

PAPER • OPEN ACCESS

## Energy efficiency of multi-apartment residential houses with individual heat supply

To cite this article: Uladzimir Navaseltsau *et al* 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **896** 012057

View the [article online](#) for updates and enhancements.

You may also like

- [A Numerical Approach for Buildings Reduced Thermal Model Parameters Evaluation](#)

Abhinandana Boodi, Karim Beddiar, Yassine Amirat *et al.*

- [Many-body approach of electron elastic scattering on sodium clusters](#)

P Descourt, M Farine and C Guet

- [Energy consumption of modern residential houses of the same energy efficient classes](#)

Uladzimir Navaseltsau, Vitali Khaletski and Vladimir Melnikov



## ECS Membership = Connection

**ECS membership connects you to the electrochemical community:**

- Facilitate your research and discovery through ECS meetings which convene scientists from around the world;
- Access professional support through your lifetime career;
- Open up mentorship opportunities across the stages of your career;
- Build relationships that nurture partnership, teamwork—and success!

**Join ECS!**

**Visit [electrochem.org/join](https://electrochem.org/join)**



# Energy efficiency of multi-apartment residential houses with individual heat supply

Uladzimir Navaseltsau <sup>1</sup>, Dzina Navaseltsava <sup>1</sup> and Mikhail Shenogin <sup>2</sup>

<sup>1</sup>Brest State Technical University, Faculty of Engineering systems and Ecology, Maskouskaya str. 267, 224017, Brest, Republic of Belarus

<sup>2</sup>Stoletov State University of Vladimir, Institute of Architecture, Construction and Energy, Gorky str., 87, 600000, Vladimir, Russian Federation

\*Corresponding author: vnovoseltsev@yandex.ru

**Abstract.** The aim of this work is to study the functioning of heating and hot water systems of the discussed houses, to find the reasons for increased energy consumption. Four energy-efficient houses in the Brest region (Republic of Belarus) with apartment heat supply and a mechanical ventilation system with heat recovery were selected as the object of study. The research methodology of the heating and hot water supply systems of the houses consisted of the following stages: study of project documentation; thermal imaging inspection of building structures and instrumental studies of the operation of heating systems and hot water supply; questionnaire of residents to analyze the nature of their use of the studied systems; processing received data. The values of the operational specific consumption of thermal energy for heating were determined, which doubled the design values equal to 43 kW·h/m<sup>2</sup>. The main reasons for the excess of the operating specific consumption of thermal energy for heating and ventilation over the design value is the increased heating season compared to the design average for a month and the maintenance of elevated indoor air temperatures in apartments, on average, at +21°C, which leads to increased heat losses. The functioning of the hot water supply system of energy-efficient houses is generally satisfactory for the used design solution, but sometimes due to the specific apartments' planning leads to an excessive consumption of water and causes dissatisfaction of residents with a long waiting time for hot water with required temperature. Studies have shown that currently, the existing tariff policy in the Republic of Belarus due to low tariffs for gas and thermal energy for the population does not contribute to the efficient use of energy-efficient solutions by the masses of the population, which leads to an excessive consumption of thermal energy in modern residential buildings.

## 1. Introduction

In the Republic of Belarus, an energy-efficient building is a building that meets the specific heat consumption for heating and ventilation class A +, A or B in terms of specific heat energy consumption for heating and ventilation. Classes of residential buildings in terms of specific heat energy consumption for heating and ventilation were introduced in 2010 and finally adjusted in 2015.

Along with buildings connected to the centralized heat supply system, in the Republic of Belarus in recent years the number of constructed energy-efficient residential buildings with apartment heating from double-circuit gas-fired boilers has increased.

Last years it is relevant to study the energy consumption of existing buildings, to analyze the functioning of heating and hot water systems, to determine the reasons for the increased consumption of thermal energy and the possibilities of reducing energy consumption [1-5].



Monitoring the functioning of the engineering systems of apartment buildings with individual heat supply is necessary, as it will allow us to get real operational data, to analyze and to use this experience during design of similar houses.

Four energy-efficient houses in the city of Pinsk, the city of Malaryta and the city of Drahichyn (No. 34 and No. 36 on Yunaya St. in Pinsk, No. 2 on Nesenyuk St. in Malaryta and No. 50 on the Shaseynaya street in the city of Drahichyn), the first houses in the Brest region (Republic of Belarus) with apartment heat supply and a mechanical ventilation system with heat recovery.

The aim of this work is to study the functioning of heating and hot water systems of the discussed houses, to find the reasons for increased energy consumption.

## 2. Methods

### 2.1 Description of design options of the studied houses

The study of functioning of heating systems and hot water supply of energy-efficient houses was carried out in several stages:

- at the first stage, the study of project documentation was carried out;
- at the second stage, field visits and inspections of heating and hot water systems were carried out in order to identify their technical condition, compliance with design options and correct functioning. During the inspection, temperature and humidity measurements, air velocities in air ducts and thermal imaging of building structures were carried out in apartments,. At the same time, a survey of residents and collection of data (meter readings) on the consumption of resources (gas, electricity, water) by each apartment was carried out;
- at the third stage, the processing of the obtained data was carried out in order to specify the functioning of heating systems and hot water supply.

### 2.2. Survey

To identify possible problems with the functioning of heating and ventilation systems, defects in building structures of energy-efficient houses, it is important to interview and questionnaire residents. A base of 22 questions was prepared for this purpose. The idea of questions was on the basis of observations of people constantly living in apartments, to find possible defects in building structures and engineering systems, as well as to analyze the residents' habits of using heating, ventilation, and hot water systems. Surveys and questionnaires were conducted in the winter while examining building structures and studying the functioning of engineering systems. The survey was conducted anonymously – without indicating the names of the residents and numbers of apartments.

### 2.3. Description of heating and hot water systems

Nowadays, there is an increasing number of constructed residential buildings with apartment heating from double-circuit gas-fired boilers in the Republic of Belarus.

With apartment-by-apartment heat supply, a wall-mounted gas double-circuit boiler is installed in each apartment, providing both heating and hot water. 24 kW boilers are often used for this purpose. They can be open (air to maintain the combustion process comes from the room in which the boiler is located) or closed by a combustion chamber (the air for combustion and exhaust products are gas-tight ducts that communicate with the atmosphere and are not connected with the airspace of the apartment). In accordance with the regulatory requirements of the Republic of Belarus, boilers with a closed combustion chamber are used in multi-story buildings, and any other type of boiler is used in single-story buildings.

The use of a wall-mounted double-circuit boiler with a flow-through heat exchanger is the simplest and cheapest solution for autonomous heat supply.

Heat sources for heating and hot water supply systems for each apartment in these houses are double-circuit gas boilers AOGV-24-ZP (manufactured in Belarus) with a capacity of 24 kW. The domestic hot water network is mounted from polypropylene pipes.

The heating system is designed as a two-pipe one with polypropylene pipes laid in the floor structure for each apartment. The heat carrier for the heating system is water with parameters 80-60°C. Aluminum radiators "MISOT-Style" were adopted as heating devices, in the bathrooms – as heated towel rails.

Heating of stairwells and basements is not provided. The projects provide for the adjustment of the heat transfer of devices by thermostatic valves. Connections to heating devices are polypropylene pipes laid in a stroob.

### 3. Results and discussion

#### 3.1. Results of research

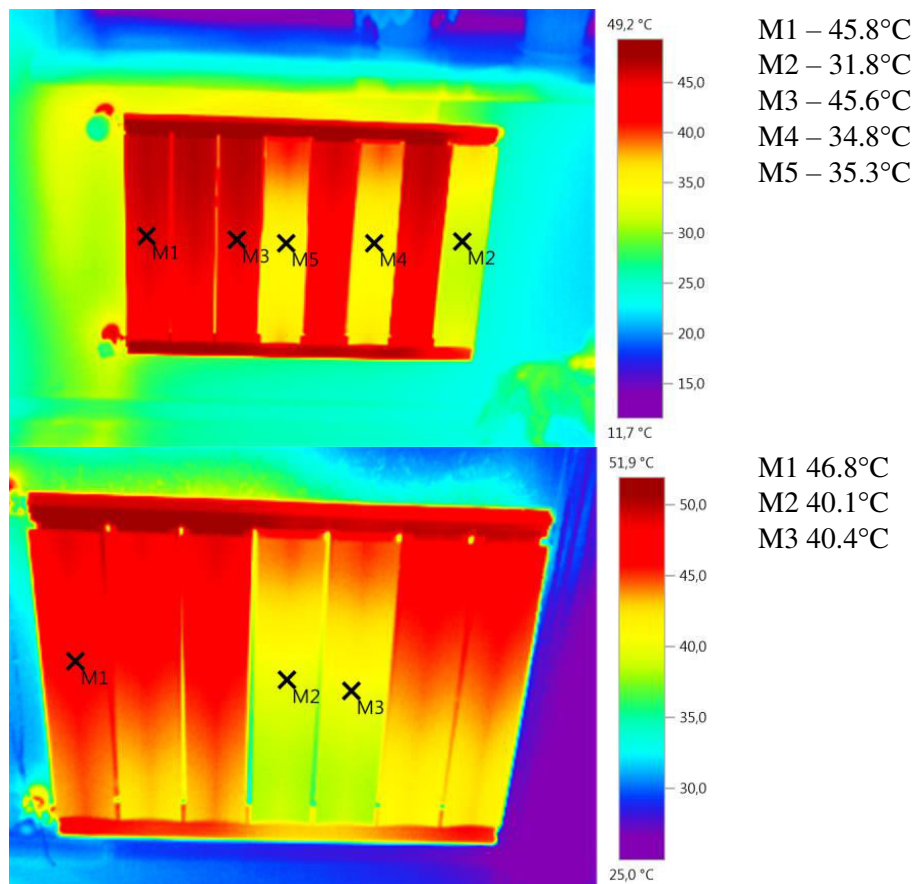
Based on the results of the thermal state of the exterior walls inspection, the following conclusions were made:

1. There are minor areas with increased heat loss (on the outer walls, mainly on the end walls, lintels above the windows) in all houses.
2. There is a lower temperature on the inner surfaces of the walls at the locations of the ventilation ducts associated with the rollover of the ventilation system.
3. The heat flux densities obtained in the course of the measurements in characteristic places made it possible to establish the average heat transfer resistance of the exterior wall structure, which was equal to the average 3.3-3.4 m<sup>2</sup>.°C/W.

Thus, the houses under consideration have a heat transfer resistance of the external wall structure which is slightly lower than the design values, but meets the regulatory requirements of building design standards (3.2 m<sup>2</sup>.°C/W) operating in the Republic of Belarus.

As a result of the study of heating systems of energy-efficient houses, the following was established:

1. The houses have non-residential apartments that are heated in a standby mode (the largest number is 5 apartments);
2. Air temperature in apartments is generally maintained at the level of thermal comfort of residents and is in the range from 20.3°C to 24.0°C with air humidity in the range of 40-59.1% (in some apartments (less than 1% of apartments) air temperature is 18.3-18.6°C). The outdoor temperature at the time of the research ranged from –1 to 0°C;
3. Air temperature in unheated stairwells is 12-12.5°C with air humidity in the range of 40-42.6%;
4. On the average about 24% of residents (22-26%) made changes to the heating systems of apartments (replacing and increasing the number of radiators);
5. From 38% to 61% of residents do not use installed thermostatic valves to control the heat transfer of heating devices (questionnaire data). In some apartments (up to 5%) thermostatic valves are absent on some heating devices or the thermal heads are not fixed on the valves themselves);
6. In general from 32 to 55% (questionnaire data) of apartments are not satisfied with the heating system (the main drawback is the small number of radiator sections and their heating (19-27%)).



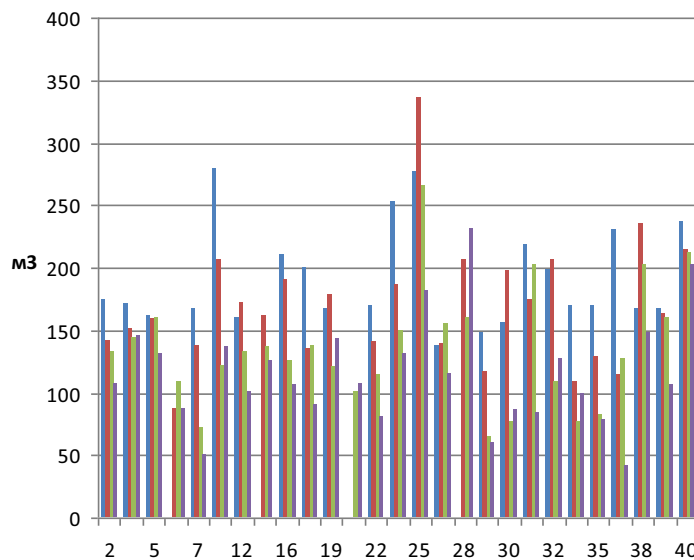
**Figure 1.** Examples of radiator thermograms illustrating the unsatisfactory heat transfer of a part of the sections.

As a result of the study of the hot water supply system of energy-efficient houses, the following was established:

1. The average waiting time for hot water from the most distant tapping point is 37 seconds, while waiting for hot water with a standard temperature of 55°C – more than 60 seconds when the boiler is set to 55°C;
2. In general from 51 to 62% (questionnaire data) of apartments are not satisfied with the operation of the hot water supply system (the main drawback is the long waiting time for hot water and a large over-expenditure of water (32-41%)).

### 3.2. Determining of operation specific heat energy consumption for heating

To determine the operation specific heat energy consumption for heating energy-efficient houses on the basis of data on the monthly gas consumption of each apartment during the life of the buildings, the average gas consumption by year is determined (minus the average gas consumption calculated for each apartment used for hot water supply). The calculation results are presented in figures 3-5 (three houses have been taken as examples).

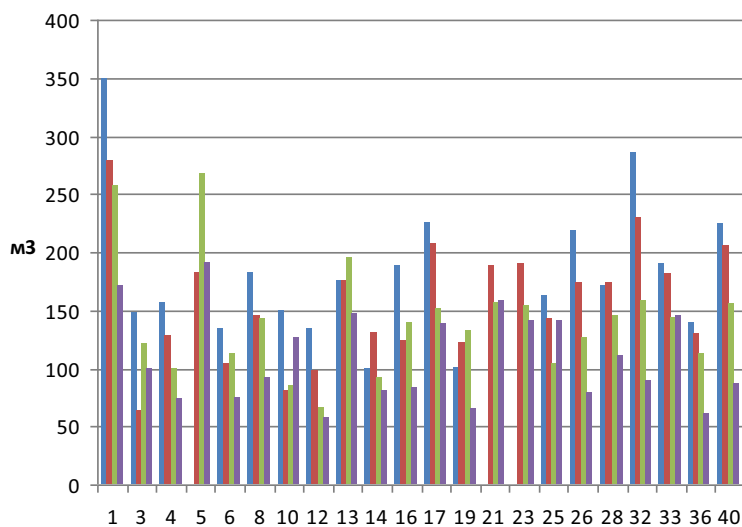


**Figure 2.** Average monthly gas costs for apartments of house No. 34 on Yunaya str. (Pinsk)

According to the calculation, the average gas consumption for heating per month was obtained, which is in the heating seasons: season 1 – 183 m<sup>3</sup>, season 2 – 169 m<sup>3</sup>, season 3 – 135 m<sup>3</sup>, season 4 – 115 m<sup>3</sup>; 139 m<sup>3</sup> is an average number over the last 3 years. To determine the specific consumption of thermal energy for heating, the main parameters are defined as follows:

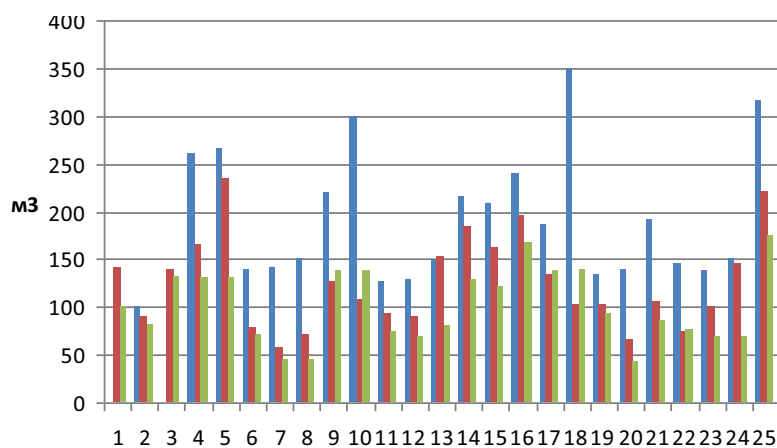
- the lowest calorific value of natural gas is adopted according to data provided to the gas-supplying enterprise and amounts to 7600 kcal/m<sup>3</sup>,
- coefficient of efficiency (COE) of a gas boiler – 85%. The boiler efficiency according to the passport data for the AOGV-24ZP boiler installed in the houses under study is 93%, but this is the maximum value in a uniform operating mode. The actual boiler efficiency during operation for a sufficiently long period of time in a similar heating system is taken from studies [2].

The specific heat consumption for heating based on the calculations made was for the heating seasons: season 1 – 143 kW·h/m<sup>2</sup>, season 2 – 132 kW·h/m<sup>2</sup>, season 3 – 105 kW·h/m<sup>2</sup>, season 4 – 90 kW·h/m<sup>2</sup>.



**Figure 3** Average monthly gas costs for apartments of house No. 34 on Yunaya str. (Pinsk)

The specific heat consumption for heating based on the calculations made was for the heating seasons: season 1 – 156 kW·h/m<sup>2</sup>, season 2 – 135 kW·h/m<sup>2</sup>, season 3 – 122 kW·h/m<sup>2</sup>, season 4 – 95 kW·h/m<sup>2</sup>.



**Figure 4.** Average monthly gas costs for apartments of house No. 2 on Nesenyuk str. (Malorita)

The specific heat consumption for heating based on the calculations made was for the heating seasons: season 1 – 149 kW·h/m<sup>2</sup>, season 2 – 98 kW·h/m<sup>2</sup>, season 3 – 79 kW·h/m<sup>2</sup>.

The decrease in specific heat energy consumption for heating over the years is caused by increased heat losses during the operation of the building in the first year after construction (the presence of moisture in building structures) and a gradual increase in the average outdoor temperature during the heating period.

The main parameter of the effectiveness of the hot water supply system is to obtain hot water of the required temperature for a fairly short period of time. The data obtained as a result of the study of the hot water supply system, in general, correspond to the existing data on the characteristics of the boiler equipment of this type (double-circuit boiler). Thus, the operation of the hot water supply system is generally satisfactory for the used design solution, but leads to an excessive consumption of water. The layout of the corner apartments is so that the bathroom is located at a considerable distance from the gas boiler located in the kitchen, and this leads to an even longer waiting time for hot water due to the large length of the pipelines. Processing data on gas consumption of three houses showed that the average gas consumption for hot water is 32 m<sup>3</sup> per month for an apartment.

#### 4. Conclusion

The functioning of the hot water supply system of energy-efficient houses is generally satisfactory for the used design solution, but sometimes due to the specific apartments' planning leads to an excessive consumption of water and causes dissatisfaction of residents with a long waiting time for hot water with required temperature.

The actual specific heat energy consumption for heating and ventilation is 79-90 kW/m<sup>2</sup>, which significantly exceeds the design value. For five-storey energy-efficient residential buildings, the specific heat consumption for heating and ventilation should be 43 kW·h/m<sup>2</sup> for the climatic conditions of the Brest region. In the buildings the indoor air temperature is higher than about 21°C; what leads to increased heat loss, normative air exchange is not ensured due to poor operation of the ventilation system [4].

One of the main reasons for the excess of the specific heat energy consumption for heating and ventilation above the design value is the tenants' ability to start the heating season at any outdoor temperature. Design values are calculated for the normative heating season, while the actual number of

days of the heating season in the houses in question is on average 1 month longer according to the data received.

It should be noted that the tariff policy in the Republic of Belarus due to the rather low tariffs for gas and thermal energy for the population does not contribute to the most efficient use by the general public of energy-efficient solutions used in modern residential buildings, which leads to an excessive consumption of thermal energy.

### References

- [1] Gorshkov A, Vatin N, Nemova D, Shabaldin A, Melnikova L and Kirill P 2015 *Procedia Engineering* **117(1)** 1080-1089
- [2] Tumanova K, Borodinecs A and Geikins A 2017 *IOP Conference Series: Materials Science and Engineering* **251(1)** 012058
- [3] Korniyenko S V 2018 *IOP Conference Series: Materials Science and Engineering* **463(2)** 022060
- [4] Odineca T, Borodinecs A, Korjakins A and Zajecs D 2019 *IOP Conference Series: Earth and Environmental Science* **290(1)** 012105
- [5] Tarasova D S and M R Petritchchenko 2017 *Magazine of Civil Engineering* **72(4)** 28-35
- [6] Navaseltsau U and Klimovich I 2015 *Bulletin of the Brest State Technical University: Water construction, heat power engineering, geoecology* **2** 46–48 (in Russian)
- [7] Navaseltsau U, Navaseltsava D and Khaletski V 2019 *E3S Web Conf.* **136** 05007