

Factors influencing the rating of low-rise wooden houses as "green" buildings

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Abstract. The article presents a program of scientific and practical research on the assessment of "green" technologies in wooden low-rise housing construction in the field of energy efficiency and resource conservation. The objects of research are two identical experimental buildings built in 2020 in Murmansk and Petrozavodsk using different technologies of wooden housing construction and various thermal insulation materials. Attention is focused on assessing the factors affecting the energy efficiency class and the internal microclimate of a wooden building, taking into account the changing environmental conditions and operating modes of buildings in cold climates. The stages of the study were determined, the tasks for each type of experiment and the expected results were formulated. Methods fixed in the regulatory documents of the Russian Federation are considered as the main ones. A method for monitoring the parameters of the internal microclimate, environment and temperature and humidity in the layers of the enclosing structures of model objects is proposed and implemented. The implementation of the research program will allow assessing the influence of the factors under study on the energy efficiency class of a wooden building and developing recommendations for the design, construction and operation of low-rise wooden buildings in a cold climate, taking into account the criteria of "green" construction.

1 Introduction

"Green" construction is based on the concept of sustainable development and is based on the following principles: favorable and healthy conditions for human life, limiting the negative impact on the natural environment and taking into account the interests of future generations [1, 2]. In scientific, regulatory and methodological sources, the concept of "green building" is interpreted as a unified approach to the entire life cycle of a building. This approach contains measures and solutions, as well as criteria for materials and equipment, which are aimed at: energy efficiency and resource conservation, safe and environmentally friendly natural environment and at ensuring comfortable and safe living conditions for people [3, 4, 5].

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In the Russian Federation, the "green" construction sector is at the beginning of its development. Along with the use of international green certification systems, voluntary certification standards are being developed in Russia, which include: National standard of the Russian Federation GOST R 54964-2012, GREEN ZOOM - 2014, National Association of Builders Organization standards STO NOSTROY 2.35.4–2011 and STO NOSTROY 2.35.68–2012.

The number of buildings in Russia certified according to "green standards" is still small. However, there are a lot of publications with research on this topic. The authors analyze the approaches and criteria for certification of green buildings according to various standards, investigate the reasons that impede the large-scale application of "green" standards in construction, develop proposals for the development of "green" construction [6, 7, 8, 9].

This work is dedicated to the development of a multi-stage program for researching the factors affecting energy efficiency, resource conservation, environmental friendliness, comfort and safety of an individual residential building and its assessment as a potentially "green" building.

2 Materials and Methods

This work was performed using empirical research methods (material modeling, observation, measurement, experiment, comparison) and analytical methods (analysis and synthesis).

At the preliminary stage, two identical model objects (laboratories) were developed for testing "green technologies" and assessing their effectiveness in the conditions of the northern territories. The main areas under consideration are the Murmansk region and the Republic of Karelia. Comparison of natural and climatic conditions is presented in Table 1 and Figure 1.

Laboratories are experimental one-story buildings, which are made using modern technologies of wooden housing construction. The buildings are equipped with engineering equipment and a monitoring system for research.

Wood was used as the main structural material [10]. This material is an environmentally friendly and renewable resource. As shown in Figure 2, the experimental building has two parts. Parts of the building are symmetrical in relation to the vestibule and have the same building volume and internal area of the premises. One part of the building is made according to the technology of frame housing construction, the second part is made according to the "double log" technology from rounded logs (Figure 2). The simultaneous use of two technologies will make it possible to compare them in the conditions of the two considered climatic regions (Republic of Karelia and Murmansk region).

The choice of double log technology is due to the following:

- Preservation of the historical appearance of a log house, typical for the northern territories of Russia;
- The possibility of using more affordable raw materials (average diameter of a log is 200-250 mm);
- Less wood waste in production.

Insulation of the frame, roof and lower floor is made of mineral wool heat-insulating material. Insulation of the log part is done with wood chips and sawdust. The space between the logs of the north-facing wall is divided into 3 parts. One part is filled with linen mats, the second with wood shavings, and the third remains unfilled. The north wall of the frame is also divided into three sections. One part is insulated with linen mats, the middle part is made of cellulose wool by spraying, and the third part is insulated with mats made of hemp fibers and seaweed. This solution will allow evaluating the effectiveness of various thermal insulation materials in different climatic conditions. Compliance with

"green" technologies was the main criteria for the selection of structural and heat-insulating materials.

Table 1. Climatic parameters of the territories under consideration (in accordance with the set of rules SP 131.13330.2012 "Building climatology").

Climate parameters	Considered territories	
	Murmansk region, the city of Murmansk	Republic of Karelia, city of Petrozavodsk
Height above sea level, m	13	26
Geographical coordinates	68°58'45.1"N, 33°5'33"E	61°47'5.6"N, 34°20'48.8"E
Air temperature of the coldest five-day period, ° C, with security 0.92	-30	-28
Absolute minimum air temperature, ° C	-39	-43
Duration, days, and average air temperature, ° C, of a period with an average daily air temperature $\leq 8^\circ\text{C}$	275 -3,4	235 -3,2
Average monthly relative humidity of the coldest month, %	84	86
Rainfall for November - March, mm	138	169
Average wind speed, m / s, for a period with an average daily air temperature of $\leq 8^\circ\text{C}$	4,9	3,2
Average annual temperature, ° C	0,3	2,8

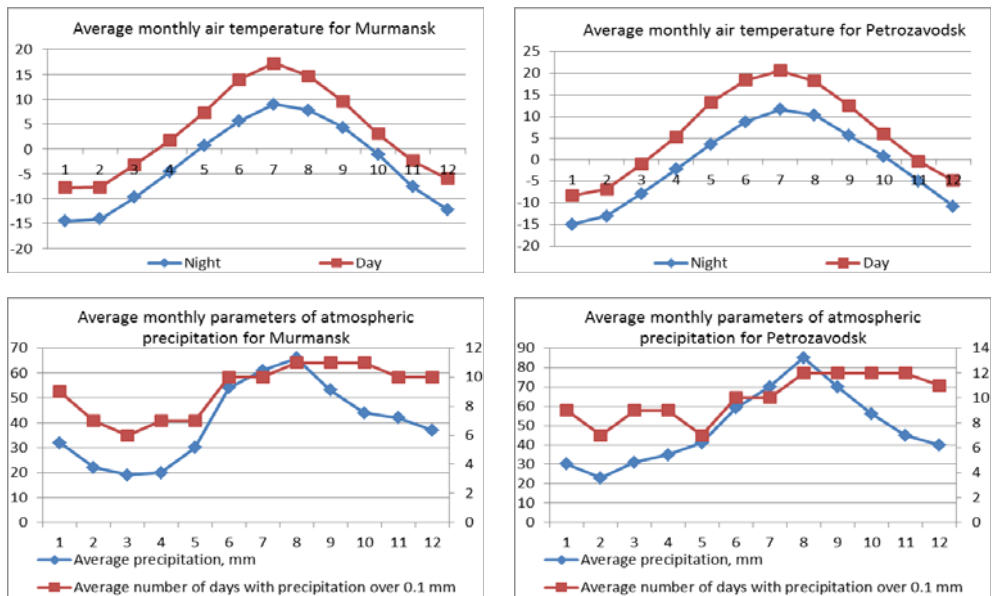


Fig. 1. Average monthly climate data for Murmansk (left) and Petrozavodsk (right) according to the Hydro metrological Research Centre of Russian Federation.

The calculated characteristics of materials are presented in Table 2. The thickness of the insulation is chosen by calculation to ensure the energy efficiency class of the entire building - A + (very high) for the coldest climate [11]. The buildings in Murmansk and Petrozavodsk have the same orientation relative to the cardinal directions (a solid wall without windows is oriented to the North). Wood for the manufacture of both buildings was procured in the Prionezhsky central forestry (compartment 19, unit 23) of the Prionezhsky district of the Republic of Karelia. The timber was harvested from December 15 to December 31, 2019. The logs were debarked and laid out in a cage for atmospheric drying. The atmospheric drying period was 4 months - from January to May 2020. After atmospheric drying, the wood acquired a moisture content of 20-30% (air-dry wood).

An electric heating system was chosen to supply heat to the facility [12]. Supply and exhaust ventilation with recuperation is adopted as the main ventilation system of the building. For a comparative study, the possibility of arranging an alternative natural ventilation system is considered, which is more relevant for the log part of the building.

For the experiments, it is planned to use a number of methods specified in the regulatory documents of the Russian Federation.

1. Thermal imaging survey. The survey methodology is provided by GOST R 54852-2011 "Method of thermovision control of enclosing structures thermal insulation quality". The purpose of the survey is to control thermal protection in natural conditions, to identify places with reduced heat-shielding qualities, as well as to compare data for two objects in different regions.

2. Measurement of heat flux density through enclosing structures in real conditions. The measurement technique is described in GOST 25380-2014 "Method of measuring density of heat flows passing through enclosing structures". Purpose: to obtain data on actual heat fluxes at specific selected points of the structures under study, to compare them with calculated data and to estimate real heat losses.

3. Determination of the actual thermophysical properties of building materials in accordance with GOST 7076-99 "Method of determination of steady-state thermal conductivity and thermal resistance". To implement this study, samples of structural and heat-insulating materials were collected during the construction process. The technique provides for laboratory testing of samples at a stationary heat flow regime. The actual thermophysical characteristics of materials are necessary to refine the design solutions and further build theoretical models of the thermal fields of the enclosing structures and spatial modeling of the distribution of heat fluxes of the experimental building.

4. Determination of air permeability of enclosing structures in natural conditions according to GOST 31167-2009 "Methods for determination of air permeability of building envelopes in field conditions". Purpose: to evaluate the generalized characteristics of the air permeability of the enclosures of the experimental buildings. The study of air permeability simultaneously with thermal imaging will increase the detail of the integrated assessment of the enclosing structures.

Along with the normative methods, it is planned to use the experimental method. The experimental method is based on a system for monitoring the parameters of the internal microclimate, environment and building structures, developed and implemented in buildings [13]. The main controlled parameters are temperature and humidity. During the construction of experimental buildings, a system of sensors [14, 15] was installed in the layers of structures. At the design stage, 25 key measurement points were identified (Figure 2): insulated roof and lower floor, in the walls of the building - at different heights, in the locations of various types of thermal insulation materials, as well as in the corners and near windows. In the measurement point, in each layer of the structure, from 8 to 9 sensors are installed (8 sensors for the frame part, 9 sensors for the log part). One measuring point is

installed on the frame rack to assess the state of the potential "cold bridge". Remote data transmission has been implemented to record data in real time.

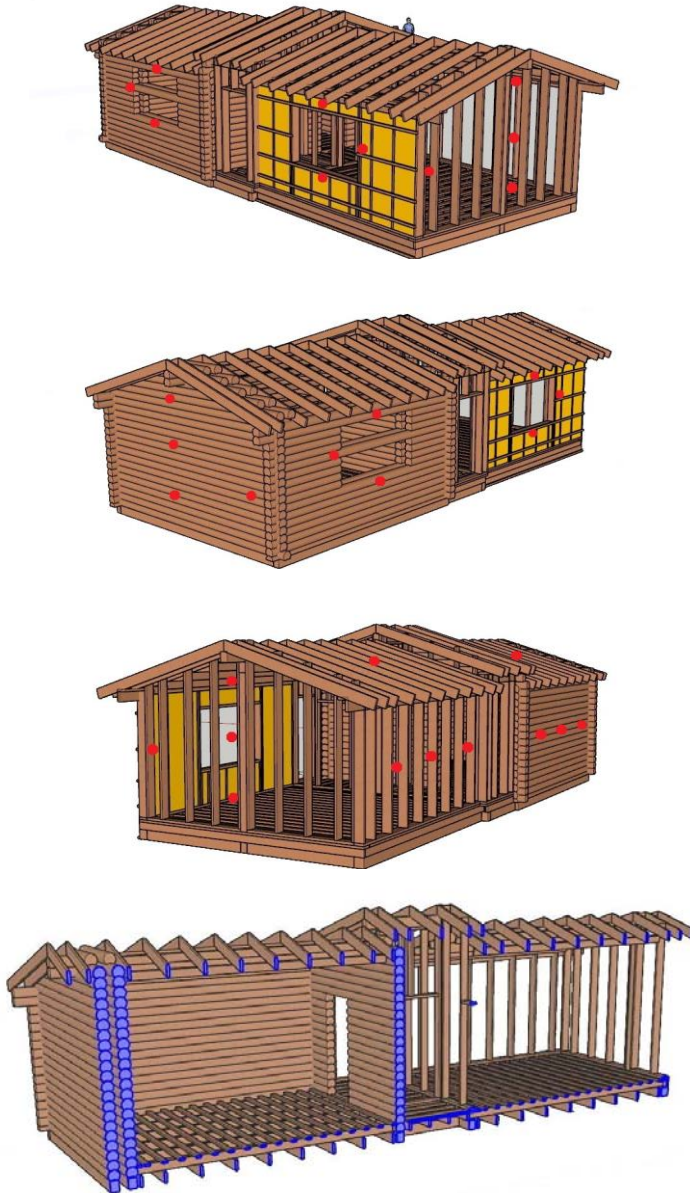


Fig. 2. Model of the experimental building (red dots indicate the location of sensors for measuring temperature and humidity).

Table 1. Design characteristics of structural and heat-insulating materials.

Material name	Material characteristics		
	δ , mm	ρ , kg / m ³	λ_B , W / m °C
Insulated roof			
ISOROC super warm	350	26	0,037
Insulated bottom floor			
ISOROC super warm	300	26	0,037
Frame walls			
Main insulation material			
ISOROC super warm	250	26	0,037
Additional thermal insulation materials			
Flaxan Briz, hemp and seaweed fiber	250	32-35	0,043
AKOTHERM FLAX, flax fiber	250	30	0,038
Cellulose wool, "ecowool"	250	35	0,039
Log walls			
Main construction material			
Wood	173 (average thickness for a log Ø 200 mm)	500	0,25
Main insulation material			
Wood shavings	126	80-120	0,06
Additional thermal insulation materials			
AKOTHERM FLAX, flax fiber	126	30	0,038
Air gap	126	1,2-1,27	0,24

3 Results

Taking into account the complex nature of the project, a structural and logical scheme of the study has been developed (Figure 3). The research includes three main stages. Time periods for the implementation of research: Stage 1 - January 2021 - March 2021, Stage 2 - October 2021 - March 2022, Stage 3 - 2022 2024. The time periods of the program are determined taking into account the need to carry out the main part of the experiments only in the winter.

At the first stage, an assessment of the influence of the constructive solutions of the enclosing structures on the heat-shielding characteristics and parameters of the internal

microclimate during stationary operation is made. Stationary conditions for conducting experiments are provided in accordance with sanitary and epidemiological requirements: air temperature - 22-24 ° C and air humidity - 40-60%.

The second stage of research involves taking into account the results obtained at the first stage. At the second stage of research, it is planned to conduct experiments with a changing regime of the internal microclimate of buildings. Such changes can be triggered by various operational situations, which include the following:

- Different modes of operation of the building (different modes of operation of the heating and ventilation system);
- Different requirements for the energy efficiency of the building (seasonal residence buildings, year-round residence buildings, temporary residence buildings);
- Accounting of technological processes in the building.

The third and subsequent stages of the research program are associated with assessing the impact of technologies and criteria for a "green" building applied at model facilities on the level of energy consumption and environmental safety. A separate stage of research will be devoted to the environmental parameters of the internal microclimate.

The experimental buildings completed in 2020 have a high enough potential for retrofitting and modernization. In the future, it is possible to replace individual structural elements and install additional elements, systems and equipment. Potential for consideration are automated building management systems (smart home systems), control and metering of electricity, alternative renewable energy sources. At subsequent stages, it is advisable to conduct research on the impact of these systems and equipment on the level of environmental friendliness, energy efficiency and comfort of the building.

4 Discussion

To create a building that meets "green" criteria throughout its lifecycle is a complex task. To solve such a problem, it is necessary to perform a complex of theoretical and field studies [16, 17, 18, 19, 20, 21, 22, 23, 24, 25]. Within the framework of the theoretical part, it is necessary to perform a theoretical justification and selection of the optimal system of criteria for determining the rating in the certification system, indicating that the building meets the "green" category. Field studies will reveal the real effect of the use of specific technologies and solutions. An integrated approach to solving the problem posed makes it possible for an objective and comprehensive assessment.

Much attention was paid to an attempt to solve such a complex task during the implementation of the international project "Green Building in the Arctic", funded under the Kolarctic cross-border cooperation program. The research involves studying the factors that influence the energy efficiency, indoor comfort and environmental safety of a wooden low-rise building on models built in two northern regions.

The study is based on the model objects discussed above - experimental buildings (Figure 2). Research on the basis of two laboratory buildings located in two northern regions can serve as the basis for solving the following tasks:

1. Life Cycle Assessment (LCA) of pilot buildings in Petrozavodsk and Murmansk. This study can be carried out taking into account the assessment of the carbon footprint of building materials and buildings at all stages - production of building materials, construction and operation of buildings. From the latest estimates [16, 17, 18] it follows that the use of wood is the most environmentally friendly.

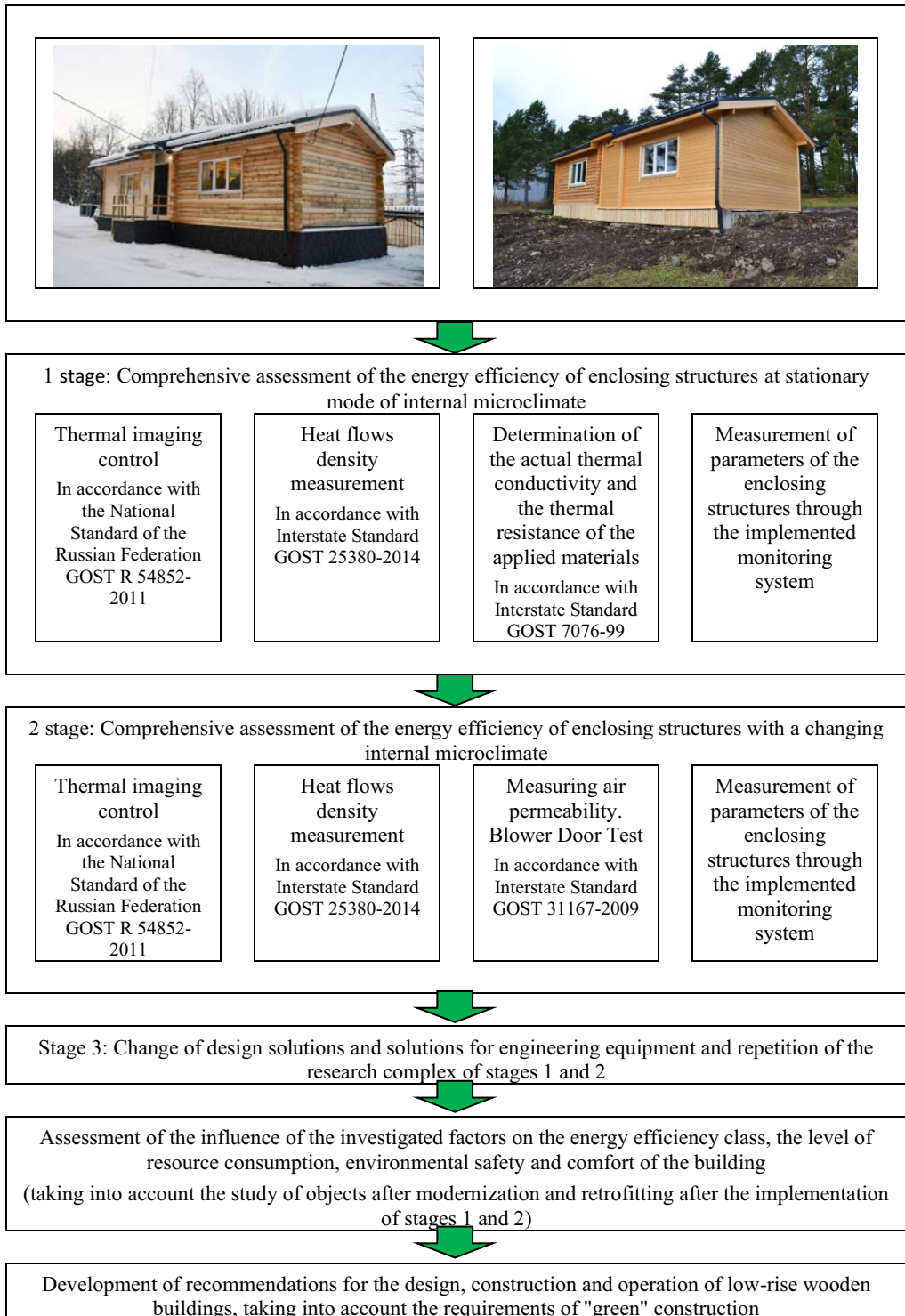


Fig. 3. Structural and logical scheme of the study.

2. Comparison of various structural and technological solutions of wooden structures at the stage of calculation and design (simulation, modeling) and at the stage of their actual operation in real conditions of different mathematical conditions. Field studies during the operation of buildings are especially interesting. The results of comparing the results of calculation and field measurements of the parameters of heat transfer and distribution of moisture in enclosing structures [19] are relevant.

3. Evaluation of the effectiveness of various thermal insulation materials during the operation of the building. The main emphasis is on the consideration of thermal insulation materials, which are positioned by the manufacturer as "green".

4. Development of models of real distribution of heat fluxes and humidity for individual sections of the enclosing structures and for the entire building on the basis of monitoring data during operation. Simulation results can be used to refine design calculations.

5. Comparison of costs for the construction and operation of buildings of different categories by the level of thermal protection and operation mode (temporary residence buildings (tourist facilities), seasonal residence, permanent residence). The results of such an assessment will make it possible to estimate in monetary terms the increase in the cost of improving thermal protection and the corresponding decrease in operating costs.

6. Comprehensive assessment of technical and economic parameters of energy systems taken into account in the design and identified during the operation of model buildings. The aim of the study is to analyze and compare the heat engineering and economic indicators of the energy systems of the two parts of the building, made in different design solutions, operated in different climatic conditions.

7. Assessment of the minimum required and sufficient capacity and efficiency of various options for engineering systems of buildings of different categories by the level of thermal protection and operating mode. The results of the assessment can become the basis for the selection of the optimal set of engineering equipment for specific conditions.

8. Investigation of the potential of a low-rise wooden building in improving the balance of heat transfer by automating the operation of all systems and processes occurring in the building (smart home systems) and its impact on increasing the level of energy efficiency, environmental friendliness and comfort in the building.

9. Assessment of errors and defects in design and construction, identification of "best practices" and development of recommendations for the design, construction and operation of low-rise wooden houses, taking into account the requirements of "green" construction.

5 Conclusions

As of February 2021, the following results were obtained.

The calculation and design of experimental buildings located in two northern territories - in the Murmansk region in the Republic of Karelia were performed. The choice of materials for buildings is made taking into account the criteria of "green" construction [10]. The use of a complex of engineering systems for engineering support of buildings has been substantiated [12].

A working hypothesis has been formulated about the degree of influence of each element of the building, as a system, on the energy efficiency class [11].

In 2020, the construction of two identical buildings in the city of Murmansk and in the city of Petrozavodsk was implemented [13].

A system for monitoring temperature and humidity [14, 15] has been developed, tested and is functioning in the premises and in the enclosing structures of the constructed facilities (Figure 2).

The urgency of the problem of cold bridges in enclosing structures has been confirmed [23]. To solve this problem, two variants of bearing and enclosing structures have been

proposed and implemented. The best of these options will be determined using the results of monitoring temperature and humidity in the constructed facilities (Figure 2).

In order to ensure the energy efficiency of the objects under study, the choice of heat recovery devices in the ventilation system of these objects is justified [12]. The efficiency of recuperation systems is assessed using the above-mentioned temperature and humidity monitoring system [14, 15] in constructed facilities, as well as taking into account the monitoring of energy consumption for heating these facilities.

A database has been created for the accumulation and analysis of data obtained as a result of the above monitoring [14, 15].

A detailed program for conducting a set of experiments for the first stage of research has been developed. At the first stage, an assessment is made of the impact of structural solutions of the enclosing structures on the heat-shielding characteristics and parameters of the internal microclimate in real operating conditions.

The results of the first stage were tested in reports at scientific conferences [11]. The approbation confirmed the feasibility and necessity of continuing research on the project in accordance with the developed structural and logical scheme (Figure 3).

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