Conceptual framework for implementing energy-efficient technologies into construction

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Abstract. The energy problem is becoming global every year. The reason for this is the growth of the world's population and the intensive development of technologies, which causes a constantly growing level of energy consumption. The construction industry is the largest sector of final energy consumption, accounting for a higher share of consumption than in industries such as industry and transport. The relevance and versatility of the problem of improving the efficiency of energy-efficient technologies in construction determines the need to improve the methodological foundations of the mechanism for managing production and economic processes for the introduction of energy-efficient technologies. Improvement and implementation of current methodological foundations and principles will form a systematic approach to the issue of mass use of energy efficient technologies in construction.

The reduction of natural energy reserves leads to the problem of energy saving. The solution to this problem is directly correlated with an increase in the use of energy-efficient technologies in construction, since the construction industry is the largest sector of final energy consumption, which accounts for a higher share of consumption than in industries such as industry and transport. Based on this, one of the main tasks of today is to find the most effective measures to maintain a modern and comfortable living of citizens, ensuring the rational use of energy resources and increasing the energy efficiency of buildings.

Currently, most of the utility costs are spent on heating buildings and structures and account for more than 60% of the total cost structure. However, the use of energy efficiency technologies will provide an opportunity to reduce the costs of the federal and municipal budgets to 100-150 billion rubles [1]. Despite the possibility of achieving sufficiently high indicators of economic and environmental efficiency, energy efficiency technologies in Russia are still not fully developed. From the Russian Federation development of energy-efficiency technologies are supported through development of regulatory documents, codes of practice etc. However, these measures are not sufficient to pilot projects of energy-efficient houses have become a real energy-efficient buildings, which is a collection of architectural planning, design, engineering solutions, and is aimed at reducing the buildings consumption of energy resources without losing their reliability and comfort.

In the process of developing energy-efficient technologies, the term "energy efficiency" has changed and expanded the boundaries of its influence on the construction industry. Due to the fact that energy efficiency technologies include the use of not only thermal energy, but also the use of other types of energy resources and energy, it is necessary to give a more precise definition of this concept. As the
definition of energy-efficient buildings shows, it is a fairly broad concept that includes a large number of methods aimed at minimizing energy costs and saving resources [2].

Issues of energy efficiency and energy saving are now relevant not only in the regions of Russia, but also in all countries of the world. Construction companies that are focused on the future and aimed at creating competitive advantages are moving to a higher quality level of construction by using energy-efficient technologies. Buildings of the present and future must demonstrate a rational approach to the use of energy resources, including respect for the environment, while maintaining the comfort of the consumer’s stay in it.

Due to rapid urbanization and industrialization, the demand for energy is growing very strongly. New construction and renovation methods can minimize energy consumption by using more efficient construction methods. However, it is necessary to develop a regulatory framework to facilitate energy decision-making, along with indicators of the life cycle of the deployed technology. The prospects for energy-efficient buildings are to improve the quality of energy services provided, such as lighting, and to ensure minimum economic and environmental costs. Adopting an environmentally sustainable energy efficiency ideology will provide tremendous energy and cost savings in the use and consumption of resources.

Despite the high importance of using energy-efficient technologies, there is no methodological support for the life cycle of energy-efficient buildings. Currently, most of the regulatory documents in the construction industry are Advisory in nature [3,4]. They are not able to clearly regulate the use of energy-efficient technologies in the construction of low-rise buildings. Based on this, we will define the main organizational aspects and regulatory documents for the design, construction and operation of energy-efficient low-rise buildings (table 1).

Table 1. Organizational aspects and regulatory documents for the design, construction and operation of energy-efficient buildings

| Stage of life cycle | Organizational aspect | Normative document |
|---------------------|------------------------|--------------------|
| **Designing**       | Selection of materials, structures, and equipment that can reduce energy costs | Letter from the state committee for construction of the Russian Federation № NK-5607/6 from 10.09.2003. |
|                     | Conduct monitoring of compliance with regulatory requirements for energy savings in the project | Resolution Government of the Russian Federation № 87 from 16.02.2008 |
|                     | Ensuring the availability of devices in the project accounting and regulation of main energy carriers | Resolution Government of the Russian Federation № 235 from 13.04.2010 |
|                     | Availability of the "Energy efficiency" section in the project documentation | Order of the ministry of economic development of the Russian Federation № 229 from 4.06.2010 [5] |
|                     | Filling in the energy passport of the building at each stage of the project | Order of the ministry of regional development № 262 from may 28, 2010 |
|                     | Determining the energy efficiency class of buildings | Resolution Government of the Russian Federation № 318 from 25.04.2011 |
Construction | Certification of the construction production process to obtain the projected energy efficiency indicators  
| Conducting internal supervision of construction process and control of energy efficiency indicators  
| Delivery of the object in accordance with the projected indicators energy efficiency  

| Operation | Filling in the energy passport (repeatedly)  
| Ensuring constant monitoring of specific heat energy consumption indicators for heating and ventilation of the building  
| Conducting periodic and unscheduled surveys buildings and their engineering systems  
| Conducting periodic energy audits building and indications of metering devices of energy resources  

|   | Law № 190-FL of 29.12.2004  
|   | Law № 261-FL from 23.11.2009 [6]  
|   | Resolution Government of the Russian Federation  
|   | Order of the ministry of regional development № 262 from 28.05.2010  
|   | Order of the ministry of energy of Russia № 182 from 19.04.2010  
|   | Resolution of the government of the Russian Federation № 19 from 25.01.2011  

As the table shows, in order to increase the energy efficiency of buildings, the life cycle processes must be organized in such a way that a high level of energy efficiency is achieved at each stage of the life cycle. Based on this, it is appropriate to develop and implement a methodology for organizing the life cycle of energy-efficient buildings, together with the use of a systematic approach and international standards ISO 14001, ISO 9001 and ISO 50001 [7].

Experience in implementing building construction projects using energy-efficient technologies shows that at the stage of planning and designing a new facility, the potential for energy saving is higher, and investment costs are significantly lower than when implementing measures to improve the energy efficiency of the facility during operation [8] (Picture 1).

![Picture 1. The ratio of the level of energy saving potential and investment volumes at the design and operation stages](image-url)
Based on the data in table 1, we will design a conceptual diagram of the building life cycle processes using energy-efficient technologies (Picture 2).

**Picture 2.** Conceptual diagram of the life cycle processes of low-rise buildings using energy-efficient technologies

Thus, the process of organizing the life cycle of an energy-efficient building will not only achieve a high level of implementation of energy-efficient technologies, but also allow:
- determine the logical relationship between the stages of design, construction, operation, reconstruction, and decommissioning;
- determine the energy efficiency of each stage of the life cycle;
- develop estimates of energy efficiency of buildings depending on the stage of the life cycle;
- determine the timing of current and major repairs of buildings, taking into account the loss of energy resources due to wear and tear of materials and structures.

Based on the life cycle of energy-efficient buildings, it is necessary to form current principles for the use of energy-efficient technologies in low-rise construction. The principles take into account a systematic approach to construction, the specifics and requirements of energy efficiency (Picture 3).
1. Functional and system principle of energy efficiency of buildings
The system-forming factor is the specific result (target function) of the system functioning [9]. It is the result—the achievement of the required level of energy efficiency by buildings is a system-forming factor in the construction industry and requires a reorientation of many organizational, technological and managerial decisions.

2. Probabilistic and statistical principle of energy efficiency
Application of probabilistic models in which the variables considered (energy consumption, thermal protection, etc.) are random variables. At the same time, the value of the target function is expressed by statistical distributions that are in stochastic dependence on all statistical distributions of the system parameter values [10, 11].

3. Simulation-modeling principle of energy efficiency of buildings
The principle is to study complex systems using mathematical modeling methods. It is relevant for energy-efficient buildings, as the systems of design, construction and operation of energy-efficient buildings, of course, belong to the class of the most complex systems, both in their structure and functioning [12]. The application of the simulation-modeling principle is associated with the complexity of construction systems, the organization of their functioning in conditions of energy efficiency requirements, when the number of parameters that most significantly reflect the functioning of the system and the achievement of the desired result increases [13,14]. Functional modeling of the life cycle of energy-efficient buildings is a complex task, the solution of which requires the use of special techniques and tools.

4. Engineering and economic principle of energy efficiency of buildings
According to this principle, it is necessary to evaluate the energy efficiency of buildings not only from a technical, but also from an organizational and economic point of view, since the lack of comprehensive indicators and criteria for evaluating economic efficiency is the most significant methodological disadvantage of the methods used to assess energy efficiency in construction. Economic methods for evaluating efficiency should take into account the economic interests of individual participants in the investment and construction process and the country's construction industry as a whole.

Picture 3. Principles of using energy-efficient technologies in construction

Thus, the implementation of these principles should become a methodological basis for the construction of energy-efficient buildings and contribute to improving energy efficiency not only within the normalized indicators, but also the entire construction industry as a whole.

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