Evaluation of Energy Efficiency of Buildings Operated by the Example of Housing Stock of Yakutsk

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Abstract This article discusses the problem of improving the energy efficiency of buildings. An express assessment of the energy efficiency of apartment buildings was carried out on the basis of the specific characteristics of the actual consumption of heat energy for heating and ventilation of the building. In the course of the study, the main problems of introducing energy-saving technologies were highlighted. The proposed approach can be used for monitoring energy consumption and energy audit of buildings.

1. Introduction

Energy consumption is one of the problems widely discussed by specialists and scientists nowadays. In Yakutia, in one of the coldest regions of Russia, the issue of saving energy consumption remains an urgent task. As the statistics show, residential buildings are the main consumers of heat energy, since almost 60% of the energy consumed in Yakutsk is used by apartment buildings.

Development of construction of stone apartment buildings (MFH) in Yakutsk began in the beginning of 2000-s (figure 1), which is associated with the spread of monolithic-frame technologies in the construction of multi-storey buildings.

Figure 1. Total area of apartment buildings in Yakutsk by years, m²
There is a tendency to use energy-efficient materials for building construction and to popularize the assignment of energy efficiency class. 10% of MFH has a class of energy efficiency, which was obtained at a design stage. However, even these buildings do not have a performance rating, there is no official data on achieving the desired energy efficiency during operation.

This paper examines the energy consumption of MFH, including buildings with an assigned energy efficiency class. Some builders tend to blindly save “advanced” energy-saving technologies for the sake of “green” certificates without taking into account the cycle of operation. There is a need to consider actual energy consumption of all MFHs, to study the main factors affecting their energy efficiency.

There are 3051 houses in Yakutsk [1], with a total area of 6007056 square meters. Today, the monolithic-frame structure is one of the most common technologies for construction of residential multi-apartment buildings in Yakutsk. There is information about 303 MFH monolithic-frame structure on the basis of Dom.MinZHKH service [1]. 46.86% of these apartment buildings do not have a collective (common house) metering device and the heating system is decentralized on the basis of individual gas boilers, since these MFHs were excluded from consideration in this work.

2. Methods

Indicators characterizing the energy efficiency of MFH, according to which the class of its energy efficiency is determined, include the specific and basic annual consumption, which is determined as the sum of specific annual heat energy consumption for heating needs (including the consumption of heat energy for general house needs, such as heating staircases, basements, etc.), ventilation, hot water supply of MFH and electricity costs for general house needs.

A significant part of energy consumption in Yakutsk is associated with the need to heat buildings, in this work only indicators of annual specific heat energy consumption for heating needs were considered.

Thus, when establishing the base level of specific annual consumption [2] for heating, the following design conditions were adopted:
- internal air temperature in apartments - 20°C;
- duration of heating period in Yakutsk - 252 days;
- average outside air temperature of the calendar year - -20.9°C.

The actual values of specific annual consumption of energy resources are presented for 2017, 2018 on the basis of data from common house devices for recording the consumption of heat energy in the heating system. Actual values are given to design conditions by linear interpolation from design conditions depending on deviations of actual climatological characteristics of corresponding year and storey of an apartment building.

The class of actual energy efficiency of the building is estimated by the interval of deviation of actual specific energy consumption from the standard (according to GOST 31427-2010 “Residential and public buildings. Composition of energy efficiency indicators”). MFH energy efficiency class is indicated by Latin letters on the scale from G to A++ [2] and is determined by the value of relative deviation, defined as the difference between the value of specific annual consumption of energy resources \( q_f \) and the value of normalized base level \( q_n \)

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\Delta = \frac{q_f - q_n}{q_n} \times 100\%
\]

Indicators of specific annual consumption of energy resources are determined in kWh/m², including common house needs of apartment buildings [2].

3. Results

The class of energy efficiency of multi-family buildings of monolithic-frame construction, which have been in operation for at least 2 years was determined. The amount of heat energy for heating obtained
from the readings of metering devices for heating period is converted to standard conditions taking into account the degree-day (GSOP) of measurement period [3,4,5].

![Figure 2. Building energy consumption grading in Yakutsk.](image)

Further, obtained specific values of energy resources consumption for MFH heating needs are compared with a base level of specific annual consumption of energy resources in MFH. The deviation of a value of actual specific annual consumption of energy resources for heating from the base level in% is represented as MFH energy efficiency class in operational period (figure 2). At the same time, for MFH of one series, the specific heating costs may vary markedly, since they differ in parameters of thermal protection. Analysis shows that in Yakutsk buildings up to 5 floors are not energy efficient due to high specific heat consumption; buildings from 7 to 10 floors can be considered energy efficient, judging by optimal heat consumption for infiltration and specific indicator. The difference in the base specific heat consumption (figure 2) indicates the existing energy saving potential in heating and ventilation system, half of the buildings (51%) belong to classes “D” and “E” where the deviation from base level varies from -15% to +25%. 40 buildings (24.8%) belong to the energy efficiency class “C” (increased) and higher, these houses spend 15-60% less heat energy by 1 sq.m. than a house with a basic energy efficiency value, that is, residents will be able to save comparable amounts for paying for heat energy.

Since 2014, high-rise 12-16-story MFH have been built in Yakutsk, of which 65% have an energy efficiency class. However, high-altitude MFHs from 12 floors and above showed very poor energy efficiency (figure 3), as the heat consumption for heating infiltrating air increases sharply. In the coldest months, at an external air temperature of -40°C/-55°C, the pressure drop between the external and internal air reaches up to 180-200 Pa for 16 storey buildings. Under such conditions, any defect in external enclosing structures leads to penetration of cold air into the building and, accordingly, to a loss of heat. The construction of higher-rise buildings is unsustainable due to the large heat losses for heating infiltrating air, which in turn increases the load on the heating system.
Figure 3. High-rise apartment buildings energy consumption grading.

With the approval of procedure for assigning energy efficiency classes to houses since 2015, the letters “A”, “B”, “C”, “D” or “E” began to appear on new buildings, denoting these classes. However, not all MFH s confirmed their status (figure 4), energy efficiency was below class B (“high”), not a single building confirmed class A (“very high”) assigned during the commissioning of the building by the developer.

Class “G” (very low) included 24 houses, the bottom of them 21 without assigning an energy efficiency class, built before 2012. In other words, it turns out that assigning a class of energy efficiency does not guarantee the actual reduced heat consumption of the building. It is very important to make an operational assessment of energy-efficient technologies adopted during the project period in order to avoid unnecessary investments.

Figure 4. Comparison of building energy consumption.

The most important element of heating system is a unit for introducing coolant into the building. Recently, the practice of connecting building heating systems according to an independent scheme has become relevant, when a separate heating circuit is created inside the building itself, when the coolant from heating network does not enter the heating system (only when it is filled and made up). In the reviewed sample, MFH 50% have an independent interconnection scheme. In class “A” and above, the MFH with an independent connection scheme are mainly presented. Indeed, an independent heating scheme is considered more energy efficient. It is interesting that the lowest class “G” (figure 5)
included 13 buildings with an independent heat supply scheme with an intermediate heat exchanger at the heating point. These are 3-5 storey buildings until 2010 built. The main reasons for the high heat consumption can be physical wear of the building, poor operation of heating system equipment. It is worth noting that houses with energy efficiency class “A” have an elevator thermal unit and hot water supply is provided from the city CHP.

![Figure 5. Comparison of dependent and independent heating systems.](image)

Thus, for conditions of Bratsk city, the optimal height of a building, in terms of energy consumption, is a building of 12 floors. So, due to the large number of factors affecting the parameters of heating energy use for similar MFHs, the specific heating costs vary greatly. This is dictated by the fact that each MFH has different parameters of heat protection of enclosing structures, depending on the year of construction and on operating conditions of heating system (inlet units, heat exchangers, pumps, pipelines, heat insulation, etc.) different, and also depends on provision of corresponding temperature schedule (possible overheads/underheads). In order to establish the actual class of energy efficiency in operational period, it is necessary to collect detailed data and carry out diagnostic instrumental measurements on individual MFHs in order to more accurately assess heat balance of a house. Only the generation of a report on energy audit of a separate MFH gives an assessment of energy efficiency level and possible measures, the effectiveness of which is determined in accordance with identified features of this MFH.

4. Conclusions
Reducing energy consumption for heating in Yakutsk is a central task of energy efficiency policy. This work made it possible to assess 2 main problems:

- energy efficiency class assigned prior to building operation does not correspond to actual. This problem can be attributed to the fact that some developers tend to blindly save “advanced” energy-saving technologies only for the sake of certification and ignore their actual efficiency and return on investment. It is necessary to carry out a detailed assessment of suitability of certain energy-efficient technologies during operation.
- Poor operation and management of MFH buildings. During the entire period of operation, the building should carry out measures that will ensure the serviceable operation of the heat supply systems, good heat protection indicators of enclosing structures of a building, as well as compliance with temperature schedule by a heat supply organization. As a result, this should actually reduce the cost of heat consumption while improving the quality of indoor microclimate.

5. References
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