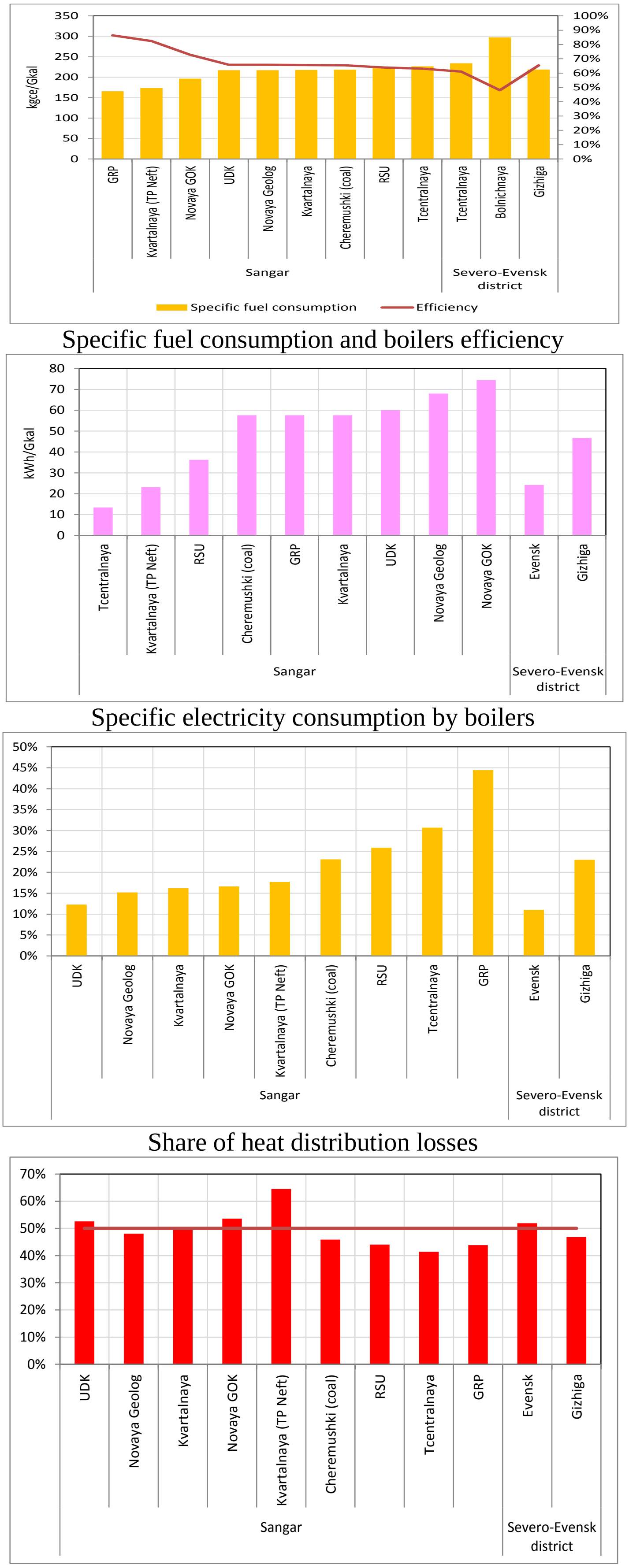


Residential and public buildings. Large heat losses through buildings envelopes and clogged up heat radiators with low emissivity



Source: CENEf

Figure 4.17 Efficiency parameters of local district heating systems



Specific fuel consumption and boilers efficiency

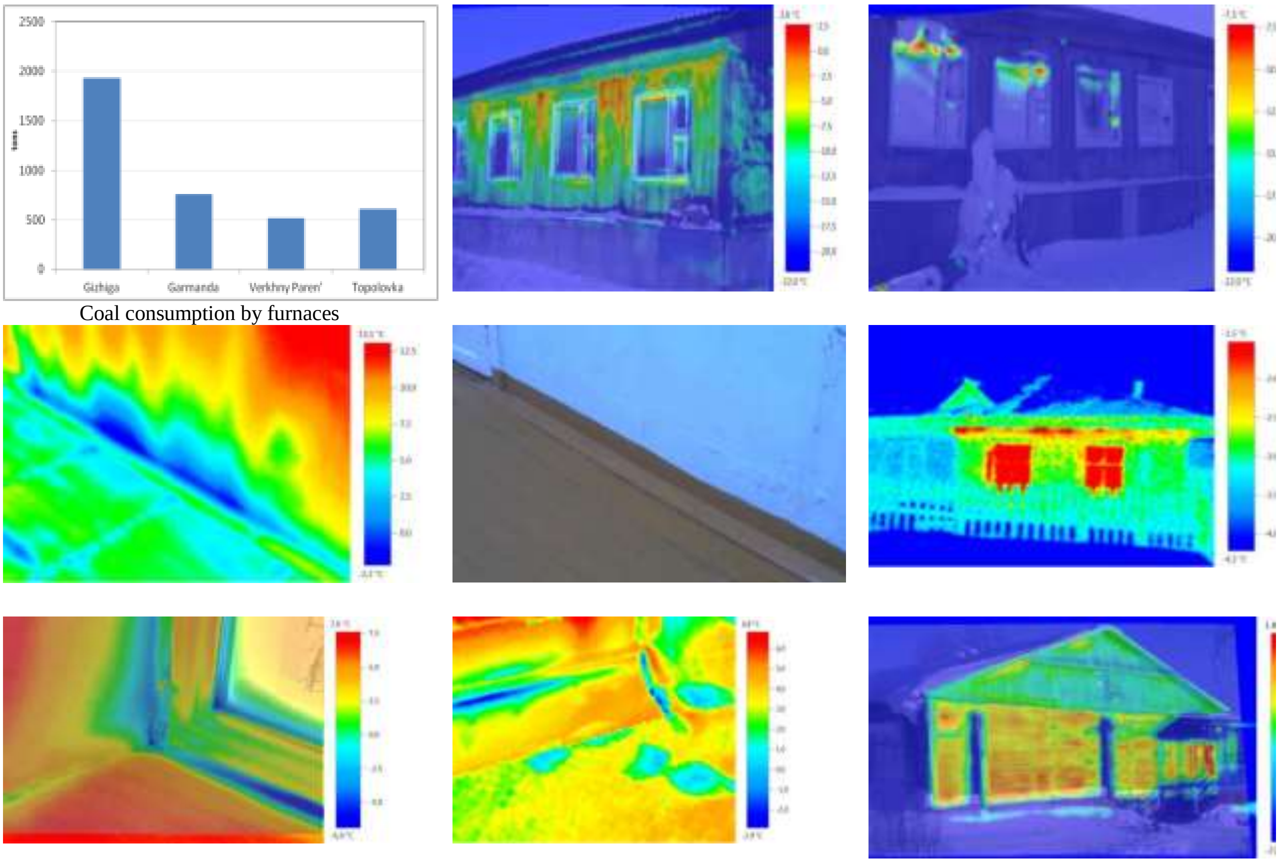
Specific electricity consumption by boilers

Share of heat distribution losses

Overall efficiency of local district heating systems

Source: CENEf

Figure 4.18 Coal consumption for furnace space heating in Severo-Evensk region and thermal imagery of one-storey buildings in Sangar and Evensk. January-February 2017



Source: CENEf

4.4 Typical measures to save electricity

Pilot programmes *'Low-carbon solutions for Russian off-grid regions with high energy costs'* shall consist of typical measures that yield electricity-, heat-, and fuel savings and include renovation of inefficient electricity and heat sources (or replacement with low-carbon ones) and renovation of power and heat distribution networks. Only technologies that have proved their efficiency in Extreme North conditions shall be deployed.

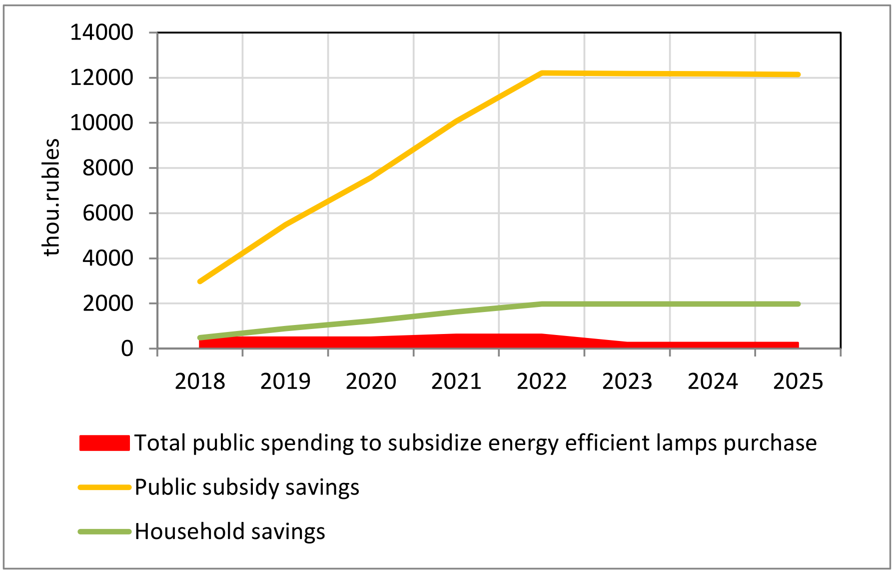
Regarding electricity efficiency improvements, we suggest that the following typical measures be included in the programme:

- subsidies to purchase efficient lamps (to compensate for the difference in prices between a LED lamp and a 60 W incandescent lamp with the same luminous flux);
- subsidies to purchase efficient refrigerators (4,000 rubles/refrigerator, given nameplate electricity consumption 300 kWh/refrigerator/year);
- weatherization of residential buildings to reduce electricity consumption for space heating (for more detail see the next section);
- renovation of lighting systems in public buildings;
- weatherization of public buildings and reduction of electricity consumption for space heating;
- installation of variable speed drives (VSD) at pumps in heat- and water supply systems.

A programme to incentivize people in Severo-Evensk region to purchase efficient lamps can be shaped as follows:

- replacement of 13,650 incandescent lamps with LED lamps in 2018-2025;
- 3413 thou. rubles in public spending to subsidize the purchase of LED lamps;
- 74,812 thousand rubles in public subsidy savings on reduced compensation for the difference in economically justified electricity tariff and the actual residential tariff;
- 12,177 thousand rubles in residential electricity bills reduction;
- 17 days payback for the public spending.

Figure 4.19 Incentives for Severo-Evensk households to purchase efficient lamps: the programme economics



Source: CENEf

By 2025, the whole set of typical measures can save 24% of total 2016 electricity consumption. These savings can be even more substantial, if the appliances replacement component is extended to include other appliances in addition to refrigerators. Over 2018-2025, public spending to subsidize electricity consumption will go down by 33 million rubles driven by reduced power use for space heating.

In Sangar, electricity savings that can be yielded through a set of typical measures equal 12% (VSD are already installed at the boiler pumping equipment), whereas in a small settlement such as Topolovka, they equal 43% because of the large electricity consumption for space heating and lighting. In other words, small settlements with the highest electricity prices have larger electricity saving potentials that can be implemented through simple typical measures, than larger settlements.

Typical measures also include renovation of power transmission lines and transformer substations. The smaller electricity distribution losses, the larger electricity sales (with specified RGR and diesel generation), and so the lower the electricity tariff.

4.5 Typical heat saving measures

The following typical measures are recommended for heat efficiency programme in residential buildings:

- installation of automated individual heating points and house-level heat meters;

- energy efficient windows (with high heat transfer resistance coefficients: not less than 0.95 $m^2 \times °C/W$) and entrance groups;
- repair of heat supply engineering systems;
- insulation of facade;
- insulation of roofs and attic floors;
- insulation of basement floors;
- installation of new efficient solid fuel-fired boilers for households with furnace space heating.

Typical measures can also include flushing of house-level space heating systems.

Costs and benefits of these measures are mostly determined by the buildings parameters (Table 4.4). The estimates were made using the *'Methodology to assess energy and water cost savings yielded by energy efficiency measures implemented as part of buildings capital repairs'* developed by CENEf-XXI (hereinafter referred to as *'Calculator'*).

5-storey buildings in Evensk are mostly of the 123^{rd} regional series. These are large-block houses typically built in Tyumen and Magadanskaya Oblast. Heat consumption by these buildings for space heating is estimated by Komenergo municipal utility according to the *Methodology to estimate fuel-, electricity-, and water demand for heat production and distribution in municipal utility services sector* approved on August 12, 2003. Heat consumption as specified in contracts is based on 15^oC indoor air temperature, whereas the required temperature is $18\text{-}20^oC$. Energy consumption limits were estimated for 5-storey residential buildings of the 123^{rd} series using the *Calculator to assess energy cost savings yielded by energy efficiency improvements under capital repairs* developed by CENEf-XXI for the Fund for promoting housing and utilities reform.

Table 4.4 Typical heat saving measures in residential buildings: costs and benefits. Severo-Evensk region

	Units	5-storey, 2,000 m^2	5-storey, 6,000 m^2	3-storey	2-storey	1-storey
Measures implementation costs						
Installation of automated heating point	rubles/m^2	2,000	960			
Energy efficient windows and entrance groups	rubles/m^2	380	340	360	400	880
Repair of engineering systems	rubles/m^2	260	240	260	340	
Weatherization of façade	rubles/m^2	1,800	2,400	1,900	2,000	2,600
Weatherization of roofs	rubles/m^2	220	200	360	540	540
Weatherization of basement floors	rubles/m^2	240	240	400	600	600
Total	rubles/m^2	4,900	4,380	3,280	3,880	4,620
Heat savings	Gcal/m^2	0.190	0.150	0.187	0.225	0.300
Heat savings	rubles/m^2	1,260	995	1,240	1,492	1,990
Payback period	Years	3.9	4.4	2.6	2.6	2.3
Payback period with an account of electricity savings on space heating	Years	3.6	4.1	2.5	2.4	2.1

Source: CENEf

The Calculator requires input of detailed information for each multifamily building and can be used to estimate heat consumption for space heating with an account of transmission/infiltration losses and inner heat gains, as well as distribution losses in district heating systems. Heat consumption for space heating as estimated by municipal enterprise Komenergo and as estimated using the *Calculator* (with similar climate and indoor air temperature parameters) differ by maximum 5% (Komenergo estimates slightly exceed the Calculator assessments). Because information in technical passports is not sufficient, and for some multifamily buildings energy passports were not available, input data for the Calculator were supplemented with design characteristics for the 123^{rd} buildings series.

Because no heat meters are installed in multifamily buildings, savings yielded by energy efficiency improvements can only be assessed against energy consumption estimates. For the same reason it is impossible to make reliable (metering-based) assessments of under- or over-heating in multifamily buildings. CENEf made instrumental audits in a number of individual flats in Evensk multifamily buildings to find that indoor air temperature varies between 17 and 23^{o}C, i.e. some buildings and/or facilities are underheated, whereas others are overheated. Model estimates of the energy saving potential can be obtained for a conditional building that has design energy consumption or is under/overheated.

Where buildings are not overheated, heat use controls cannot yield any heat savings, but may yield substantial electricity savings, if electricity is used to ensure thermal comfort. Heat savings can be obtained by improving thermal performance of buildings envelopes, by insulating space heating and DHW pipes, and by improving the heating capacity of heat radiators through flushing or replacement. Electricity savings can also be obtained through the replacement of lighting equipment in common use facilities with LED lamps and motion sensors.

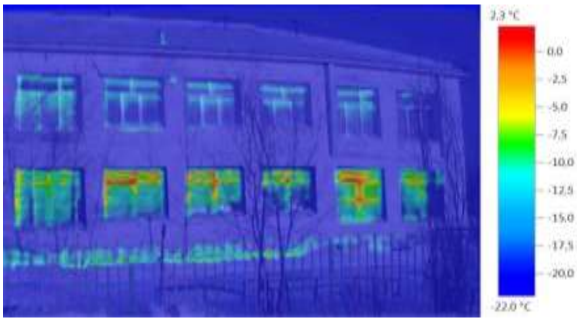
If we want to implement the whole saving potential from the above set of measures, then even if the building is not overheated, it is important to have heat regulation to account for changing heat loads. Otherwise the multifamily building will keep getting the same amount of heat, but reduced heat losses will bring indoor air temperature up, and people will have to let extra heat out through open windows. If energy efficiency improvements are implemented at a group of multifamily buildings, heat regulation can be practiced at the heat source. However, if energy efficiency improvements only take place in some of the buildings, heat source regulation may result in the underheating of non-weatherized houses.

A similar set of typical measures can be implemented in public buildings:

- installation of automated individual heating points;
- energy efficient windows and entrance groups;
- repair of heat supply engineering systems;
- insulation of facade;
- insulation of roofs and attic floors;
- insulation of basement floors;
- installation of new efficient solid fuel-fired boilers for buildings with furnace space heating.

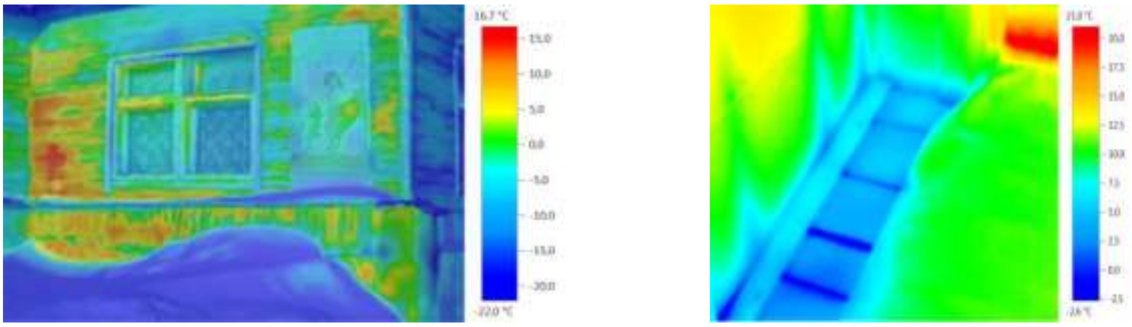
Flushing of heat supply systems can be included in the set of typical measures. Fig. 4.19 shows, that envelopes of public buildings ought to be insulated, and that such insulation can yield a tangible effect. Implementation costs and effects (per 1 m^2) are close to those indicated in Table 4.4 for residential buildings with a similar number of floors.

Figure 4.20 Thermal performance parameters of envelopes in public buildings (Sangar)

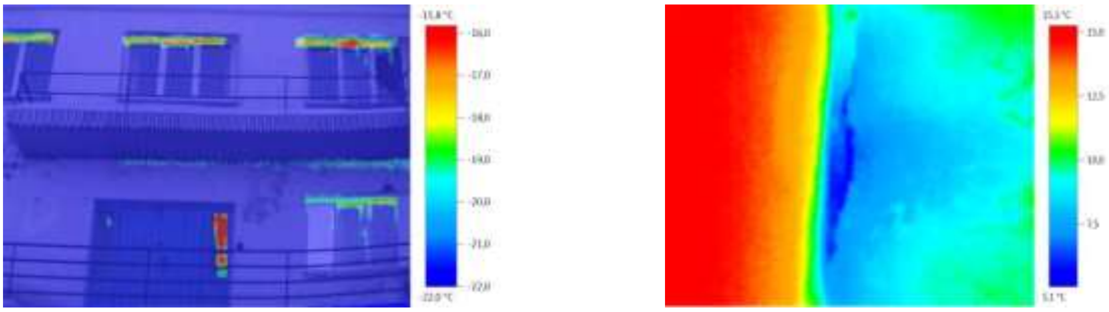


Efficient windows are installed on the second floor of Skazka kindergarten. Heat losses are therefore much smaller, than on the first floor, where old wooden frames were not replaced.

Skazka kindergarten, Sangar



Cheremushki kindergarten, Sangar



Children’s activity centre, Sangar

Source: CENEf

Typical measures also include renovation of heating networks. With a specified heat production amount, the lower distribution heat losses, the larger heat sales and the lower heat tariff. In some instances, very small heat sales by a boiler-house (like, for example, in Gizhiga) may provoke a decision to completely switch the few buildings (2 buildings) connected to the boiler-house to individual space heating, or, on the contrary, to connect more customers to the heat source. The choice depends on the boiler-house reserve capacity and requires a return-on-investment analysis.

4.6 Typical measures for electricity- and heat sources

Typical measures for renovation (or replacement) of electricity- and heat sources under the programmes *‘Low-carbon solutions for off-grid regions with high energy costs’* for various types of settlements include (Table 4.5):

- renovation and optimization of existing diesel energy and boiler capacities. In Sangar, most boilers have been renovated or replaced in the recent years;

- construction of solid fuel-fired mini-CHP (biomass or coal) to replace diesel electricity generation and to close down dated boilers, in full or in part;
- construction of wind/diesel hybrid systems;
- construction of solar/diesel hybrid systems.

Table 4.5 Typical measures to renovate (or replace) electricity and heat sources

Options	Large settlements	Settlements connected to district heating	Small settlements
Renovation and optimization of existing capacity:			
Diesel energy units	+	+	+
Boilers	+	+	
Installation of wind/diesel units	+	+	+
Installation of solar/diesel units	+	+	+
Construction of mini-CHP	+	+	
Phasing out boilers		+	

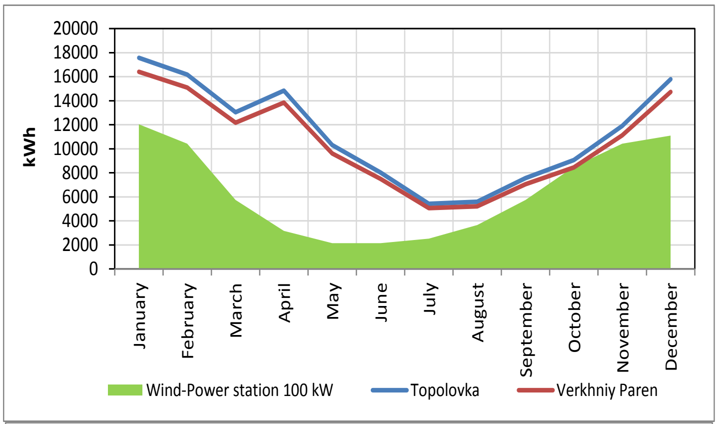
Source: CENEf

Renovation and optimization of existing diesel electricity capacity and boilers can provide a substantial effect. Like shown in Chapter 3, **optimization of diesel energy capacity to serve specified load curve can yield 15-20% fuel savings. Boilers renovation to improve their efficiency from 65% to 85-90% can yield more than 25% fuel savings.**

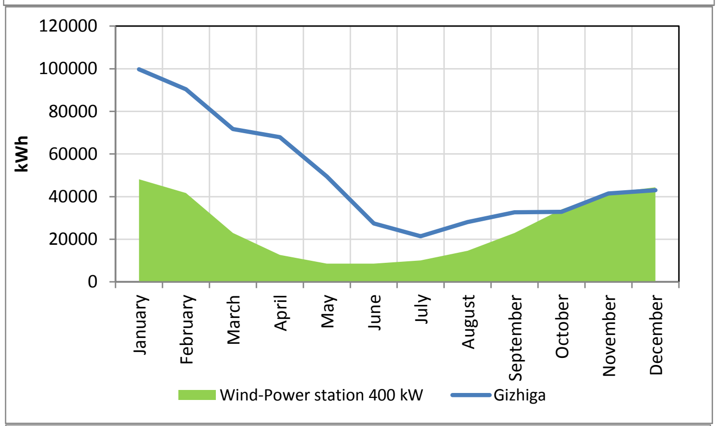
Construction of low-carbon energy generation capacities should be optimized to serve energy load curves (Fig. 4.21). HOMER model can be used for this purpose (see Chapter 3). It is also important to use standard equipment to benefit from the procurement, spare parts, and maintenance cost savings, and to set up a competence center in Evensk so that local energy utility could serve all the neighboring settlements. Even with a pessimistic assessment of wind energy generation per unit of capacity, present value of wind energy generation is 15-19 rubles/kWh [15], which is much below current economically justified electricity tariffs (Table 4.6). Russia already has practical experience in less than 10 rubles/kWh wind energy generation.[16] So the argument that wind energy is relatively costly is true for the central part of Russia, but not for off-grid inhabited localities in Extreme North with tariffs higher than 20 rubles/kWh and sometimes amounting to 200 rubles/kWh. Using standard, Extreme North-proven, equipment for wind energy generation in the region is key to improve the reliability of energy supply and to reduce specific capital costs and operation costs.

[15] Using 10% actual discount rate.
[16] Berdin V., O. Kokorin and M. Yulkin. Renewable energy sources in off-grid inhabited localities of the Russian Arctic. Moscow. 2017.

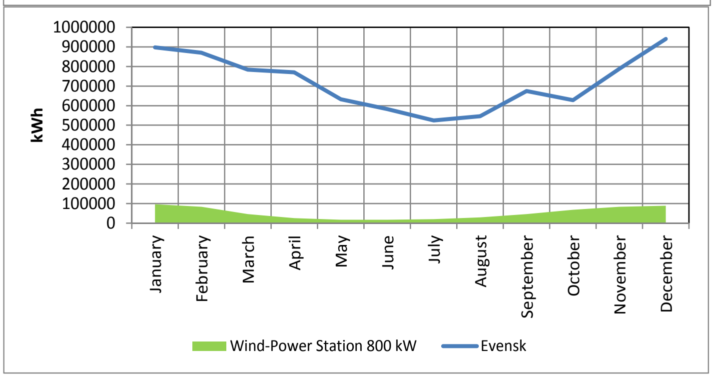
Figure 4.21 Assessment of wind energy capacity demand for small settlements of Severo-Evensk region and integration with diesel energy capacities



Meeting a large part of electricity demand through 100 W wind energy generation in small settlements, such as Topolovka or Verkhny Paren’



Meeting a smaller part of electricity demand through 400 kW wind energy generation (4 x 100 kW) in Gizhiga; electricity consumption limits set for October-December



Meeting a relatively smaller part of electricity demand through 800 kW wind energy generation (8 x 100 kW) in Evensk with an extension potential

Source: CENEf

Table 4.6 Installation of wind turbines in small settlements of Severo-Evensk reigon and their integration with diesel energy sources

Settlement	Wind energy capacity	Wind energy generation	Diesel energy generation	Present value of electricity	Diesel fuel savings
	kW	thou. kWh	thou. kWh	rubles/kWh	t
Evensk	800	551-616	4,642-4,160	15.2/28.2	1,650
Gizhiga	400	275-308	348-227	15.5/42.1	142
Garmanda	200	138-154	245-211	15.8/46.4	75
Topolovka	100	69-77	58-42	16.5/80.1	32
Verkhny Paren'	100	69-77	52-22	19.0/80.2	30
Total	1,600	1,102-1,232	5,345-4,662		1,930

Source: CENEf

For Sangar, it is recommended to build a 400 kW solar energy plant to generate 343 thousand kWh per year at 17.6 rubles/kWh present value of electricity generation. All estimates are based on the operation of solar energy source in the neighboring settlement of Batamai (Fig. 4.22). Analysis of a 1 MW solar energy source operation experience in Batamai will allow for decision-making regarding the construction of a similar or larger solar energy source in Sangar.

Figure 4.22 60 kW autonomous solar plant in Batamai

Source: Kobyaisky ulus government

One relatively new trend is construction of solid fuel-fired mini-CHP with an organic Rankine cycle turbine (ORC technology).[17] These units (Fig. 4.23) improve coal use efficiency and, in addition to heat production, generate electricity in amounts sufficient to replace diesel energy generation, in whole or in part.

[17] BIOTECH. Technical/commercial proposal for the construction of a boiler-house with coal-fired ORC-module in Evensk, Severo-Evensk region of Magadanskaya Oblast. BIOTECH. Presentation on the construction of boiler-houses with ORC-modules to replace boilers and diesel energy plants in hard-to-reach localities.

Figure 4.23 Exterior of boiler-house with organic Rankine cycle turbine

Source: BIOTECH

Table 4.7 shows mini-CHP construction options for Evensk, and Table 4.8 in Sangar. Option 1 for Evensk is based on the estimates by BIOTECH company assuming there is a potential to increase electricity and heat sales. Option 2 was estimated by CENEf based on the actual electricity and heat consumption, whereas Option 3 was estimated by CENEf assuming that the commissioning of the mini-CHP will be delayed until 2021, and that the mini-CHP capacity will be verified to account for the implementation of a large part of the existing electricity and heat saving potential. The costs of the mini-CHP construction are quite high. Therefore, energy efficiency improvements prior to the CHP construction will allow for substantial capital cost savings.

Table 4.7 Mini-CHP with ORC module options for Evensk depending on the parameters of heat and electricity markets

Parameter	Units	Option 1	Option 2	Option 3, 2021
		BIOTECH	CENEf	CENEf
Installed electric capacity	MW	2.625	2.625	1.5
Installed heat capacity	MW	17.7	17.7	6.6
Electricity generation	thou. kWh	11,300	8,300	6,500
Heat generation	Gcal	38,807	30,000	15,400
Coal use by boilers	t	10,140	10,140	10,140
Coal consumption	t	9,981	5,788	3,375
Diesel fuel savings	t	2,303	2,075	1,625
Mini-CHP costs	mln rubles	1,680	1,680	900
Payback period	years	7	11.6	7.4
Electricity costs	rubles/kWh	4.97	5.78	3.83
Heat costs	rubles/Gcal	5,890	4,999	5,166

Sources: BIOTECH (Option 1) and CENEf (Options 2 and 3).

With current economically justified electricity and heat tariffs, in any one of these options capital cost payback is 12 years maximum, whereas today investment payback period in the wholesale market is 15 years. Economically justified electricity tariff will go down from 28 to 3.83-5.78 rubles/kWh, and heat tariff to 5,000-5,890 rubles/Gcal.

Development of the programme ‘Low-carbon solutions for off-grid regions with high energy costs’ should carefully focus on **the optimization of CHP generation capacities to meet perspective electricity and heat demand and on a variety of energy saving measures to be implemented prior to the mini-CHP construction, so as to balance costs and effects**.

Analysis of data for Sangar shows, that the cost-effectiveness of mini-CHP construction is mostly determined by electricity and heat tariffs. With economically justified 2017 tariffs, the construction of a mini-CHP in Sangar will pay back in some 15 years. If the tariffs in Sangar were similar to those in Evensk, the payback period would be 8 years. Importantly, mini-CHP is not supposed to meet the entire heat demand, and the equipment configuration must ensure maximum electricity and heat generation per unit of fuel use. It is also important that the equipment installed at most boilers in Sangar was recently renovated. Therefore, the economic practicability of a mini-CHP construction in Sangar is questionable, because despite the fact that the costs of electricity and heat generation will go down, it will take 15 years to get the return on investment from the cost savings. So it is nearly like 'at the continent', but much slower, than other measures in off-grid energy supply systems. In Sangar, responsibility for the operation of power and heat supply systems is split between 'Sakhaenergo' utility and 'ZhKH of Sakha Republic (Yakutia), which is another administrative barrier.

Table 4.8 Mini-CHP with ORC module options for Sangar, depending on the parameters of heat and electricity markets

	Units	Estimates by CENEf, Option 1	Estimates by CENEf, Option 2
Installed electric capacity	MW	5,8	4,4
Installed heat capacity	MW	25,4	19,3
Electricity generation	thou. kWh	17500	13600
Heat generation	Gcal	51000	39000
Coal use by boilers	t	13757	10520
Coal consumption	t	18798	10586
Diesel fuel savings	t	4375	3400
Mini-CHP costs*	mln rubles	2570	2150
Payback period*	years	15,1	14,5
Electricity costs	rubles/kWh	4,97	9,47
Heat costs	rubles/Gcal	3990	3656

Source: Estimated by CENEf based on information from BIOTECH

4.7 Development of programmes 'Low-carbon solutions for off-grid regions with high energy costs' based on typical measures

4.7.1 Programme structure

Programme *'Low-carbon solutions for off-grid regions with high energy costs'* is to be developed for various types of settlements like a jigsaw puzzle consisting of typical projects based on the number of population, the structures of building shock and energy supply systems (Table 4.9). An individual typical project can be included in the programme based on the economic analysis of such project for a specific settlement or based on the economic analysis of the whole programme. It is important to include complementary projects, even if their cost-effectiveness is questionable if implemented separately, but becomes obvious if implemented as part of the package of measures. It is also important to take account of additional effects: for example, weatherization measures save not only heat, but also electricity which is used for space heating, and reduce fuel consumption by individual solid fuel-fired boilers or furnaces.

Programme development is not only about the identification of a set of typical measures, but also about the implementation schedule. Energy efficiency improvements are the most cost-effective method to reduce diesel energy demand, and so they should come first in the programme implementation schedule. More capital-intense measures, such as low-carbon energy generation development, should be implemented with an account of reduced energy consumption and peak loads. Lighting and electric space heating are two sectors responsible for electricity peak loads in off-grid energy supply systems. So reduction of electricity consumption for these uses results in a substantial decrease in the peak loads and therefore mini-CHP, wind and solar energy installed capacities can be substantially reduced allowing for significant capital cost savings.

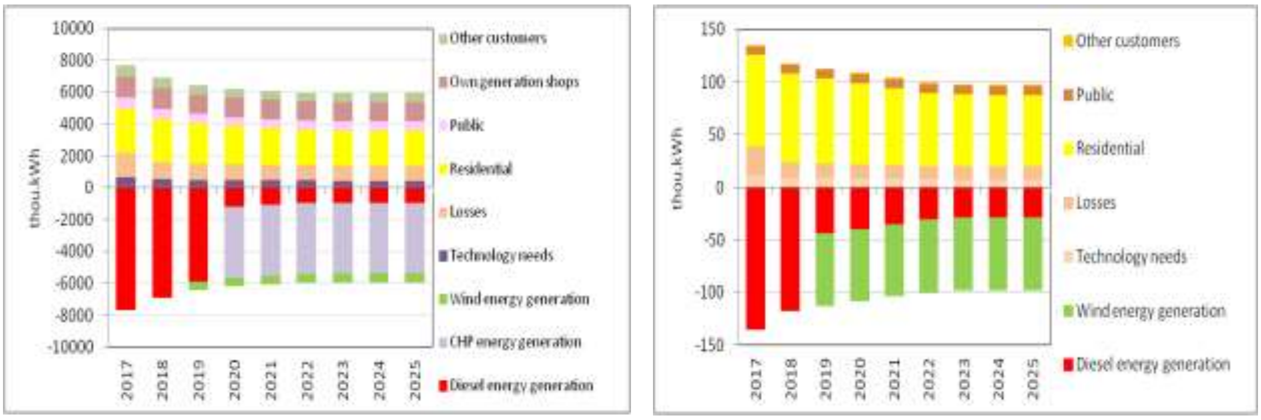
Table 4.9 Typical projects for various groups of settlements. Programme 'puzzle'

Typical projects	Number of population (people)			
	Over 4,000	1,000-4,000	100-500	50-100
Renovation of lighting systems	+	+	+	+
Subsidies to incentivize the purchase of efficient appliances	+	+	+	+
Installation of VSD on pumps in heat- and water supply systems	+	+		
Installation of automated individual heating points in residential and public buildings	+	+		
Weatherization of residential and public buildings	+	+	+	+
Repair of engineering systems in residential and public buildings	+	+		
Installation of new, efficient individual solid fuel-fired boilers	+	+	+	+
Renovation of electric networks	+	+	+	+
Renovation of heating networks and optimization of heat supply systems	+	+		
Renovation and optimization of diesel energy generation units	+	+	+	+
Renovation of boiler-houses and optimization of boiler capacity	+	+		
Construction of mini-CHP	+	+		
Construction of hybrid wind/diesel units	+	+	+	+
Construction of hybrid solar/diesel units	+	+	+	+

Source: CENEf

Energy efficiency improvements can bring down electricity (Fig. 4.24) and heat demand (Fig. 4.25). **Dramatic reduction in diesel energy generation is feasible through low-carbon energy generation development.** Then diesel energy generation gets into the 'low-carbon vise' and drops manifold (Fig. 4.24).

Figure 4.24 "Low-carbon vise". New electricity balances



Evensk Topolovka

Source: CENEf

Wind and solar energy **mini-generation can add pressure to the 'low-carbon vise'.** Some businesses in Evensk consider it a quite possible development. An order issued by

A. Dvorkovitch, Deputy Chairman of the RF Government, aims to promote the development of renewable energy (RE) microgeneration (Resolution No. AD-P9-776 dated February 11, 2017):

> RF Ministry of Energy (A.V. Novak), RF Ministry of Economic Development (M.S. Oreshkin), and RF Federal Antimonopoly Service (I.Yu. Artemiev), with the involvement of other stakeholders, before April 1, 2017, should submit to the RF Government draft action plan to promote the development of RE microgeneration by customers (including physical persons).
>
> Development of the draft action plan should account for the following:
>
> - ✓ RE microgeneration includes up to 15 kW installed unit generation capacity;
> - ✓ exclude multifamily buildings;
> - ✓ installation costs of smart (double-way) electric meters to ensure separate hourly electricity accounting and of control equipment shall be covered by the applicant;
> - ✓ where there is no need to alter the existing connection to the energy grid, RE equipment shall be commissioned by giving a notice and by mandatory registration of a reverse electric meter. In any other cases when power is generated to meet a household's own demand with extra power supplied to the grid, a simplified procedure shall be used for technology connection to the power network and for the commissioning of a generation unit;
> - ✓ energy utilities are mandated to purchase power generated by micro RE sources;
> - ✓ power shall be purchased at the average weighted wholesale electricity price;
> - ✓ revenues of a physical person obtained from the sale of extra power generated to meet his household's demand shall not be subject to tax.

Parameters of micro-wind plants that are operable in the Extreme North climate are shown in Table 4.10. For a 2 kW or larger wind energy capacity, the costs of electricity generation are lower, than for diesel energy plants in any settlement of Severo-Evensk region. For a smaller wind energy capacity, the costs of electricity generation are lower, than in small settlements with up to 80 rubles/kWh electricity tariffs.

Table 4.10 Basic parameters of micro-wind units operable in Extreme North

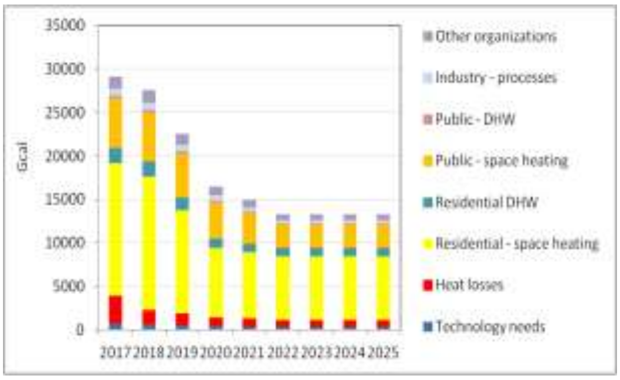
Capacity	Diameter	Base costs	Specific costs		Specific costs, including delivery	Annual generation	Electricity present value
kW	D, m	rubles	$/kW	rubles/kW	rubles/kW*	kWh	rubles/kWh
0.9	2.7	115,300	2,164	128,111	256,222	1,282	43.4
1.5	3.2	168,200	1,894	112,133	224,267	1,801	27.1
2.0	3.6	176,800	1,493	88,400	176,800	2,280	16.9
3.0	4	148,300	835	49,433	98,867	2,815	7.6
5.0	6.2	515,600	1,742	103,120	206,240	6,762	6.6
10.0	8	962,000	1,625	96,200	192,400	11,259	3.7

* Assumption was made that the costs will double with delivery.

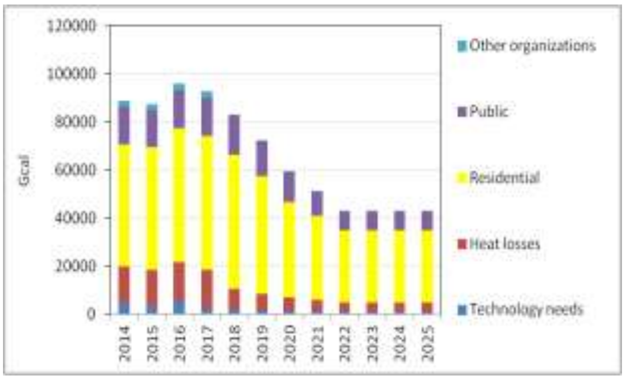
Source: CENEf based on data from Energystock (energystock.ru) and Energywind (energywind.ru)

Because low-carbon heat production in the two selected pilot territories is not feasible for the lack of relevant resources, reduction in fuel consumption is only determined by more efficient heat use and decrease in heat distribution losses (Fig. 4.25), as well as through the renovation of boilers and decline in specific fuel consumption. Heat sales are dominated by buildings with high heat losses, and therefore, weatherization and installation of automated individual heating points can ensure substantial (approximately 2-fold) heat savings.

Figure 4.25 Evolution of heat consumption



Evensk



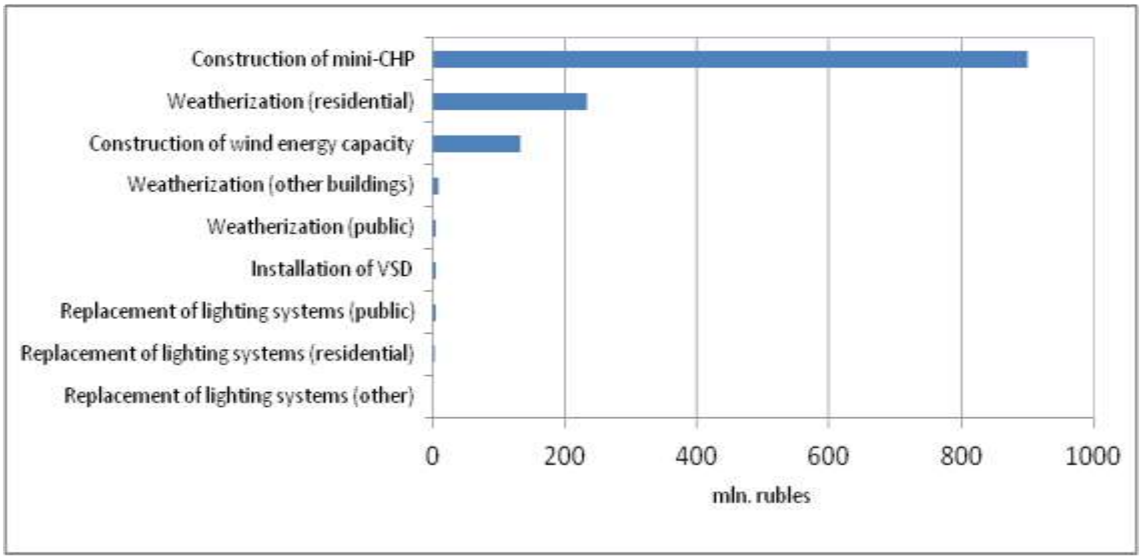
Sangar

Source: CENEf

4.7.2 Programme costs and benefits

In Severo-Evensk region, total programme costs are 1,376 mln rubles. These include the construction of a mini-CHP (900 mln rubles) and of a wind energy plant (132 mln rubles). In other words, nearly all capital costs (75%) are related to the replacement of electricity and heat sources. Only 25% of costs (343 mln rubles) are related to energy efficiency improvements. Of these, 79 mln rubles are the costs of power and heating networks renovation, while 264 mln rubles are spent for end-use energy efficiency improvements. However, it is the latter investment that yields at least 700 mln rubles in the construction and renovation cost savings.

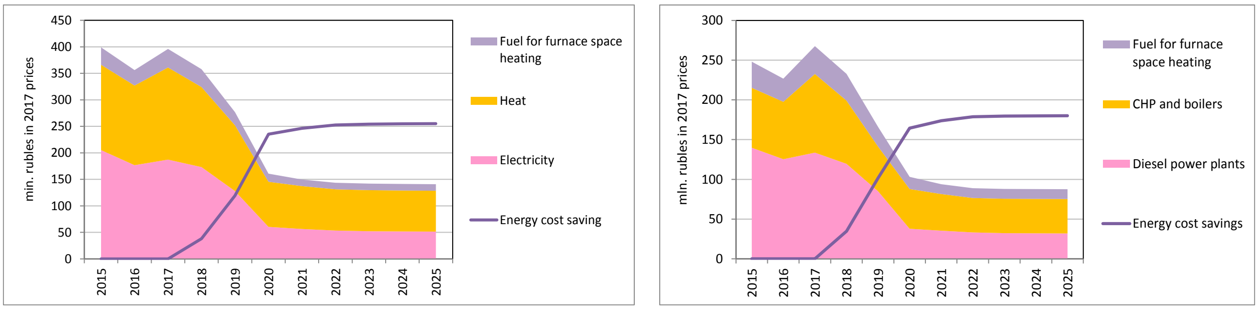
Figure 4.26 Total implementation costs of pilot programme "Low-carbon solutions for energy supply to Severo-Evensk region of Magadanskaya Oblast"



Source: CENEf

Between 2018 and 2027, the pilot programme will yield 2,142 mln rubles in total energy cost savings and 1,528 mln rubles in fuel savings (Fig. 4.27). In other words, the entire investment will pay back within 9 years from fuel cost savings alone or within 7 years from total energy cost savings. Discounted payback period is 6 years. Evolution of net present value and internal rate of return in shown in Fig. 4.28. Both these parameters are mostly determined by whether or not a mini-CHP will be built. An alternative includes eventual renovation of diesel power plant and of two boiler-houses in Evensk. This option was not estimated in the programme. However, in this case, too, priority implementation of energy saving measures with short paybacks will clearly allow for the installation of smaller generation capacity and so for substantial capital cost savings.

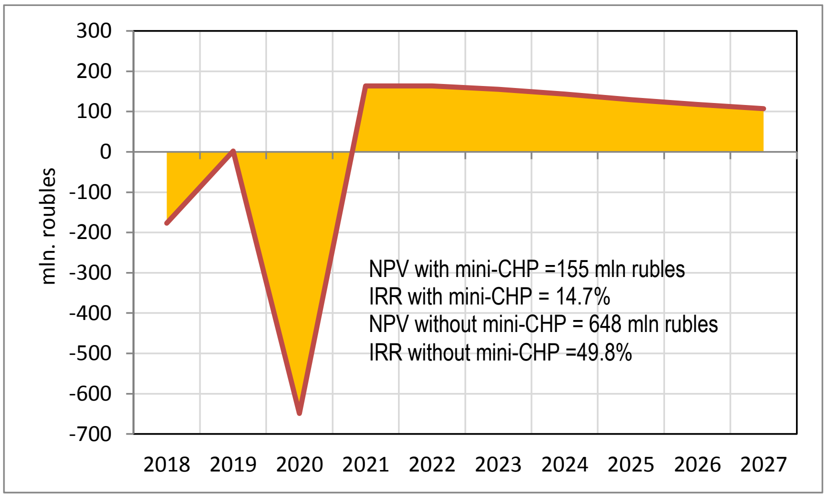
Figure 4.27 Energy and fuel cost savings yielded by pilot programme "Low-carbon solutions for energy supply to Severo-Evensk region of Magadanskaya Oblast"



energy cost savings | fuel cost savings

Source: CENEf

Figure 4.28 Net present value (NPV) and internal rate of return (IRR) for various implementation options of pilot programme "Low-carbon solutions for energy supply to Severo-Evensk region of Magadanskaya Oblast"



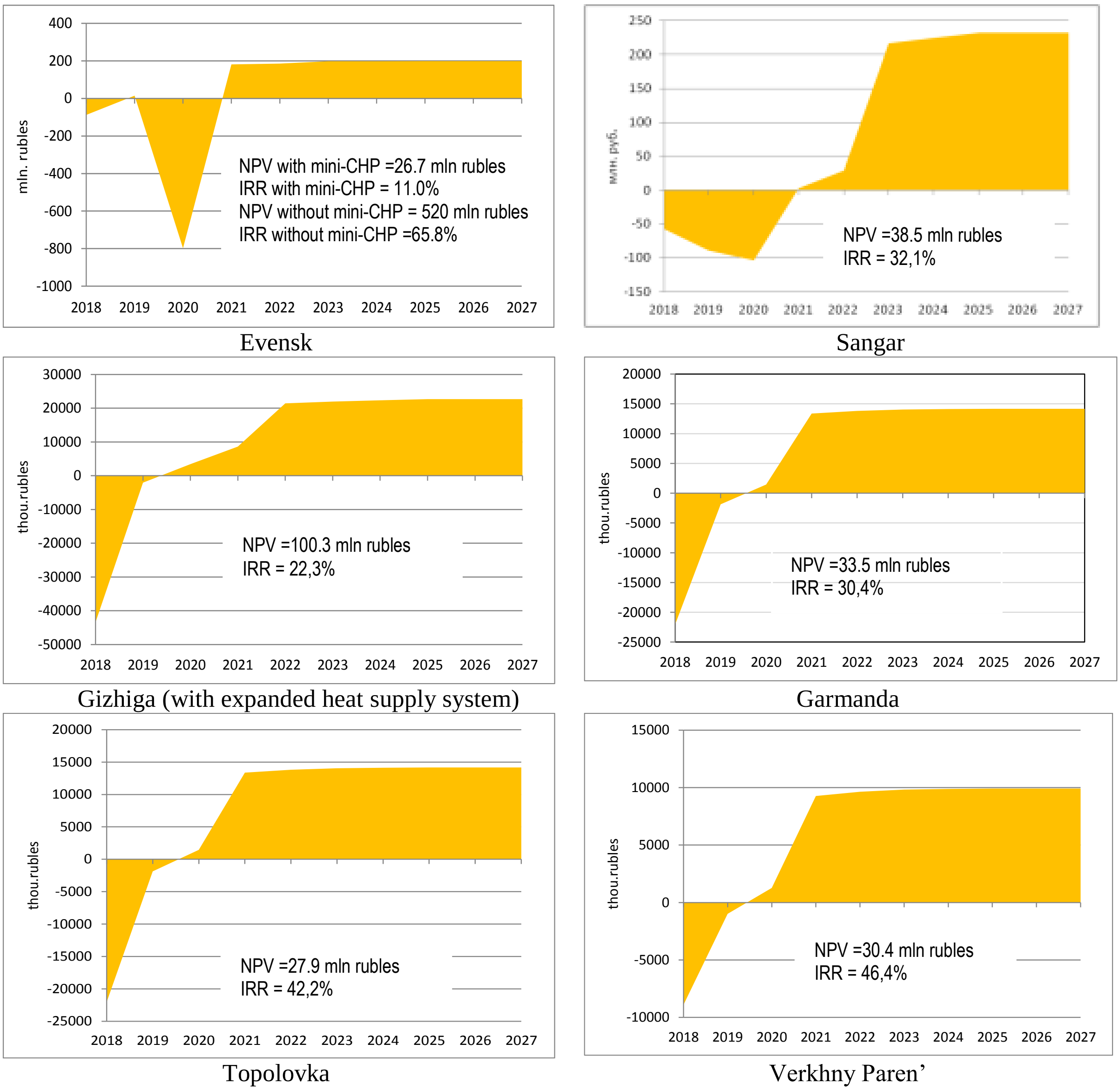
NPV – estimated for 2018-2027 in 2017 prices with 10% discount rate. IRR – estimated in 2017 prices.

Source: CENEf

Parameters of regional programme 'Low-carbon solutions for energy supply in Severo-Evensk region of Magadanskaya Oblast' were described above. Fig. 4.29 shows charts for individual settlements. Energy efficiency and renewable energy programmes have pretty short paybacks in all of the pilot settlements. Discounted paybacks with 10% discount rate are as follows: Verkhny Paren' – 3 years, Garmanda and Topolovka – 4 years, Gizhiga (including expansion of heat supply system) – 5 years, Evensk (including a mini-CHP) – 7 years.

The highest internal rates of return are seen in small settlements with high economically justified electricity tariffs. Energy efficiency improvements and low-carbon energy generation yield a very good economic effect in terms of energy cost savings.

Figure 4.29 Net present value (NPV) and internal rate of return (IRR) for pilot programmes “Low-carbon solutions for energy supply systems”



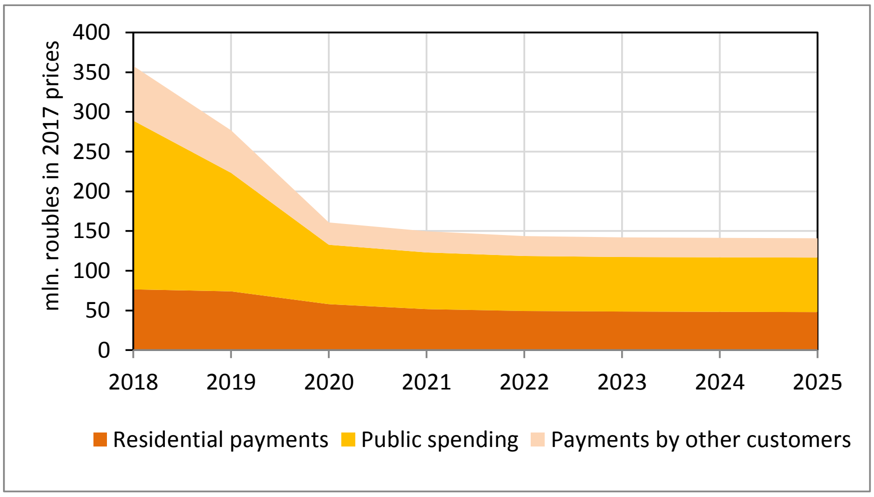
NPV – estimated for 2018-2027 in 2017 prices with 10% discount rate. IRR – estimated in 2017 prices.

Source: CENEf

Energy costs will be decreasing for the residential sector and other customers, but most prominently for the public sector (Fig. 4.30). Residential energy bills in Severo-Evensk region will drop from 87 to 47 mln rubles, or by 40 mln rubles. Public energy bills will drop from 308 to 72 mln rubles, and energy bills of other customers, which mostly include the energy costs of providing municipal utility services by Komenergo utility, will decline from 32 to 21 mln rubles.

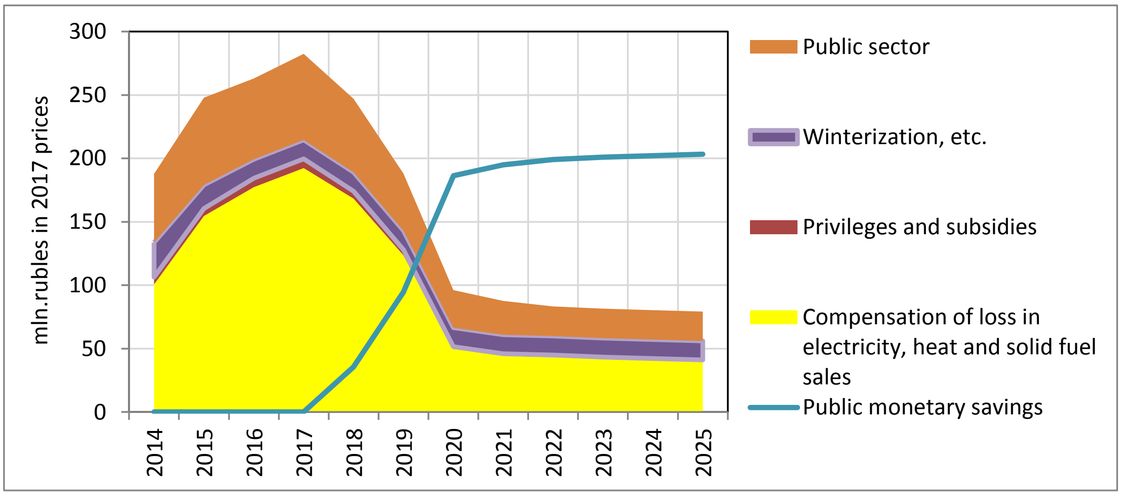
Total programme-related decline in public energy bills will equal 1,700 mln rubles. A large part of this decline (1,276 mln rubles over 2018-2027) is determined by reduced public spending for electricity, heat, and solid fuel compensation (Fig. 4.31).

Figure 4.30 Reduction in energy bills resulting from the implementation of pilot programme "Low-carbon solutions for energy supply to Severo-Evensk region of Magadanskaya Oblast"



Source: CENEf

Figure 4.31 Reduction in public energy supply spending through the implementation of pilot programme "Low-carbon solutions for energy supply to Severo-Evensk region of Magadanskaya Oblast"

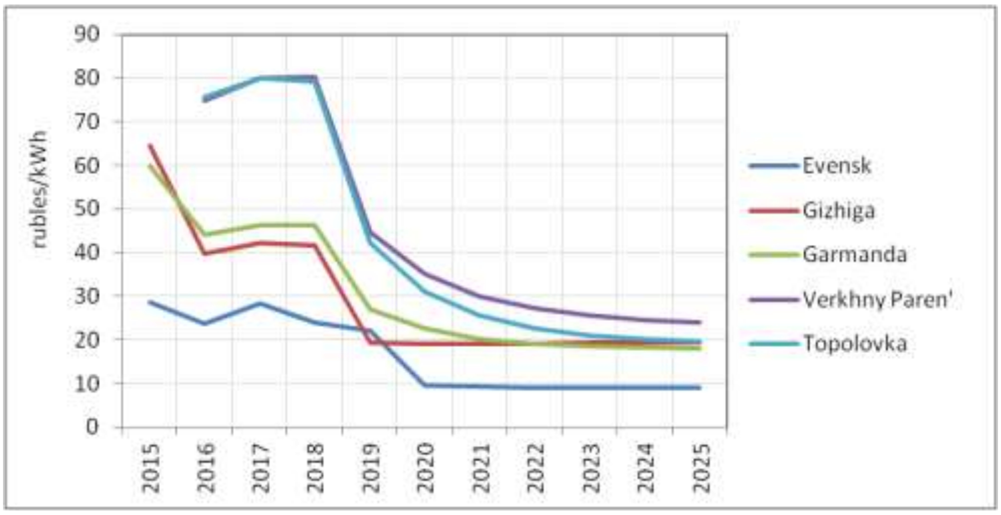


Source: CENEf

The programme will bring down the costs of electricity generation (Fig. 4.32) from 22-28 to 10 rubles/kWh in large settlements and from 40-80 to 20-25 rubles/kWh in small settlements. A 2- or 3-fold decline in electricity price and improved energy affordability may spur the economic development in the inhabited localities of the region.

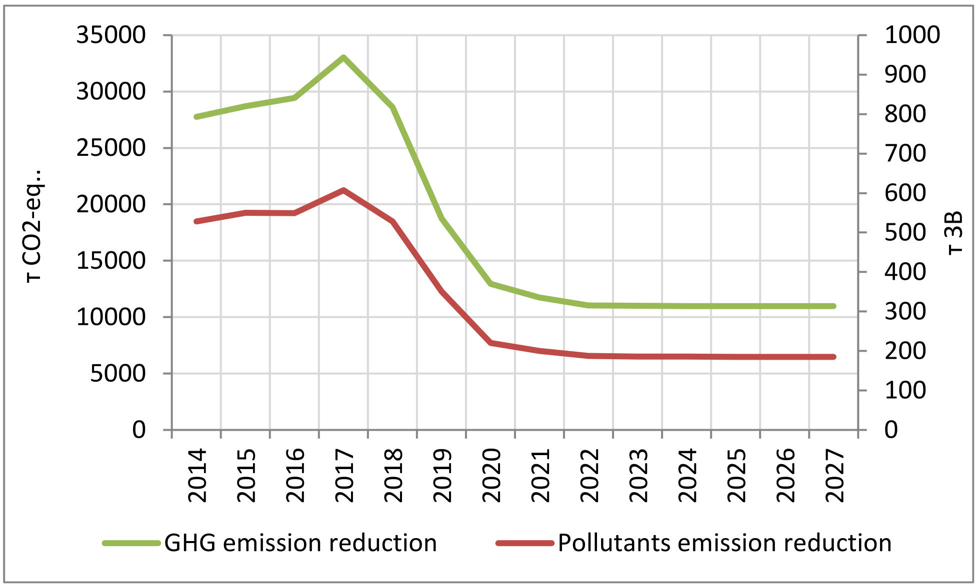
In addition to the economic benefits, the programme will provide substantial environmental effects. Overall decline in emission between 2018 and 2027 will equal 3,476 tons of atmospheric pollutants and 196 thousand $tCO_{2\text{-eq.}}$ of GHG (Fig. 4.33). With 5 USD/$tCO_{2\text{-eq.}}$ carbon price, this reduction could additionally yield 59 mln rubles/year. This should be added up with halved cancer and respiratory morbidity as a result of 5-fold reduction in coal use by furnace space-heating, reduced indoor air pollution, improved thermal comfort and reduced incidence of cold-related diseases.

Figure 4.32 Reduction in average electricity generation costs in Severo-Evensk region through the implementation of pilot programme



Source: CENEf

Figure 4.33 Reduction in GHG and pollutants emissions resulting from the implementation of pilot programme "Low-carbon solutions for energy supply to Severo-Evensk region of Magadanskaya Oblast"



Source: CENEf

4.8 Upscaling of the 'Low-carbon solutions for off-grid regions with high energy costs' programme for the whole Extreme North

The pilot programmes only include 6 settlements in Extreme North. The scale of a similar federal-level programme was estimated by extrapolating the obtained results to all off-grid settlements. It was shown in Chapter 1 that overall diesel fuel costs in off-grid energy systems amount to 60-80 billion rubles/year. The costs of diesel fuel in Severo-Evensk region are 140 million rubles/year, and in Sangar 180 million rubles/year. Therefore, the programme can be scaled up more than 400 times in Severo-Evensk region and more than 300 times in Sangar. If we assume 400 times upscale for Severo-Evensk, then:

- the costs of a federal programme can be estimated at 420 billion rubles, including:
    - energy efficiency - 130 billion rubles;
    - construction of wind and solar facilities - 65 billion rubles;
    - construction of mini-CHPs (x 200) - 225 billion rubles;
- annual energy cost savings:
    - total energy cost savings - 130 billion rubles;
    - fuel cost savings - 90 billion rubles;
    - **reduction in public energy spending - 100 billion rubles;**
- simple payback period of a federal programme - 3.2 years.

These are, of course, tentative parameters of the federal programme, but they give a good idea of potential costs and benefits.

The federal programme will need to address the following problems:

- incentivize energy efficiency and renewable energy programmes in remote localities through:
    - aggregation and upscale;
    - the use of standard equipment to allow for:
        - ✓ equipment delivery at much lower prices;
        - ✓ effective technical support and expertise;
        - ✓ financing by large banks, increased number of potential lenders, and competitiveness to reduce loan interest rates.

It is important to address the difficult problems of distributed institutional and economic responsibility for energy supply to off-grid territories, which requires effective coordination of action taken by the federal government and regional and local authorities. Therefore, it is key to develop and implement energy efficiency and renewable energy programmes for off-grid regions with high energy costs.

The huge market for renewable energy to replace diesel energy generation is where Russia can become a global champion. To attain this purpose, it is important to develop and implement an energy efficiency and renewable energy programme for off-grid regions with high energy costs to lay the basis for the modernization of local energy supply systems and ensure cost-effective, sustainable, and reliable energy supply at the minimal cost to all-levels budgets. Russia will have to address energy supply problems of its off-grid areas. Relevant, albeit limited, experience has been accumulated abroad. It must be explored. But at the same time it is important to accumulate and export our own experience. There is a huge market for renewable energy to replace diesel energy generation. Globally, 50 to 250 GW of total installed capacity can be hybridized with renewable energy sources.

The ultimate goal is to reduce the costs of energy supply to the regions of Extreme North. However, it is important that the savings be used for the development of remote localities, rather than be taken away.

4.9 Potential financing options for the federal and regional programmes 'Low-carbon solutions for off-grid regions with high energy costs'

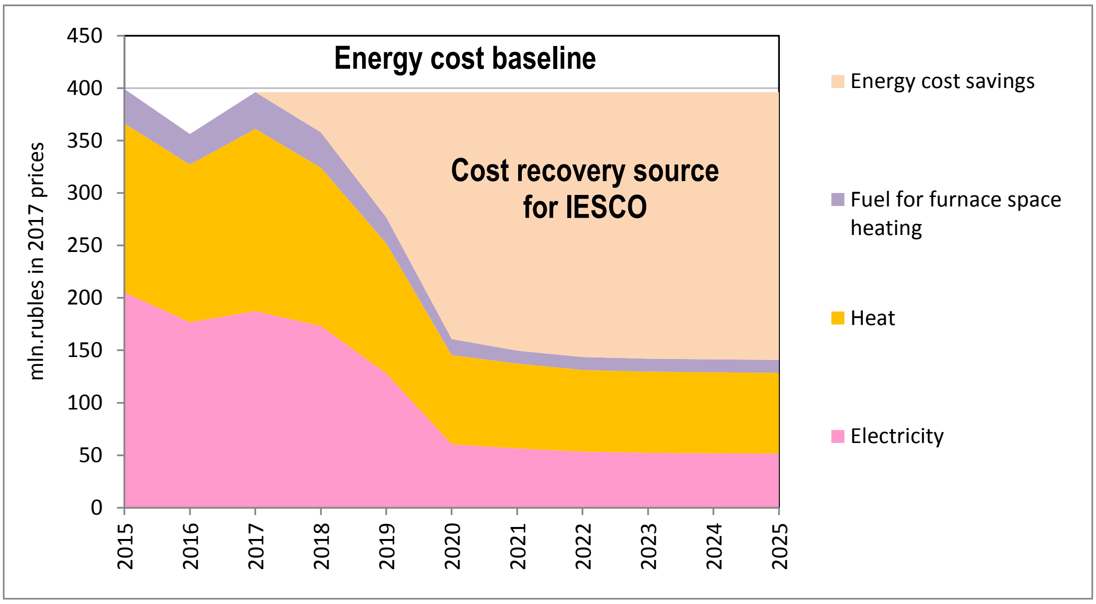
Option 1. Competition for the budget co-financing. This option implies that a fixed amount of public funds will be allocated for regional programmes to compete for co-financing (perhaps under a new energy efficiency programme). This can be done similarly to the scheme outlined in the RF Government Resolution No. 18 of January 17, 2017 *'On the approval of the Rules for providing financial support from the budget of the federal corporation – Fund for the promotion of municipal utility sector reform to finance capital repairs of multifamily houses'*. The procedures as specified in this Resolution allow for 2-4 years' payback reduction (for a typical programme). Implementation of such scheme implies the following:

- allocation of initial financing (say, 5 billion rubles per year of public funds) which would allow for the implementation of 10-25 billion rubles-worth programmes with 2-5 leverage factor;
- setting up a project office (similarly to the Fund for the promotion of municipal utility sector reform to finance capital repairs of multifamily houses);
- development of:
    - the Rules to develop the programme applications;
    - the Rules to assess potential savings;
    - the Rules to monitor the savings.

Option 2. Integrated Energy Contract. A brief description of Integrated Energy Contract was given in Chapter 3. It is about setting an overall energy cost baseline for a particular settlement along with the implementation of energy efficiency improvements and development of low-carbon energy generation both at the generation facilities/networks and at the end-users' facilities. The Russian legislation includes a legal instrument equivalent to the Integrated Energy Contract – *energy supply contract with elements of energy service* (FZ No. 261). However, this instrument was not properly developed and is not used. In 2014, CENEf developed recommendations on the use of this instrument under the 'white certificates' scheme.[18] Under Integrated Energy Contract energy cost baseline includes overall energy supply costs (with all public subsidies), which can be reduced through both energy efficiency improvements and renewable energy / mini-CHP generation across the whole energy supply system. A 'one-contract-pack' of end-use energy efficiency measures and renewable energy deployment allows it to reduce payback period and can become an attractive instrument for the implementation of such projects in remote areas. The scale of each energy service contract is substantially larger making it more attractive to large ESCOs. The project costs are recovered from all types of energy cost savings (Fig. 4.34).

[18] CENEf-XXI. Recommendations on the development of a mechanism to incentivize energy customers to improve energy efficiency by purchasing efficient equipment through compensation (part) of the relevant costs, including with the involvement of resource suppliers, including analysis of practicability and implementation scale of the 'white certificates' mechanism. R&D report. Final. Moscow, 2014.

Figure 4.34 Concept of Integrated energy contract: Severo-Evensk region case study



Source: CENEf

The subject of the contract covers the whole energy supply system, including end-users and even the fuel supply chain. Integrated energy service company decides as to which elements of the system need to be renovated to obtain the maximum effect. This scheme is practically impossible to implement in energy supply systems that are connected to central energy infrastructure, but it perfectly fits off-grid areas, especially the ones served by one utility for all municipal utility services. Incentives may also include tax benefits for certain types of equipment used for off-grid energy systems renovation. By the way, unlike municipal utility concession, which sets the tariff formula, but does not fix resource sales volume, and so the investor has to accept the risk of potential substantial reduction in resource use, Integrated Energy Contract mitigates this risk by reduced consumption being the primary goal, rather than a risk. The settlement ultimately gets a new municipal utility infrastructure and weatherized buildings at the same or even smaller energy supply cost. Depending on the contract terms, part of energy cost savings can become an additional source of finance for the settlement development.

Option 3. Use of the RFE tariff markup. Law No. 508-FZ of 28.12.2016 “On the amendments to the Federal Law ‘On the electricity sector’” introduced a special markup on capacity charge across the whole country to compensate for the reduction of electricity tariff for the Russian Far East to Russia’s average level. For all other Russian end-users, electricity tariffs will grow by approximately 1.8%. Funding to compensate for the difference between the economically justified tariff and the actual tariff will be first accumulated on a special bank account and then transferred to regional budgets of the Russian Far East and further to the local energy utilities. Today, nearly the whole energy sector of the Russian Far East is controlled by RusHydro, which will be distributing the money collected through the markup. Development and implementation of energy efficiency and renewable energy programmes for off-grid territories may become a markup eligibility prerequisite. In this case, Law No. 508-FZ and the relevant Government Resolution can be amended to include the formation of a pool of funds to finance 'Low-carbon solutions for off-grid regions with high energy costs'.

Option 4. ‘White’ and ‘green’ certificates for large generation / distribution utilities. Large generation and distribution utilities will be required by 2025 to obtain energy savings equal to 1 or 2% of their overall generation / distribution amounts through energy efficiency and RE projects in off-grid territories in Extreme North:

- energy efficiency projects – 'white certificates';
- RE development – 'green certificates'.

The 'white certificates' scheme for Russia was already explored in detail.[19] It is important to develop the following:

- programme management schemes;
- list of typical measures;
- programme implementation procedures, paperwork, and information support;
- energy saving reporting, monitoring, and verification; monitoring of the programmes cost-effectiveness;
- incentives/penalties for energy saving (in)compliance;
- certificate trading possibilities and rules;
- programme financial sources and their combinations;
- financial source restrictions.

Option 5. Introduction of carbon cap-and-offset regulation for large companies with a scale-up factor for projects in Extreme North. Introduction of carbon cap-and-offset regulation for large companies implies caps to GHG emission from large sources for 2020 and 2030 and development of emission trade for GHG from projects in non-regulated sectors.[20] Such system may provide for scale-up factors to account for reductions yielded under *'Low-carbon solutions for off-grid regions with high energy costs'* programmes.

There are other options, including a specific type of concession (fixing energy payments, including from the budget, rather than energy tariffs).

* * *

Federal and regional programmes *'Low-carbon solutions for off-grid Russian regions with high energy costs'* shall be developed for the purpose of providing reliable and affordable energy services to remote Russian regions with currently very high costs of energy supply from off-grid small sources (including to the regions with a limited summer navigation period – *'severny zavoz'*) by implementing standard packages of energy efficiency improvements and renewable energy deployment.

By using a programme approach typical technical, institutional, and financial resources will be optimized, aggregated, and scaled up to attain the important strategic goal of Arctic territories' recovery and active development and to address the complex issue of distributed institutional and economic responsibility for reliable and cost-effective energy supply to off-grid territories, which requires efficient coordination of federal, regional, and local action. The use of standard equipment in regional and federal programmes will allow it to benefit from much lower equipment prices, develop effective technical and training support, and attract financing from large banks.

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[19] CENEf-XXI. Recommendations on the development of a mechanism to incentivize energy customers to improve energy efficiency by purchasing efficient equipment through compensation (part) of the relevant costs, including with the involvement of resource suppliers, including an analysis of practicability and implementation scale of the 'white certificates' mechanism. R&D report. Final. Moscow, 2014.

[20] CENEf-XXI. 2017. Projection of the RF emission to 2030 and 2050 and development of scenarios to regulate GHG emissions reduction in the Russian Federation. Under a contract with National organization to support carbon absorption projects. Moscow, 2017.

Programmes *'Low-carbon solutions for off-grid Russian regions with high energy costs'* aim to develop state-of-the-art cost-effective and reliable energy supply to off-grid localities at the minimal cost to all-level budgets and to ensure re-allocation of obtained cost savings to promote economic development of such territories.

Implementation of a federal programme *'Low-carbon solutions for off-grid Russian regions with high energy costs'* across the whole Extreme North will allow it to 'defrost' the time, introduce the 21st century technologies in Extreme North, overcome the economic isolation of these territories and avoid their absolute depopulation.