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Energy consumption of modern residential houses of the same energy efficient classes

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Abstract. The aim of the study is to identify and to compare the design and operation demands of thermal energy for heating and ventilation, the search for the reasons of increased energy consumption. For the study, energy-efficient class B houses were selected in terms of specific heat energy consumption for heating and ventilation, which were put into operation in Brest (Belarus Republic) in 2014-2015. The main method for determining the reasons of increased energy consumption was to study the functioning of the heating and ventilation systems of the discussed houses and to survey residents to analyze how they use heating and ventilation systems. The calculated and operation values of the specific consumption of thermal energy for heating and ventilation are determined. Operational specific heat energy consumption for heating and ventilation turned out to be higher than the project ones by 7.2% to 44.7%. A mismatch was found in the energy consumption of houses of the same class in energy efficiency. The main reasons for this are moisture in building structures, a malfunction in the automation of an individual heating unit, and non-use of installed thermostatic valves to regulate the heat transfer of heating devices. Studies have shown that currently in the Republic of Belarus there is no ground to build residential buildings of a higher energy efficiency category than the considered houses.

1. Introduction

Energy-efficient buildings are widely used in European countries. There are many concepts of energy-efficient buildings: a passive house, a multi-comfortable house, a solar house, etc.

The current European directive documents require that no later than December 31, 2020, all new buildings should have almost zero energy consumption. The long history of the development of energy-saving construction in Europe has allowed us to accumulate significant experience in this area. A lot of data on the successful implementation of energy-efficient building projects and monitoring the functioning of their engineering systems can be found in the recent articles [1-11].

The authors of the article consider the issue on energy-efficient buildings using the example of the Republic of Belarus. In the Republic of Belarus the “Comprehensive Program for the Design, Construction and Reconstruction of Energy-Efficient Residential Buildings” has been approved by the Government Decision No. 706 of June 1, 2009. It included a set of organizational, technical, regulatory and legislative measures covering all stages of the building's life cycle and determined the projected volumes of the construction of energy-efficient residential buildings for the period until 2020.

Regulatory documents related to the design of energy-efficient buildings in the Republic of Belarus over the past 10 years have undergone a number of changes in 2009, 2010, 2013 and 2015.

Classes of residential buildings have been introduced in terms of the specific heat energy consumption for heating and ventilation which are set in accordance with the classification in table 1.

Table 1. Classes of residential buildings in terms of specific heat energy consumption for heating and ventilation during the heating period.

Number of floors	Specific rates for building classes (kWh/m^2)/(MJ/m^2)
Class G	
1 - 3	231/832 and more
4 - 6	134/482 and more
7 and more	123/443 and more
Class E	
1 - 3	(230 - 154)/(828 - 554)
4 - 6	(133 - 90)/(479 - 324)
7 and more	(122 - 82)/(439 - 295)
Class D	
1 - 3	(153 - 112)/(551 - 403)
4 - 6	(89 - 66)/(320 - 238)
7 and more	(81 - 60)/(292 - 216)
Class C	
1 - 3	(111 - 92)/(400 - 331)
4 - 6	(65 - 53)/(234 - 191)
7 and more	(59 - 49)/(212 - 176)
Class B	
1 - 3	(91 - 65)/(328 - 234)
4 - 6	(52 - 35)/(187 - 126)
7 and more	(48 - 30)/(173 - 108)
Class A	
1 - 3	(64 - 55)/(230 - 198)
4 - 6	(34 - 28)/(122 - 101)
7 and more	(30 - 24)/(108 - 86)
Class A+	
1 - 3	Less than 55/198
4 - 6	Less than 28/101
7 and more	Less than 24/86

At present, in the Republic of Belarus an energy-efficient building is a building corresponding to the specific heat energy consumption classes of A+, A or B in terms of the specific heat consumption for heating and ventilation. Designing newly built residential buildings of the heat energy consumption classes of C, D, E, G is not allowed.

Currently a lot of energy-efficient houses have been built in the Brest region. It is relevant to study an operational energy consumption in houses built in recent years and to compare it with design data, to analyze the functioning of engineering systems in these buildings. Fifteen energy-efficient houses built in Brest (Republic of Belarus) in 2014-2015 were selected as an object of study. All houses correspond to class B in terms of specific consumption of thermal energy for heating and ventilation.

The aim of the study is to identify and to compare the design and operation demands of thermal energy for heating and ventilation, the search for the reasons of increased energy consumption.

2. Methods

The idea for identifying the reasons of increased energy consumption was to study the operation of heating and ventilation systems of the houses. The investigation was carried out in several stages:

– study of project documentation;

– inspections of heating systems of apartments in order to identify their technical condition, compliance with design decisions and proper functioning;

– questioning of residents to analyse how they use heating and ventilation systems;

– processing the received data.

2.1 Description of design options of the studied houses

House designs provide for the following heating and ventilation solutions. Connection of the local heating system of a residential building to heating networks is carried out through an individual heating center (IHC) according to either dependent or independent schemes. In the houses an apartment, two-pipe, horizontal heating system with the installation of heat meters for each apartment is designed.

The adopted scheme of the apartment heating system represents a pair of vertical risers (supply and return) to which the circulation rings of individual apartments are connected.

The control unit for apartment heating is located in the bathroom or in the common corridor and is equipped with:

– supply pipe - by a ball valve, filter, heat energy meter;

– return pipe - with a ball valve with a connector for a heat meter temperature sensor, in some residential buildings - with a differential pressure regulator.

Steel panel, aluminum or cast-iron radiators were used as heating devices. The wiring of the supply and return lines of the apartment heating systems is made of polymer pipes with anti-diffusion protection.

The exhaust ventilation is designed in buildings with a natural motivation according to the scheme: influx into living rooms, exhaust through kitchens and bathrooms. Air inflow is provided due to window infiltration and periodic ventilation according to the window operating instructions. Air is removed through the ventilation plastic grilles through the ventilating ducts.

2.2. Determination of specific heat energy consumption

The methodology for determining the design values of thermal energy consumption for residential buildings in the Republic of Belarus is based on determining the sum of the building’s heat losses through the external building envelopes and heat losses due to heating of the air infiltrating through the external barriers, minus the biological and technological heat inputs. During these calculations, the normalized air temperature in the rooms is taken equal to +18 °C (in the corner rooms +20 °C). The calculated values of the specific heat energy consumption for heating and ventilation in these studies are determined by the projects of the discussed houses.

The operational values of the specific consumption of thermal energy for heating and ventilation in the houses under study were obtained from the results of processing data from common house heat metering devices.

Based on the known climatic data (average outdoor temperatures for the heating seasons 2015-2018 for the city of Brest), the operational values of the specific heat energy consumption for the heating seasons were adjusted to bring the ambient temperature for the heating season for Brest to the standard temperature.

The calculated values of the specific heat energy consumption were obtained at a standardized indoor air temperature of + 18°C, therefore, to compare with real values, these values were corrected at an indoor air temperature of + 21°C (values obtained from inspection of apartments in residential buildings).

3. Results and discussion

The comparison of the operation values of the specific consumption of heat energy for heating and ventilation with the designed values is shown in Figures 1-10. For example, data are given for ten buildings.

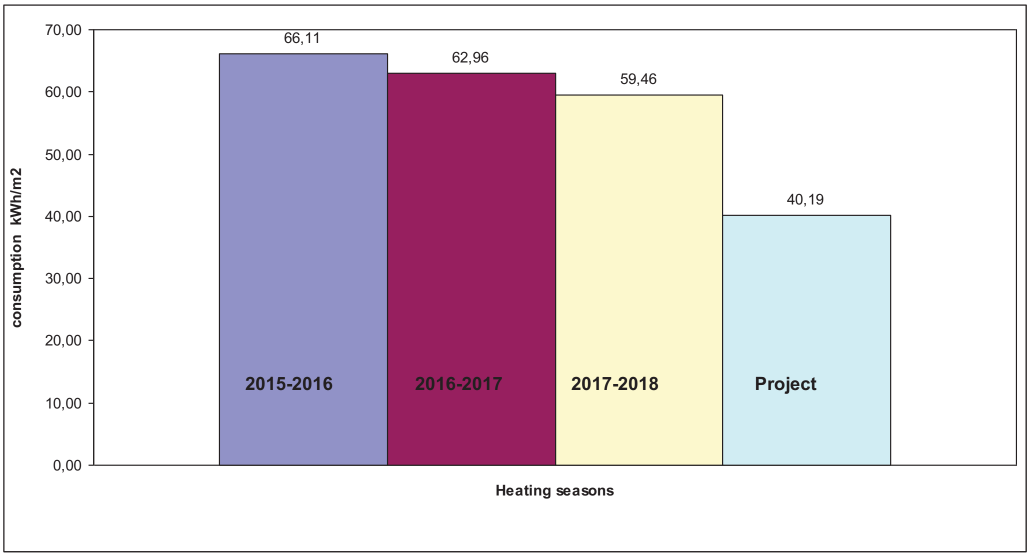

Figure 1. Operation and designed heat energy consumption for heating and ventilation of the house at General Blagoveshchensky str., 2.

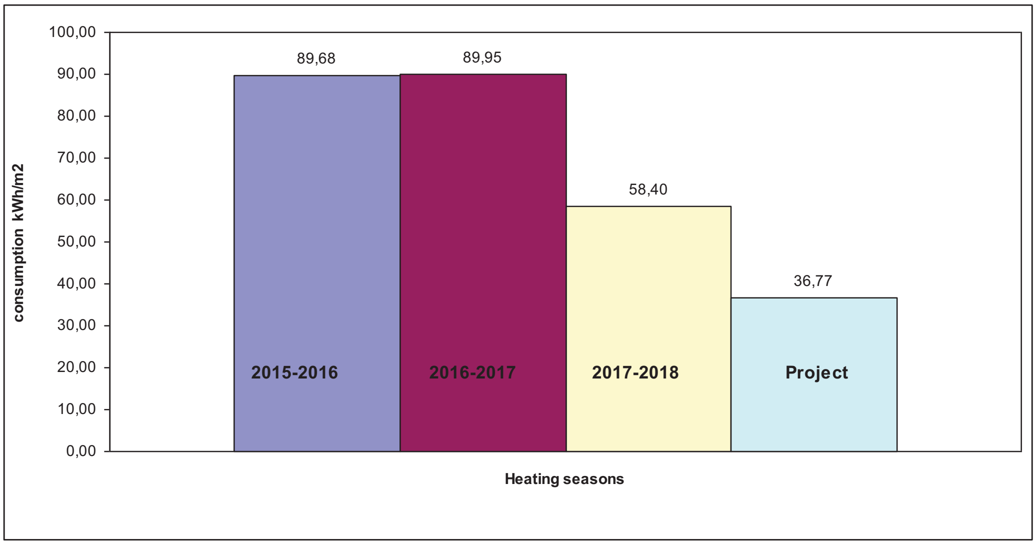

Figure 2. Operation and designed heat energy consumption for heating and ventilation of the house at Gogol str., 1G.

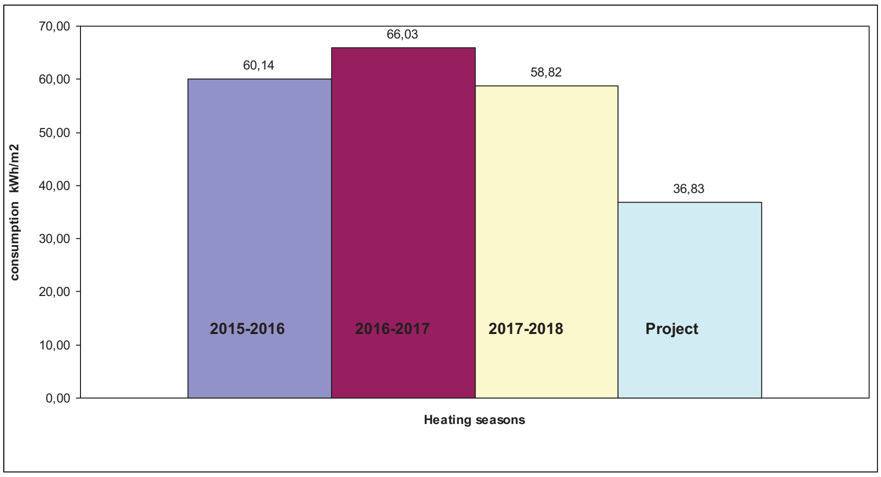

Figure 3. Operation and designed heat energy consumption for heating and ventilation of the house at Griboedova str., 27.

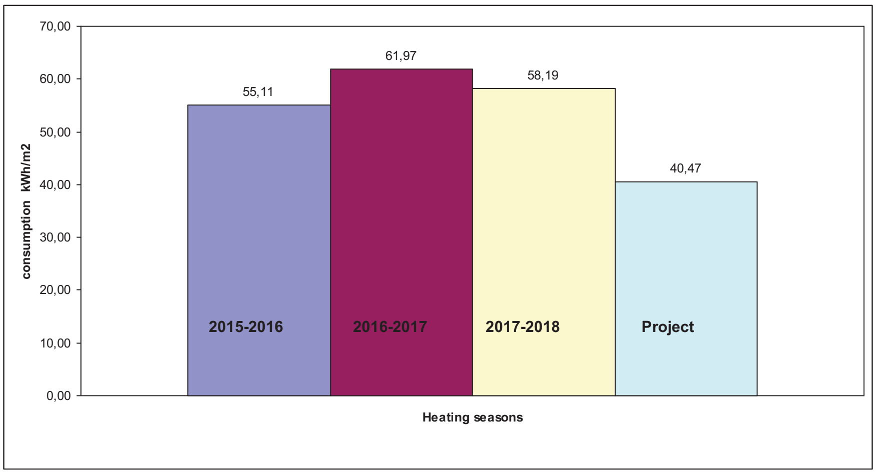

Figure 4. Operation and designed heat energy consumption for heating and ventilation of the house at Griboedova str., 29.

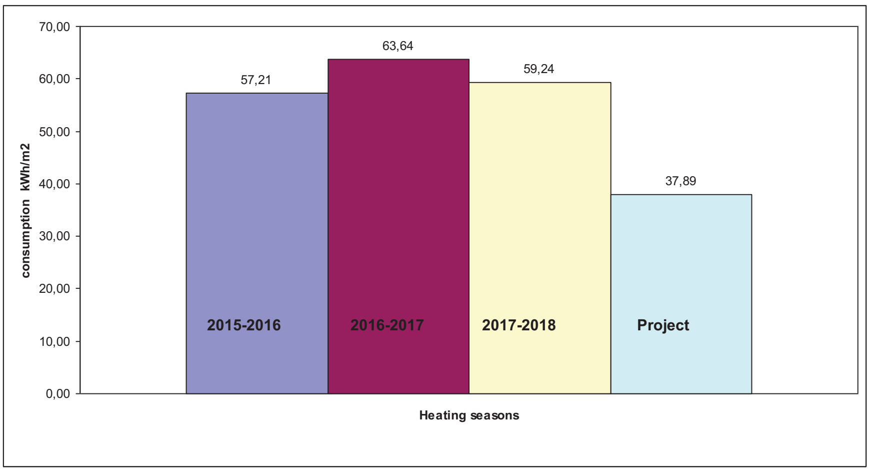

Figure 5. Operation and designed heat energy consumption for heating and ventilation of the house at Griboedova str., 33.

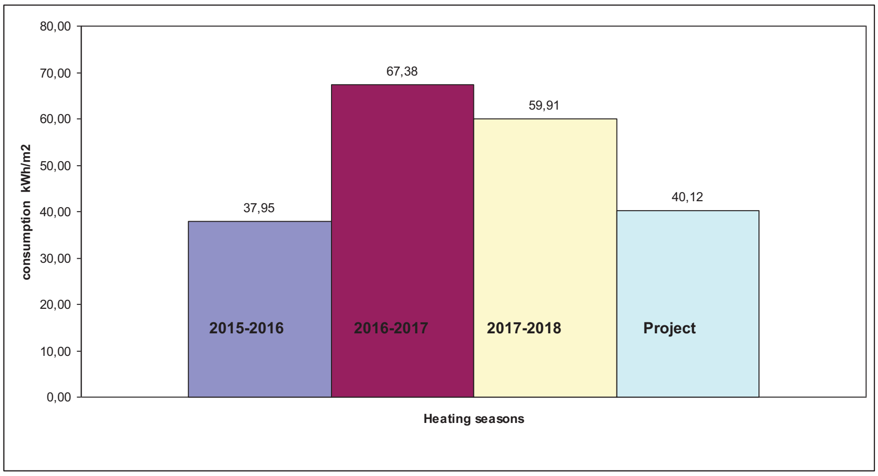

Figure 6. Operation and designed heat energy consumption for heating and ventilation of the house at Griboedova str., 35.

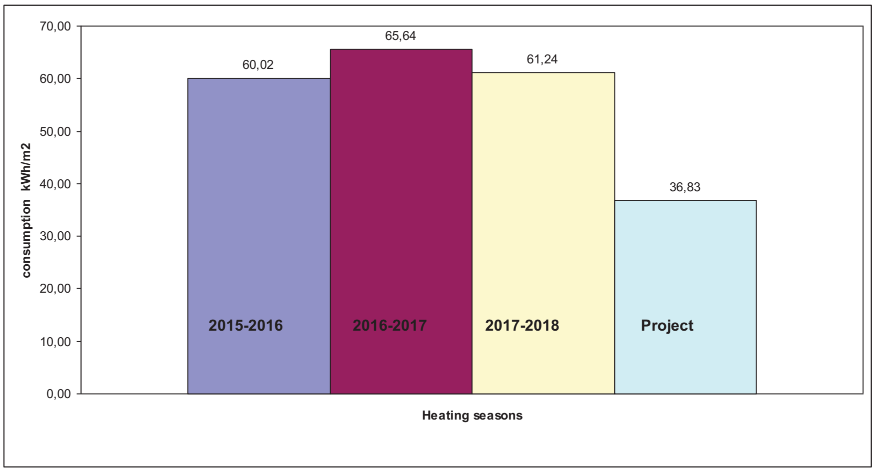

Figure 7. Operation and designed heat energy consumption for heating and ventilation of the house at Griboedova str., 37.

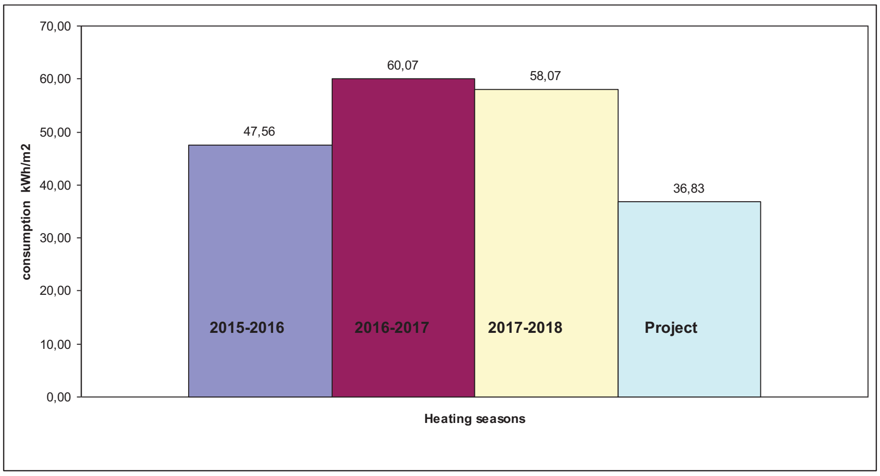

Figure 8. Operation and designed heat energy consumption for heating and ventilation of the house at Makhnovicha str., 16.

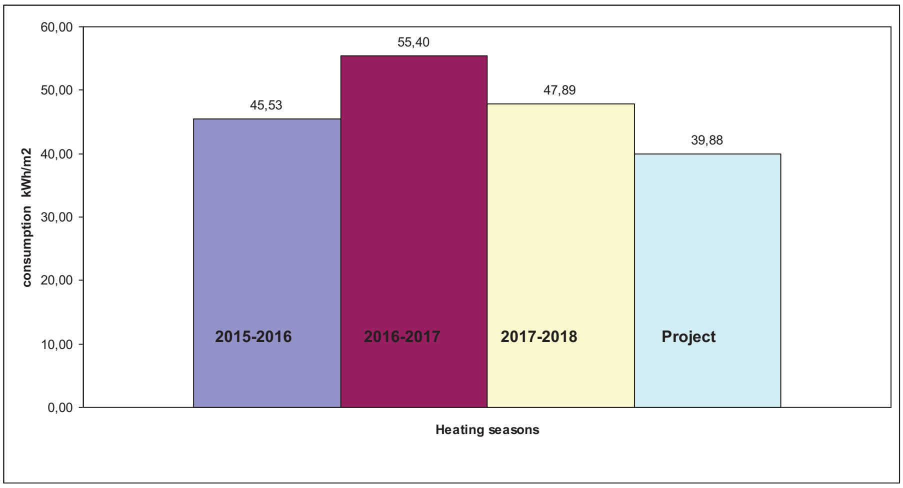

Figure 9. Operation and designed heat energy consumption for heating and ventilation of the house at Makhnovicha str., 34.

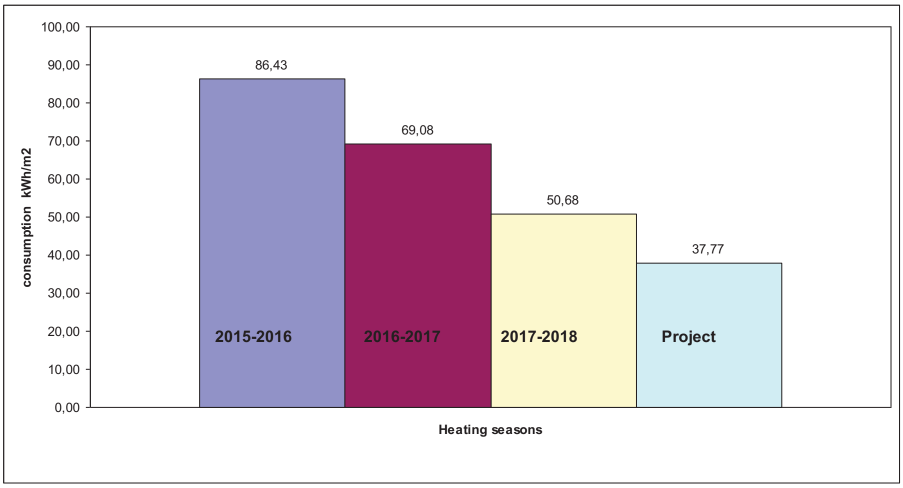

Figure 10. Operation and designed heat energy consumption for heating and ventilation of the house at Morozova str., 23.

The diagrams show the mismatch between the designed and operational energy consumption in residential buildings. The operation specific heat energy consumption for heating and ventilation of the houses in question during the heating seasons of 2015-2018 turned out to be higher than the design ones by 7.2% to 44.7%.

Data for the heating seasons of 2015-2018 obtained in the previous stages of work are summarized in table 2.

Table 2. Operation values of the specific consumption of heat energy for heating and ventilation of residential buildings of energy efficiency class W, kW·h/m^2.

No.	Address	Heating seasons		
		2015-2016	2016-2017	2017-2018
1	Krishtafovicha str., 2	51.34	48.56	41.36
2	Ryabinovaya str., 19	58.10	48.60	48.59
3	Ryabinovaya str.,11	65.31	60.07	54.72
4	Morozova str.,23	86.43	69.08	50.68
5	Gogol str., 1G	89.68	89.95	58.40

6	General Blagoveshchensky str.,2	66.11	62.96	59.46
**7	Griboedova str., 27	60.14	66.03	58.82
8	Griboedova str., 35	37.95	67.38	59.91
9	Griboedova str., 37	60.02	65.64	61.24
10	Griboedova str., 33	57.21	63.64	59.24
11	Griboedova str., 29	55.11	61.97	58.19
12	Salnikova str., 31	42.28	60.18	56.47
13	Makhnovicha str., 16	47.56	60.07	58.07
14	Makhnovicha str., 34	45.53	55.40	47.89
15	Makhnovicha str., 34A	32.47	48.19	49.74

To illustrate the comparison charts were constructed showing the specific heat consumption for heating and ventilation of the houses in question, an example of which is shown in Figure 11.

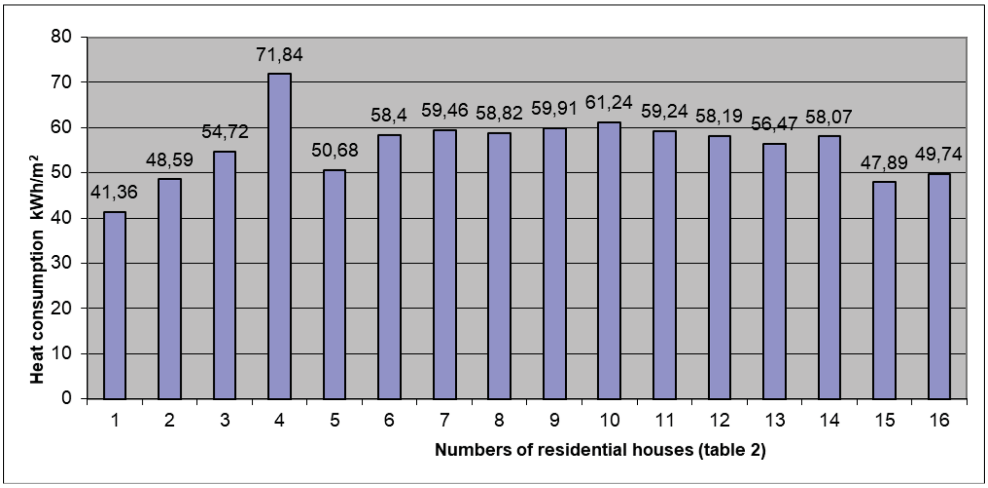

Figure 11. The operation consumption of heat energy for heating and ventilation for the heating season 2017-2018.

A power mismatch in residential buildings of the same energy efficiency class was detected. For example, the real specific heat energy consumption for heating and ventilation of the houses in question for the heating season of 2017-2018 is from 41.36 to 61.24 kWh/m^2.

Study of the functioning of heating and ventilation systems of the considered houses shows that the energy consumption of houses of the same classes in terms of heat energy consumption differs for the following reasons: short time after putting the house into operation (increased consumption in the first and second heating seasons due to moisture in building structures); malfunction of automation of an individual heat point (weather-dependent heat flow controller); the tenants do not use installed thermostatic valves to regulate the heat transfer of heating devices. According to the survey, from 38% to 61% of residents do not use installed thermostatic valves to control the heat transfer of heating devices. 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. In the vast majority of apartments, normative air exchange of at least 140 m^3/h for each apartment is not provided.

4. Conclusion

The following conclusion can be drawn based on the studies on residential buildings conducted by the authors. In the overwhelming majority of apartment buildings with double-glazed windows, normative air exchange is not provided. It is extremely important that staying in poorly ventilated rooms leads to a deterioration in the functional state of the body, contributes to the spread of a number of diseases, reduces performance, and contributes to the underdevelopment of children and adolescents. This is confirmed by a number of recent studies [12-13].

One of the most effective solutions to the problem of poor air quality in the premises of residential and public buildings is the use of mechanical ventilation systems especially with heat recovery. However, at present in the Republic of Belarus the lack of savings when paying for heat and electricity does not cause the population to trust energy-efficient houses with mechanical ventilation systems. [14].

It should be noted that a building with natural ventilation will consume less heat energy than a building equipped with a fully functioning system for utilizing the heat of the removed air. In case of natural ventilation with an air exchange level of 40% of the standard value the calculated value of the specific heat energy consumption for heating and ventilation corresponds to the value for mechanical ventilation with recovery of the heat of the exhaust air with standard air exchange. And with almost completely inoperative natural ventilation the building will consume less energy than an energy-efficient home.

Also it should be mentioned that the tariff policy existing in the Republic of Belarus does not contribute to the most efficient use of energy-efficient solutions by the broad masses of the population. In energy-efficient houses built in European countries, savings are achieved by the availability of proven design solutions and, most importantly, by high tariffs for the consumed heat and electricity which stimulates the population to save resources.

Considering the existing tariff policy the higher costs of the population when paying for energy consumed by using a mechanical ventilation system in the Republic of Belarus the vast majority of buildings are built with a natural ventilation system, the design of which is most achievable category B in terms of specific heat energy consumption for heating and ventilation.

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