Energy Efficiency of Buildings in Arctic Regions of the Russian Federation

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Abstract. This article considers a pressing issue to be addressed by those responsible for the energy efficiency management in the Arctic Regions of the Russian Federation. It presents examples of successful solutions to related problems that can be used by energy efficiency program developers in specific regions. This article reviews the introduction indicators for energy-efficient technologies and the specific consumption values for thermal energy. The monitoring of energy-saving and improvement of energy efficiency across the economic sectors is performed using the specific consumption values of fuel and energy resources. The main causes of the excessive consumption of thermal energy include the maladjustment of heating systems, excessive consumption of hot water in hot water supply systems, low heat-proof properties of the structural surfaces of buildings, and heat losses during heat carrier transport due to the low quality of pipeline insulation.

1. Introduction
The key areas of energy-saving activities in the Northern Regions include administrative and awareness-raising actions among the local residents, improving the heat insulation of buildings, using secondary resources, researching and eliminating energy losses along the entire process chain of extracting and transporting fuels and production, transport and distribution of energy. The analysis of the heating infrastructure of Apatity, Kirovsk, and Polyarnye Zori showed that supplying thermal energy to utility consumers in the Northern Regions requires reliable and cost-efficient heating supply systems. The main causes of the excessive consumption of thermal energy include the maladjustment of heating systems, excessive consumption of hot water in hot water supply systems, low heat-proof properties of the structural surfaces of buildings, and heat losses during heat carrier transport due to the low quality of pipeline insulation. The excess in the heating energy consumption within building heating systems is 15-20%. The study of the heat-proof properties and energy consumption of residential houses showed that the highest heat losses through building envelopes are caused by
unwinterized windows and doors (40%). The losses incurred through window panes amount to 15%, while 7% are lost through floors and ceilings and 38% through walls.

The majority of buildings and structures feature external envelopes that fail to comply with the modern regulations on thermal resistance.

2. Energy-efficient technologies

Energy-saving activities must be based on the results of the ongoing monitoring of the specific energy density values and aim for their reduction [1-4]. The energy density of regional economies tends to decrease. The 2017 reduction of the energy density of the gross regional product (GRP) during the implementation of the state policy on energy efficiency in regions is achieved through energy-saving activities during the production, transfer, and consumption of energy resources, the introduction of the best technologies available (BTA) and the key energy-efficient technologies in the public and utility sectors of the Arctic Regions of the Russian Federation (ARRF). The relevant data are shown in Figure 1.

![Figure 1. Key energy-efficient technology introduction indicators, %](image)

To introduce individual heat supply units with weather controls, it is necessary to determine the installation conditions for the heat supply units in apartment buildings and public organizations and to develop economic stimulation mechanisms. After the installation of a heat supply unit in a building, consumers get a chance to control the fuel rate depending on their requirements. Heating controllers featuring exterior and interior air temperature sensors are used to maintain the required temperature in the heating system. Through the specific program, such controllers can reduce the air temperature in rooms during nighttime and on weekends, which is especially relevant for public organization buildings. The automated control of the heating load can reduce energy consumption in spring and autumn when overheating typically occurs due to the specifics of centralized heating load regulation at the heat supply sources.

Energy-saving actions may significantly reduce the consumption of energy resources and fuel, resulting in the reduction of the key target indicator of energy efficiency, the specific power consumption [5-7].

The reduction of the specific annual consumption of thermal and electric energy spent on the general house needs in apartment, administrative, and public buildings is used as a benchmark.

The monitoring of energy saving and improvement of energy efficiency across the economic sectors is performed using the specific consumption values of fuel and energy resources. To analyze
the energy efficiency of residential utility and public sectors, we used the following energy resource consumption indicators:
- specific consumption of thermal energy (TE) in apartment buildings (APB);
- specific consumption of thermal energy in state and municipal healthcare establishments, Gcal/m²;
- specific consumption of electric energy in state and municipal healthcare establishments, kWh/m²;
- specific consumption of thermal energy in state and municipal educational institutions, Gcal/m²;
- specific consumption of electric energy in state and municipal educational institutions, kWh/m²;

The values of specific consumption of thermal energy in apartment buildings, healthcare establishments, and educational institutions across the regions for 2017 are shown in Figure 2.

![Figure 2. Specific consumption of thermal energy, Gcal/m².](image)

The values of the specific consumption of energy resources exceed those obtained all over Russia. Therefore, the main goal of municipalities is performing energy inspections to develop structural improvement and advanced development programs for the heating infrastructure, calculate hydraulic modes for heating systems and adjust the operational modes of heating systems, and develop and implement energy-saving actions. The implementation of such an action in the housing sector stipulates the construction of apartment buildings following the energy efficiency requirements, the implementation of actions aiming to raise the energy efficiency during major renovations at apartment buildings, actions to improve the energy efficiency of lighting through the installation of motion sensors, the installation of automated heat supply units, heat insulation of pipelines, and the improvement of energy efficiency of heat supply units, heating, and hot water supply pipelines, performing hydraulic adjustment of heat distribution systems, and the introduction of pump drive frequency regulation.

By 2025, the specific TE consumption in APB is expected to decrease by 25% compared to the 2015 values due to the Housing Utility Fund program for the construction of energy-efficient houses that began in the regions of Russia in 2010.

Designing buildings with energy efficiency classes D and E is not allowed. Classes A, B, and C are assigned to new and renovated buildings during the project documentation development stage.
Further on, the energy efficiency class should be clarified during the energy inspections. To increase the proportion of Class A and B buildings, the regions of Russia shall use economic stimulation.

Class A and B are only assigned to buildings if the project features the following obligatory energy-saving actions:

- installing individual heat supply units to reduce energy costs for the hot water supply circulation. These should be equipped with automated control systems, as well as energy resources, hot and cold water consumption metering systems.
- using energy-saving lighting systems fitted with motion and light sensors for common spaces;
- Using compensating installations for elevator, pump, and ventilation motors.

In 2019, according to the data from the Utility Service Reform Fund, 154 energy-efficient houses were built in Russia, 65 of them in the Northwestern Federal District and 37 in Murmansk Oblast. The Russian projects for the construction of energy-efficient housing use the following technologies: heat pumps, air recovery systems, solar panels, motion sensors, individual heat supply units, thermal insulation of envelopes, energy-saving light bulbs, co-generation plants.

The construction of energy-efficient houses allowed for the identification of the barriers that hinder the implementation of energy saving actions and the introduction of key energy-efficient technologies:

- the lack of funding mechanisms for construction companies that build new houses or renovate old ones;
- the lack of certified construction materials listed in the project requirements in some of the regions. Their delivery from other regions may increase the duration and overall costs of construction works;
- problems with maintaining energy-saving equipment and house automation systems.

In 2013, a 24-unit energy-efficient apartment block was built in Murmansk. Its envelopes were heat-insulated (Figure 3), and it was equipped with an automated metering system for thermal energy consumption, motion sensors, and energy-saving light bulbs. The hot water supply system was fitted with plate heat exchangers. The house was assigned energy efficiency class B. The energy-saving effect of the actions implemented during the construction of the house and the costs for the residential premises and utilities compared to a similar class C house is 20%.

Figure 3. Energy-efficient house in Murmansk.

The implementation of the set of energy-saving actions in the housing sector shall be implemented as follows:

- during the major renovations of residential buildings;
- during the useful life of the available housing facilities;
- during the construction of new residential buildings.

To obtain better results in these areas, it is necessary to ensure the following:

- obligatory energy inspections of buildings, assigning energy efficiency classes, and preparing energy performance certificates;
- obligatory posting of the energy efficiency class on the building;
- developing regional requirements for the energy efficiency of buildings during major renovations and the construction of new residential houses;
- attracting private investments in energy-saving technology through energy service contracts.

When assessing the technical parameters of energy saving and energy efficiency in regions, the main focus is on the introduction of key energy-efficient technologies, such as individual heat supply units with automated weather controls in the public sector and apartment buildings, energy-efficient light sources in public sector buildings, as well as road and street infrastructure, energy-efficient buildings housing public sector establishments, and the increase of the share of thermal energy produced through co-generation in the heat balance of large cities. In recent years, individual heat supply units with automated weather controls have been coming into common use. They produce significant savings of fuel and energy resources in apartment and public sector buildings.

Energy efficiency is a key component for reliable power supply, energy security, as well as solutions to social, economic, and environmental issues. To develop a regional energy saving program, it is necessary to justify energy efficiency indicators and perform ongoing monitoring in the context of the dynamic economic development of regions. This will allow us to obtain quality data for the development and adjustment of energy-saving programs. The comprehensive approach in the implementation of energy efficiency policy and the introduction of energy saving activities shall include the following:

- identifying the prioritized economic sectors for the development of energy efficiency indicators;
- identifying the sectors with the most significant capacity for energy efficiency improvement;
- selecting and justifying energy efficiency indicators that are most effective in reducing the consumption of energy resources;
- determining the investment attractiveness of the development and implementation of key energy-efficient actions;
- monitoring the developed energy saving programs taking into account the justified energy efficiency indicators for various economic sectors of a given region.

3. Conclusion
When assessing the technical parameters in terms of energy efficiency and saving, the main focus in the ARRF is on the introduction of key energy-efficient technologies [8-10]. We identified the following key areas of implementation for the state energy efficiency policy:

1. improving the economic mechanisms of the Northern Supply Haul through the use of renewable and alternative energy sources, including the local ones, as well as the reconstruction and upgrading of end-of-life power plants and the introduction of energy-saving materials and technologies;
2. improving the energy efficiency and ensuring energy independence of small remote settlements;
3. developing and implementing projects for energy saving and efficiency, including those involving international cooperation;
4. renovating and upgrading housing facilities and key housing and utility assets based on modern energy-saving technologies.

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