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Concept Project of Zero Energy Building

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Abstract

The acute problem of carbon dioxide emissions reduction into the atmosphere becomes more important due to the fact of the global climate change. Housing stock consumes 30 to 40% of all energy resources, according to various estimates. As the result, it is possible to get carbon dioxide atmosphere emissions reduction due to energy consumption reduction. The problem of housing stock energy efficiency improvement becomes very important. Transition to low energy consumption buildings construction becomes a trend which in the nearest future will transform to the task of Applied Research in the field of design and construction. Such exploration object is to design buildings with zero energy consumption or close, which is planned construct on the site of the Polytechnic University. The novelty of the project consists in an integrated approach of the house design, which will be entirely autonomous and independent from the urban networks.

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1. Introduction

Currently, there is almost no doubt about the processes of global warming on Earth in the scientific community [1-5] Partly, this is confirmed, including changes in regulatory documentation. So in an updated version of the standard building climatology (SP 131.13330) compared with the previous edition of this standard (SNIP 23-01-99*) for a large number of settlements, including Moscow and St. Petersburg, the calculated parameters of the climate were revised upwards the design temperature of outer air and decrease the duration of the heating season [6].

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In the history of our planet periodically climate change has happened before but for the first time these changes associated with human activities [7-12]. Carbon dioxide (CO_2) that is emitted during the combustion of fossil fuels changes the composition of our atmosphere. The uncontrolled use of fossil energy leads to the depletion of world reserves of non-renewable energy sources.

The area, where it is possible to reduce the consumption of fuel and, consequently, energy consumption and emissions into the atmosphere, is the housing stock, which according to various estimates consumes 30 to 40 % of all energy [13-15]. It is enough to increase regulatory requirements for insulation levels [16], to improve the degree of building automation when adjusting the parameters of the coolant that enter the building, to install systems heat recovery of exhaust air [17] and a more efficient heating system.

In the future, to reduce emissions of carbon dioxide in the atmosphere of the planet and protecting the environment, mankind will be forced to do a lot less energy for heating than it uses it still. If we add to this that the stocks of non-renewable energy resources are finite, it should be recognized that the main characteristic of the future buildings is ultra-low energy consumption and even energy consumption close to zero. While the existing old buildings spent from 200 to 400 kWh/(m^2·year) thermal energy for heating, the need for heating energy for buildings of the future generation will be from 20 to 50 kWh/m^2. And many countries establish similar standards of energy consumption [18].

2. First experience in the construction of buildings with low energy consumption

The German scholar Wolfgang Feist from the Institut für Wohnen und Umwelt GmbH and the Swedish Professor Bo Adamson of Lund University are the first who proposed the concept of building energy passive houses [19].

In 1990, in Germany, in Darmstadt, the first house was constructed, it gave rise to the development of new technology in the construction of energy-passive houses. The experiment was a success, and to conduct further research, the Passivhaus Institut was founded by Dr. Fastom in Darmstadt in 1996 [20]. For 17 years of the Institute working approximately 15 thousand buildings has been constructed that correspond the definition of a passive house [21].

3. Actuality of research

Developments in the field of energy saving and increase of energy efficiency of buildings in our country are carried out, both at the Federal and at the regional level. Among prominent experts in this field should be allocated Averyanov V.K., Vasilev G.P., Lichman V.A., Sokolov N.A., Livchac V.I. and many others.

The programs and guidance documents has been also developed at the regional level. There is developed regional methodological document (hereinafter - RMD) "Guidelines on energy efficiency of residential and public buildings" in St. Petersburg by construction Committee in conjunction with the relevant research and educational organizations [22] in which the basic architectural, spatial, urban planning, design and engineering activities aimed at comprehensive energy savings [23].

However, construction of building with ultra-low power consumption, passive consumption (type Passive House) or energy consumption close to zero is undeveloped in Russia. There are several objects with low power consumption in this country, for example energy efficient home that has built in Moscow, district Nikulino-2, and the "Green" house that has built near Moscow. These buildings' the annual level of energy intensity is about 50 kWh/(m^2 ·year) [24].

4. Prospects for the construction of a building with low energy consumption in Russia

Most of the existing Russian buildings have low energy efficiency according to European standards. This occurs because of three main factors:

- colder climatic conditions in comparison with most European countries
- lower regulatory requirements to the level of thermal insulation of building envelopes

- lower regulatory requirements to the level of consumption of thermal energy in buildings

Energy intensity of two identical buildings in different climatic zones, may differ significantly from each other because of differences of degree-days of heating season. For most Russian's cities the climate is colder in comparison with Western European neighbors.

To compensate for additional losses caused by climatic conditions of our country, it would be appropriate to assume the necessity of introducing higher regulatory requirements for thermal insulation or heat recovery of exhaust air. But in this respect we are lagging behind our Western neighbors, for example, from the Scandinavian countries. Under similar climatic conditions regulatory requirements for insulation levels in Finland are in 2.5-3 times higher than in the North-West region of the Russian Federation. [25]

A restrain factor is also the prevailing belief about the high cost of energy-efficient houses' construction. Calculations show that the cost of 1 m^2 energy efficient building only 8-10% higher than average cost of standard building. Additional costs are paid back within 10-20 years due to the reduction of operating costs, for example, by reducing heat loss through the external walls [26, 27].

The analysis of domestic and foreign information, design experience, construction and operation demonstrates the technical ability and economic efficiency of energy-efficient buildings' construction. The maximum power-saving effect can be achieved by an integrated assessment of urban planning, space planning, engineering, design solutions and using of engineering power systems [28].

5. The object of the research

The object of this research is the design of a building with energy consumption close to zero that is planned to be built on the Polytechnic University territory [29, 30]. After facility commissioning, the building will be the laboratory for energy-saving and innovative technologies in construction. During the operational phase there will be energy monitoring of buildings, evaluation of walling's thermophysical characteristics, determining the actual values of energy consumption. For this building will be equipped with modern measuring complexes and systems.

6. Architectural and space solutions

Space planning and design decisions have a significant impact on the energy consumption of the building. The selection of the optimal form of the building, its orientation, location, purpose of the area light openings, control filtration processes reduce the negative heat effects of outdoor climate on the thermal balance of the building.

For construction of ZEB on the territory of the Polytechnic University was chosen a bad location. Constructible surface located in a corner formed by two adjacent buildings and two-storey outbuilding of hydraulics laboratory (Fig.1). Because of this insolation areas of the future building will be largely reduced.

With a view to determine the optimal orientation of the building to maximize the possibility of using daily insolation of the designed object and thereby reducing the cost of lighting in daytime operation, in the period from 1st December 2013 to 31st January 2014 was determined the level of illumination of the area in place of the proposed construction on eight bearing angles. It turned out that the maximum facades' illumination of daylight will be observed when the orientation of the facades focuses on building of the laboratory (№ 3). With this in mind we selected following the architectural concept (Fig.2), wherein the main area of translucent structures was oriented to the direction of facades' maximum illumination. On the second floor in the area of maximum facades' illumination, was formed main workspace. The second floor is an open space area with good viewing space of the first floor to further control equipment located here. This occupancy of premises is achieved by using of "sky light".

The building consists of two overlapping squares in plan. This decision was made because of the need for a vestibule at the entrance - first, and for additional translucent structures on the first floor of the building - second.

There is the wooden pergola with climbing plants in the North-Western façade. Stained glass is above it. In the summer pergola will cast a natural shadow and serve as a gazebo. Pent roof allows reducing the impact of thermal bypasses in the coating composition.

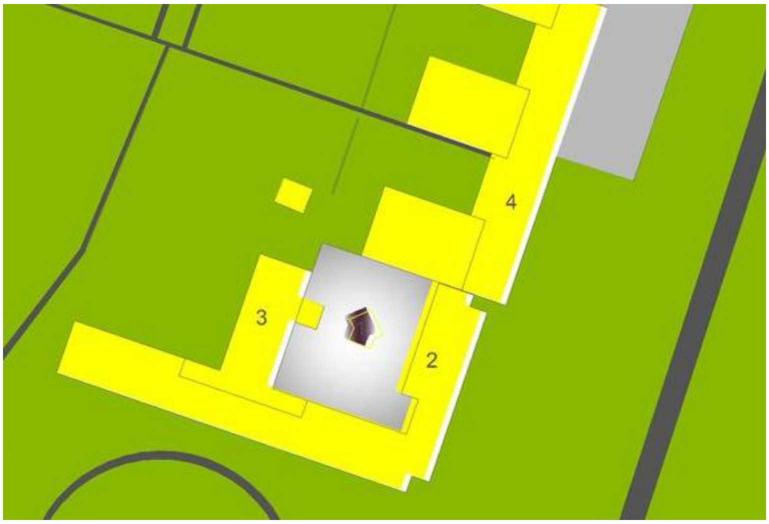

Fig. 1. ZEB on constructible surface: 1 – ZEB; 2 – hydrotechnical building; 3 – hydraulics laboratory; 4 - hydrotechnical building –II.

Fig. 2. The architectural concept of the building with low energy consumption.

Also there are provided the following architectural techniques that allow improving the energy efficiency of the building:

- maximum glazing of the North-West facades and dead walls in low-light scenes directions (according to measurements)
- reduction of the building envelopes' area by decreasing the perimeter of the exterior walls

This has become possible by avoiding frills of the facade, projections, notch and other architectural "openings".

Thus, it was chosen the optimal shape of the building that is characterized by a low coefficient of compactness and provided minimal heat losses in winter and minimum heat gains in summer. The building is designed in a contemporary style with modern elements. This is attempt to repeat the style of "Hawk's house" that has designed by American architect Jeff Kovel [31]. This architecture is harmoniously integrated into the urban planning situation.

There was developed the landscaping plan for this project. The main axial line is passing through the building, will fit into the basic concept of the Polytechnic campus that is an historical structure. Special attention is paid to planting greenery, which should provide the necessary level of absorption and support healthy ecological environment.

7. Constructive solutions, insulation

The basic requirements for structural parts of the building are the following:

- high level of thermal insulation of building envelopes (with a coefficient of heat transfer U: walls - no more than 0,09 W/(m^2·K), the coating is not more than 0.07 W/(m^2·K), the floor is not more than 0,09 W/(m^2·K);
- maximum the exception of thermal bypasses in the nodes and the abutting joins of selected design solutions;
- installation of translucent cladding structures with low-e coated glass (with a coefficient of heat transfer $U \leq 1$ W/ m^2·K)
- high air tightness of building envelopes
- reliable insulation system, ensuring the caulking of butt joints and seams enclosing structures and components during the lifetime of the building (over 30 years)

Frame design scheme based on the LVL beams is accepted for our building.

As the insulation for exterior opaque enclosing structures are adopted articles of isocyanate plastics with a thermal conductivity not higher than 0.023 W/(m^2·K) and diffusion-tight layer, which provides airtightness of the outer shell [32]. In figures 5-7 schematically are presented constructive solutions for walls (Fig.3), slab roof (Fig.4), floors (Fig.7) of the designed building

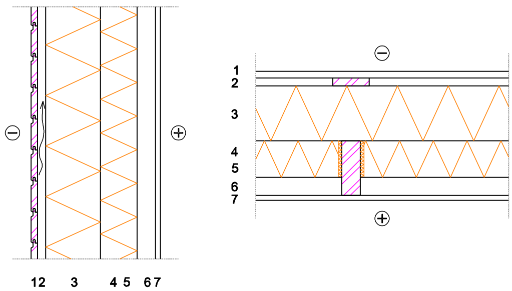

Fig. 3. ZEB wall composition: 1 – gel coating; 2 –ventilated gap; 3 – slab SPU AL 150 mm; 4 – slab SPU AL 100 mm; 5 – rack wooden frame; 6 –space for laying of engineering communications; 7 –interior finishing layer.

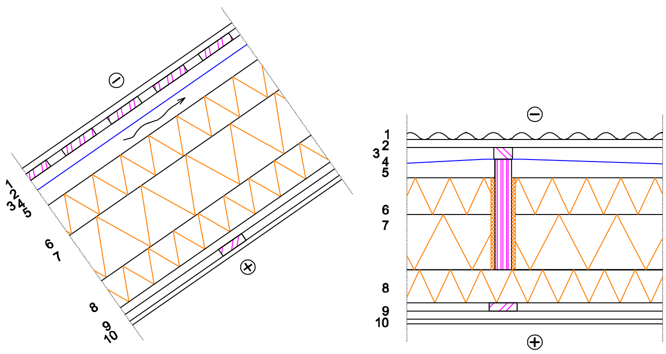

Fig. 4. Section of ZEB's slab roof: 1 – roof cladding; 2 –solid deck; 3 – wood roll; 4 – anti-condensation membrane; 5 – ventilated gap ≥ 50 mm; 6 – ceiling supporting truss; 7 – slabs SPU AL 150+100 mm (the outer layer); 8 – slabs SPU AL 40 mm (internal continuous layer); 9 –space for laying of engineering communications; 10 – interior finishing layer .

The gaps of 10-15 mm between the frame members (ceiling supporting truss in the roof structure) and isocyanate plastics insulation slabs are filled one-component of isocyanate plastics. The insulation is made in two layers. One layer of insulation is continuous, the joints of the slabs also are filled with isocyanate plastics. Adopted a constructive solution on the one hand provides the required tightness of the shell, with other addresses through thermal bypasses, which in this case are the frame uprights (of external walls) and ceiling supporting truss (cover design) of building.

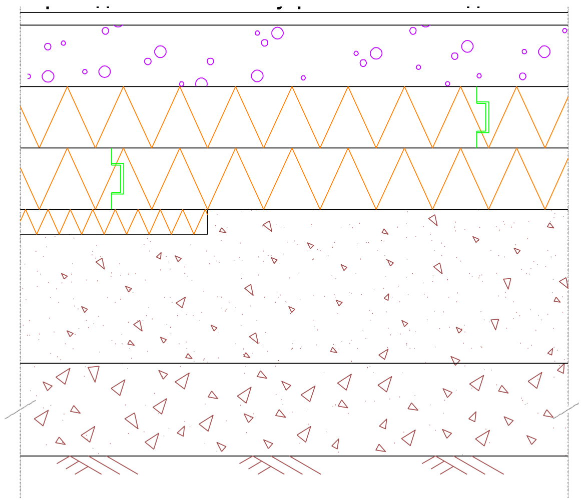

Fig. 5. Section ZEB's floor: 1 – flooring; 2 – floor cement screed; 3 – slabs SPU AL 100 + 100 mm; 4 – slabs SPU AL 40; 5 – foundation slab; 6 – pebble dash .

In solution that is presented in figure 5, additional layer is arranged of insulation thickness 40 mm in the rim zone around the perimeter of the building. It's device is due to the fact that heat loss are highest in the rim zone of the building compared to the inner part of the floor. This is because of the temperature of the ground increases from the edge of the building to the central part. The width of the rim zone with additional insulation around the perimeter of the building should be 1 meter.

8. Optimization of technical solutions engineering systems

Design solutions should provide control and monitoring of equipment within an integrated environment with the use of modern solutions in the field of information technology, automation, digital audio and video systems and engineering equipment.

Building systems that must be integrated into a single system management and monitoring:

- heating
- ventilation
- air conditioning
- heat supply
- power supply
- lighting, including automatic and automated control of lighting
- fire protection
- video surveillance
- telecommunications (telephone, LAN building with access to a global network, television)

The reliability of the system is achieved by a complex of organizational and technical measures which ensure resource availability, manageability, and serviceability.

Organizational measures to ensure the reliability aimed at minimizing the errors of the stuff of operating and carrying out maintenance work of complex technical means of the systems, minimizing the time of repair or replacement of failed components.

The project provides distribution control devices (switches, knobs) that allows users to manage in-house systems, to receive emergency and informational messages

9. Heat supply

As heating sources project should provide alternative (ground heat pump - schematic diagram is presented in Fig.6).

The temperature control of the coolant should be in accordance with the temperature schedule, depending on the outside temperature. Circulation pumps of heating systems and heat supply are provided with the frequency control.

Control and monitoring of the heating system includes on:

- remote data transmission
- the ability to remotely change the settings of the heating system (setting modes, time programs and curves of heating)
- quick and detailed information about the occurred fault in the form of emails or SMS messages (notification code fault)

There are has the metering of thermal energy in the building. In cases achieving the minimum desired temperature of the internal air in the building staff should be notified.

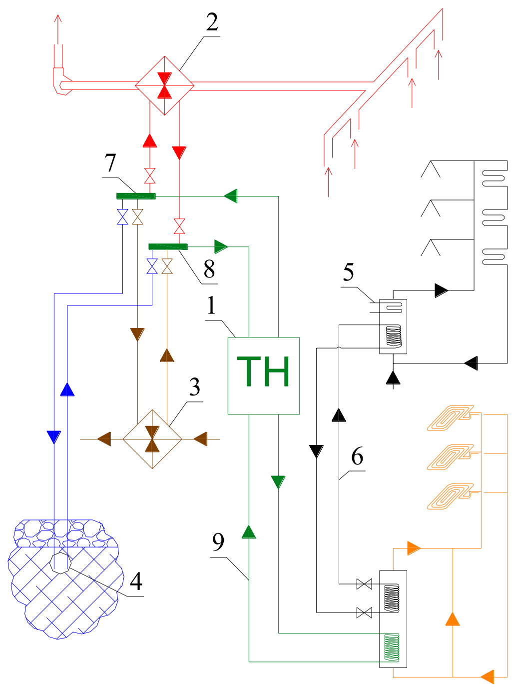

Fig. 6. Schematic diagram of (excess) heat pump system [22]: 1 – heat pump; 2, 3, 4 – heat exchangers of heat collection (remove the ventilation air, relatively clean wastewater, soil); 5 – backup heat source (heater) DHW; 6 – intermediate DHW circuit; 7, 8 – collectors (combs) of the first circuit heat pump system; 9 – second circuit heat pump system.

10. Ventilation system

The project provides the scheme with a regulated air supply and exhaust mechanical ventilation with heat recovery of the ground and the exhaust air (Fig.7).

The ventilation system is equipped with sensors CO^2 (carbon dioxide) and RH (humidity) inside air in the premises of the building.

The ventilation rate in the working time in the presence of staff is provided in the amount of: 0,5÷1 h-1.

In the winter time if necessary extra fresh air to tint=18-19°C as the heat source should be used the carrier geothermal heat pump systems (heat-insulated floors).

Fig. 7. Schematic diagram of ventilation systems with geothermal heat pump.

11. Conditioning system

The air conditioning system of the building during the warm period of operation must be combined with the scheme of ventilation is presented in Figure 10 (to give heat in summer mode of operation back into the soil)

The air-conditioning system should meet the following requirements:

- the low power consumption
- the high reliability
- the ease of management

12. Conclusion

We have produced a series of studies. It corresponds to identifying and practical application of a body of architectural and planning solutions to reduce the heat loss through the building of the building envelope.

The following architectural techniques were suggested in order to improve the energy efficiency of the designed building, which are the subject of this current study:

- the optimal building orientation to the side of light with the prevailing wind direction during the winter in order to neutralize the negative impact of climate change on the building and thermal balance
- maximum glazing northwestern facades and blank walls on the low-light scenes sides of the light (according to the results of measurements)
- the form of the building is characterized by a reduced coefficient of compactness. This goal has been achieved by reducing the area of external walling by eliminating irregularity facade projections, the West and other "architectural openings."
- the presence of the vestibule at the entrance, this avoids the additional heat loss

- pent roof on a low-light side would contribute to reducing of the number of cold bridges

The construction tendency with application of the technologies directed on increasing of power efficiency of buildings is proved to be one of the most crucial nowadays. The choice for decreasing of energy loss is dictated not only by their rise in price, but also for the purpose of maintaining of the healthy ecological environment as well as preservation of recourses of our planet for future generations.

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