

# Energy efficiency with the use of innovative materials in the Far North, using CAD

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**Abstract.** The relevance of this work lies primarily in the importance of this issue in the construction field. According to statistics, construction projects consume 40% of world energy. Industrial and residential buildings are becoming one of the main sources of thermal emissions of carbon dioxide into the atmosphere. The second argument in favor of relevance is the use of basalt composite reinforcement for brickwork. And the third argument can be the use of CAD to simulate the energy consumption of the building. The practical value of the work is to use the recommendations for the construction and reconstruction of energy efficient buildings located in the Arctic zone. The theoretical value of the developed model and the proposed technology for determining energy efficiency indicators will allow it to be used for further calculations.

## 1 Introduction

One of the priority directions of development of science and technology in the Russian Federation and not only is energy efficiency and energy saving. In modern architecture and construction, this can be achieved by improving architectural and planning solutions, the use of external building envelope structures with the necessary level of thermal protection, the introduction of effective systems to ensure microclimate and energy saving in buildings, the use of renewable energy sources, improving the quality of building design. Construction, being one of the most energy-intensive sectors of the economy, at the same time has great potential for the development and application of various energy-efficient solutions. From here such concepts as active and passive houses began to appear. Friess W. A., Wang W, Dodoo A. and others were engaged in the development of the energy concept of building design [1-6].

Bogoslovskiy V. N. [7] in their work developed the energy concept for the design of energy efficient buildings, Tabunshchikov Yu. a. [10], Savin V. K. [11], Gagarin V. G. [12], Anan'ev, A. I. [13], Yu. A. Matrosov [14], Gertis K. [15] and other scientists [16-22] have also devoted their work to the design of buildings with low energy consumption. Carlini [21] described in his article the economic evaluation of boilers on biomaterials for heating Italian residential buildings. The author argues that solid biomass, including wood and boilers on

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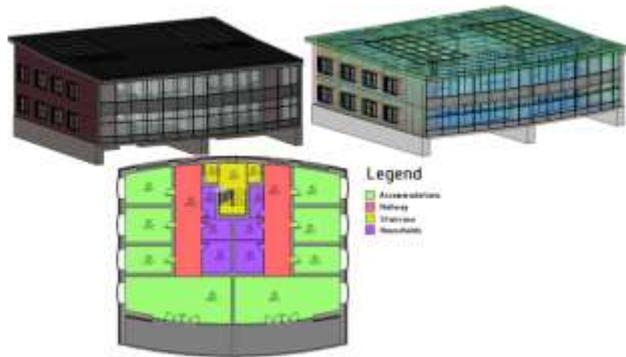
tablet fuels, can provide heat for heating the premises and heat the water in the house. They concluded that the installation of a biomaterial boiler provided economic benefits that would have been higher if a government subsidy had been offered. The review of heating on the basis of biomaterials was also presented by the authors in the article [22]. The authors stated that the use of biomaterials for heating should be considered in the early stages of building design. The study of heat production by boilers on biomaterial in residential buildings in Spain was described in article [23]. They also argued that the use of biomaterials could reduce primary non-renewable energy consumption in buildings by 93% and CO<sub>2</sub> emissions by 94%.

Article [24] reported on the introduction and expansion of the use of biomaterials in district heating systems. The authors stated that district heating meets about 60% of the demand for heat in buildings. The authors wrote about the design of district heating systems on biomass in the article [25]. The authors present a method of designing district heating systems on biomaterials using parametric logic, which helps an inexperienced engineer to design such systems. District heating of biomass in experimental facilities for public buildings was presented in article [26]. The authors propose a method of heating public buildings with district heating systems operating on biomaterials. They came to the conclusion that the gains to rural communities are important from the point of view of operating costs and environmental protection. Margaritis et al. [27] reported the introduction of renewable energy sources in the Central heating system of Greece. The authors stated that various district heating systems in Northern Greece use waste heat from brown power plants. However, these power plants are going to be closed in the coming years. They estimated that solid biomass available locally could be used instead of waste heat in existing district heating systems and that fuel replacement was cost-effective. Therefore, for the design of an energy-efficient building in any territory and with any climatic conditions, it is necessary to take into account the proximity of industrial enterprises, the waste of which can be useful and save a significant amount of energy for residents.

The authors of the article [28] reported on the use of excess heat in district heating systems. The authors noted that district heating systems have many economic and environmental advantages over individual heating systems. They also reported that excess heat could easily be used in the existing district heating system, depending on the available excess heat supply and its distance from heat demand. In [29] the authors explored the use of industrial waste heat for low-temperature district heating. The authors propose a holistic approach to the complex and efficient use of low-grade heat of industrial waste.

## **2 Methods**

The design of an energy-efficient house on the example of a two-storey residential building is presented.



**Fig. 1.** 3D, analytical model and zoning plan.

The main purpose of the work is to design an energy-efficient, environmentally friendly, comfortable for living building, as well as its energy analysis for compliance with the "Passivhaus" standard, taking into account the climatic features of the region of the proposed construction. The analysis of the building was performed using Autodesk Revit software and its extensions: Energy Analysis, Solar and Green Building Studio. In the course of the study the following tasks are solved: – Application of various architectural and planning, spatial solutions and analysis of their impact on energy consumption.

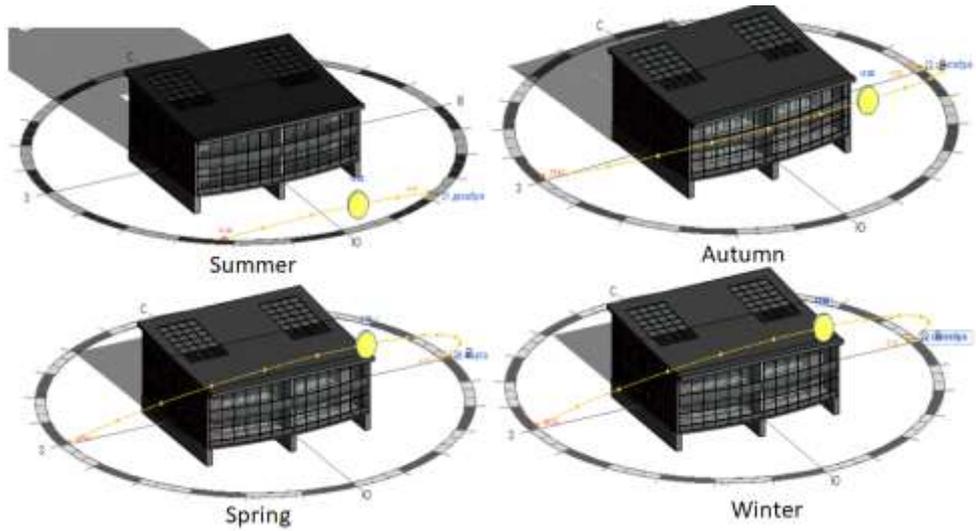
Using the special soft, determine the thickness of the insulation for this type of wall. It is equal to 41 mm. In the assortment, the thickness of mineral wool plates is a multiple of 10 mm, so we take the thickness of the insulation 50 mm.

As a tool, Autodesk Green Building Studio was used, according to which the energy parameters for the building variant adopted in the previously have the following values:



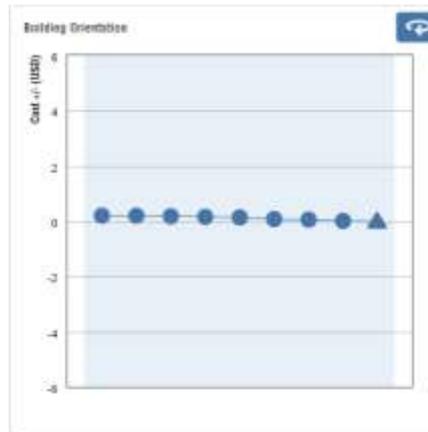
**Fig. 2.** Annual energy use.

For the analysis of the solar load was carried out a few calculations with different orientations of the building. Initial position - the most glazed facade is directed to the South.



**Fig. 3.** Light and shade analysis.

This option is the most effective, as confirmed by the program Green Building Studio. These calculations are shown in the diagram of the Insight program.



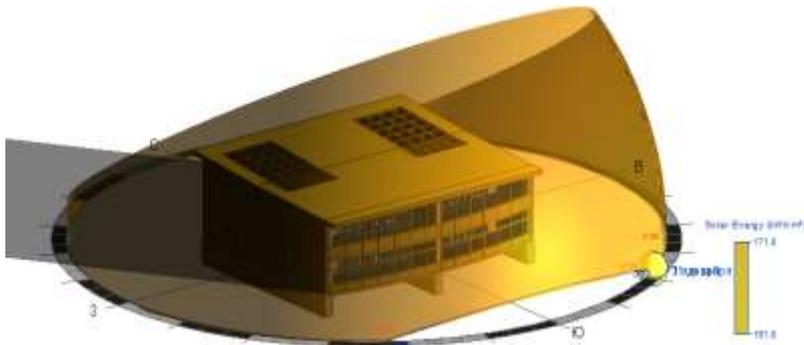
**Fig. 4.** Building orientation graph (triangle sign is our option).

The calculation showed that the attic floor is lit best in spring and winter, which positively affects the comfort of living, as well as reduces the cost of lighting and heating. In summer, projecting balconies block residential areas from excess solar radiation and, as a consequence, heating, which leads to additional costs for air conditioning. At the same time, the attic floor receives enough natural light, which reduces the cost of lighting.

Rational use of natural ventilation will reduce some energy costs, as can be seen in the figure 5. The reduction in the value of electric energy was 2 kWh/m<sup>2</sup> a year. In addition, a number of measures on the use of photovoltaic panels can significantly reduce energy. In this case, the value is 171 kWh/m<sup>2</sup> per year. This can be seen in figure 6.

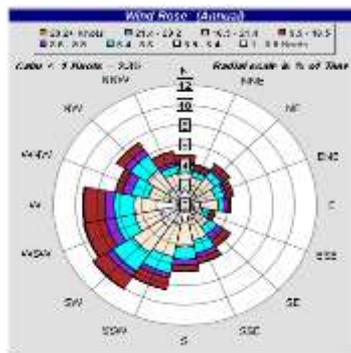


**Fig. 5.** Rational use of natural ventilation.



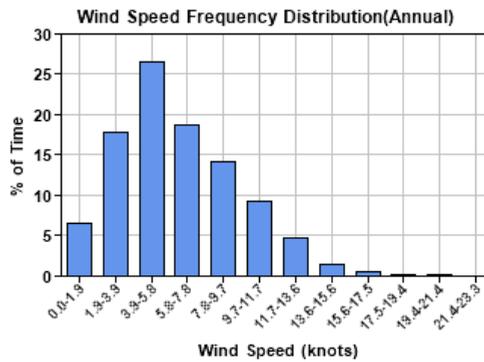
**Fig. 6.** Solar calculation output in Solar module for Autodesk Revit.

It is also necessary to take into account the high-speed wind flow and its direction. Figure 7 shows the wind rose, where the dominant direction is southwest at a speed of about 16.5 knots (30.5 km/h).



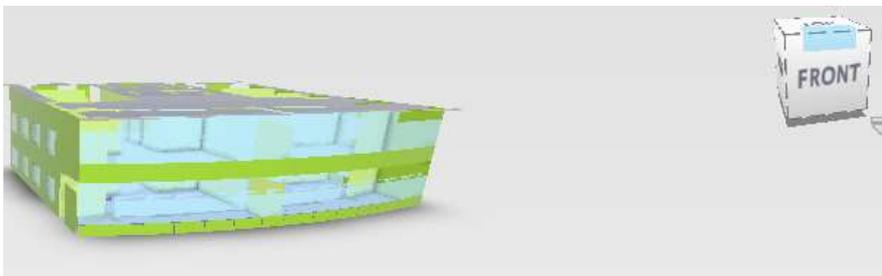
**Fig. 7.** Wind rose.

More frequent flows (25% of the total period) move at a speed of approximately 6 knots (11 km/h), as shown in the diagram shown in figure 8.



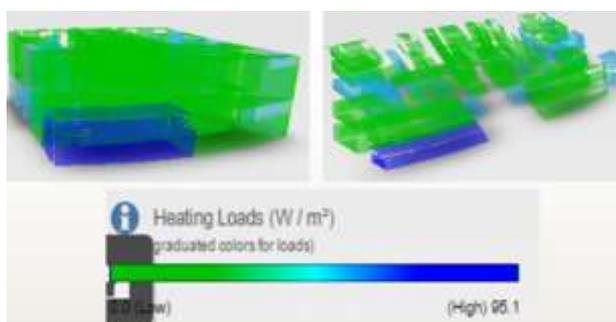
**Fig. 8.** Wind speed frequency.

The next step is to calculate the building on the influence of heating and cooling loads in the Insight program. Figure 10 shows the energy efficient model of the building in the Insight program, where the "FRONT" view is the southern most glazed facade.



**Fig. 9.** Image of an energy-efficient building model in Insight.

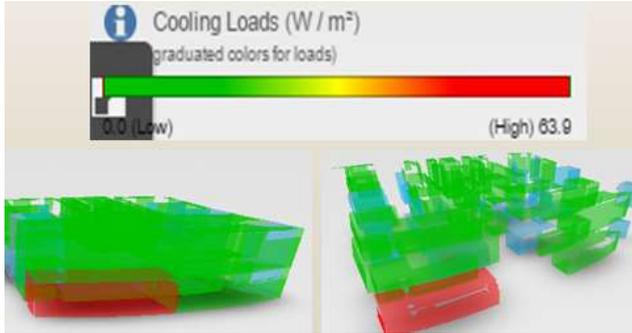
In figure 10 all the space-rooms are painted in the color corresponding to the heat load.



**Fig. 10.** Graph of heat load on the building.

Heating load is the amount of heat that must be transferred to the unit of time to the heating device, heating installation or heating line for heating the premises they serve. The thermal load is determined by the heat deficit obtained as a result of the thermal balance of the room air at the temperature of internal and external air, calculated for the design of heating of buildings in the area.

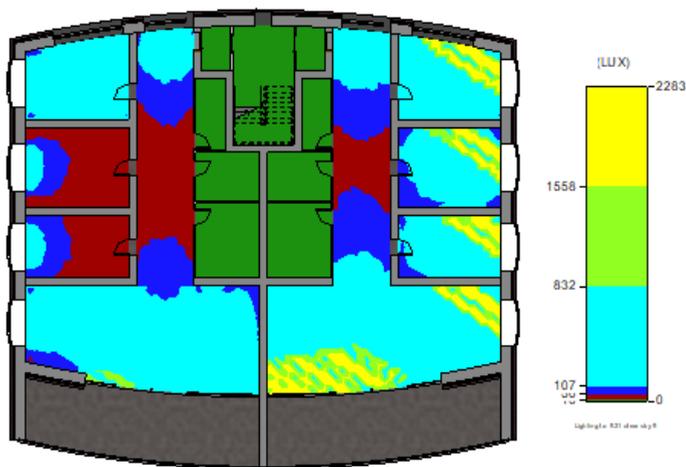
Thus, in order to heat this room, you need to spend 95.1 W/m<sup>2</sup> of heat. Further, similarly with the refrigeration load.



**Fig. 11.** Graph of cool load on the building.

Cooling load – the amount of energy that must be transferred per unit of time devices to cool their zones. To heat this room, you need to spend 63.9 V/m<sup>2</sup> of energy. The final result, it is advisable to provide this room with heating and cooling devices, using this calculation and taking into account the obtained numerical characteristics. The last step is to calculate the illumination of the premises by sunlight. In SNiP with regards to an apartment or a private house, it is written that the following lighting standards should be observed for the premises(including artificial lighting): bedroom and kitchen – 150 lux, hall and corridor – 50l, toilet, shower, bathroom – 50 lux.

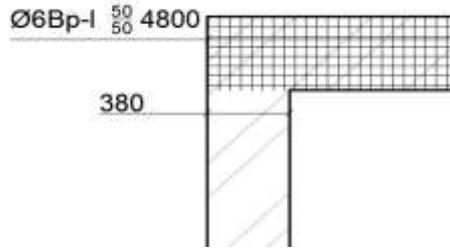
The light calculation is performed in the Lighting module of Revit and is shown in figure 12.



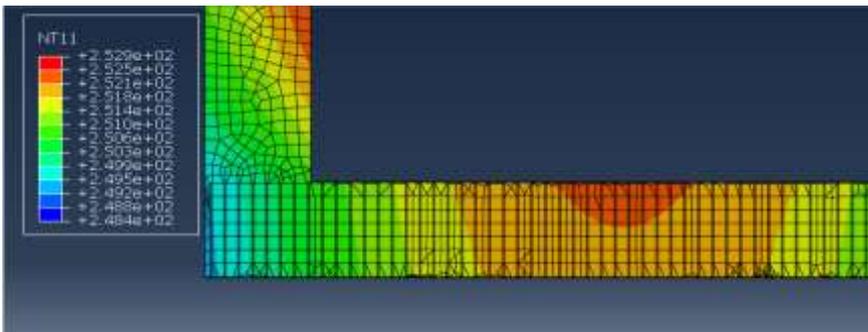
**Fig. 12.** Calculation output of lighting (blue – 50 lux, red – 107 lux).

For a residential building, the norm is performed even without artificial light, except for utility rooms and stairwells, which in the daytime allows you to save energy for lighting accommodation[7].

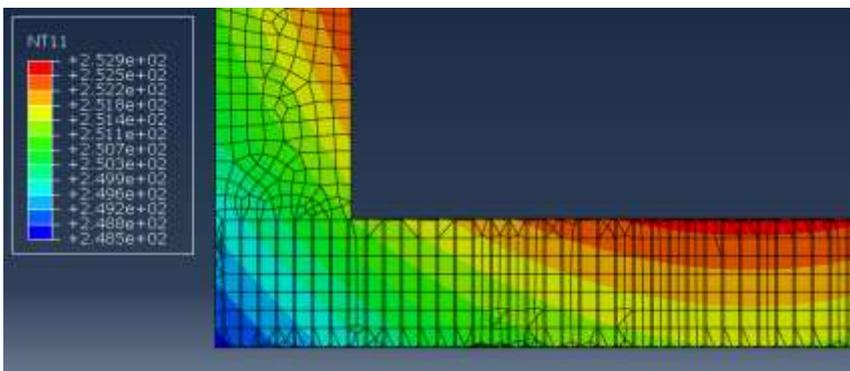
This section presents the calculation of the brick wall using reinforcing mesh of steel and basalt in the software package Simulia Abaqus 2017[8]. Figure 13 shows the wall unit with the layout of the reinforcement mesh.



**Fig. 13.** Brick wall node.



**Fig. 14.** The result of the calculation (the thermal conductivity brick is 0,6, 50.2 - steel).



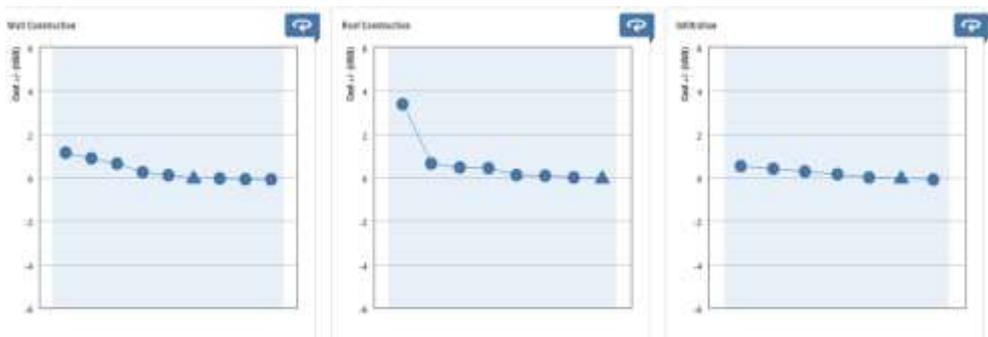
**Fig. 15.** The result of the calculation (the thermal conductivity brick is 0,6, 1,5 - basalt).

The figures show that the size of the cold bypass in the inner corner of the wall reinforced with basalt mesh is smaller than that of the wall with steel mesh (figures 14, 15). Thus, the use of composite reinforcement not only increases the strength of the reinforced structure, but also reduces the energy for heating, which is also positive for the energy efficiency of the

designed house. This decision does not greatly affect the value of energy consumption, although the graph shows how the distribution of temperature on the brick wall.

## 4 Results and Discussion

After a number of changes, based on the analysis of various energy efficiency indicators through the prism of Autodesk Green Building Studio, the following result is obtained: the Intensity of energy use (heating costs, hot water and electricity) – 691.4 MJ/m<sup>2</sup> /year, or (if you take 1 kWh = 3.6 MJ) 192 kWh/m<sup>2</sup> /year. We also used a number of measures that reduce the value obtained: using of photovoltaic panels - 171 kWh/m<sup>2</sup> per year, the use of natural ventilation – 2 kWh/m<sup>2</sup> per year. Total we obtain that the specific value of the annual energy consumption of 19 kWh/m<sup>2</sup>, which corresponds to the required value of the standard "Passivhaus". Also on the schemes obtained through the service Autodesk Green Building Studio, it is clear that the selection of structures of walls, roofs and infiltration system is rational. The diagrams are shown in figure 16.



**Fig. 16.** Rational use of wall, roof and infiltration.

## 5 Conclusions

The paper reviews the experience of energy-efficient houses and designed a house that meets the requirements of a passive house in the far North. Thus, it is possible to identify the main ways to solve the problem for the construction of a building that meets the standards of a passive house:

- Supply and exhaust ventilation of premises with heat recovery;
- Placement of glazing that meets good thermal insulation and tightness criteria, mainly on the southern façades;
- Use of renewable energy sources and special equipment for energy storage;
- The compactness of the building by refraining from excessive irregularity of the façade and reducing the area of external walling;
- Rational orientation of the building to the cardinal points with the location of residential areas on the South side and buffer compartments on the North;
- Basalt reinforcing meshes were used as reinforcement to reinforce masonry, which increased the strength of the walls;
- Offered the options of home designs and their impact on energy efficiency.

I would like to note that such good performance can be achieved largely "passive" way, that is, due to good absorption, accumulation and preservation of heat, as a result of the

correct architectural design of the building. Properly selected and installed engineering equipment, working at the expense of alternative energy sources, saves additional energy, and, importantly, significantly reduces the operating costs of the building and the amount of emissions affecting the environment. Knowing and observing the rules of designing a passive house, you can achieve a reasonable balance between losses and heat flows into the building, which will have good performance of the microclimate in the premises and have low costs for its own construction and operation. In addition, a number of structural measures were used to reduce the cost of maintenance of the house, such as the use of basalt reinforcing nets for reinforcement of brickwork. The use of this solution does not significantly affect the energy consumption of the building, but has affected the temperature distribution in the wall, as seen in figures 15 and 16, where the high temperature zone is much larger in the wall using composite reinforcement than with steel. Energy-saving options such as:

- the location of the building on the sides of the world with an iteration of 45 degrees, where
- the optimal rotation was chosen 0 degrees, were considered;
- the construction of walls, slabs, roofs, windows, doors, etc.;
- the location of the solar panels on the roof;
- the selection of HWAC devices ;
- installation of the equipment for regulation of lighting;
- the location and size of windows and skylights.

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