Problems of Energy Efficiency of Residential Buildings

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Abstract. The article is devoted to the analysis of trends and advanced technologies in the field of energy supply and energy efficiency of residential buildings. The evolution of the concept of "energy saving" in the concept of "energy efficiency" and its current interpretation are considered. The difference between the evaluation criteria of the world's leading rating systems LEED and BREEAM is shown. Considered the latest technology used in the construction of high-rise energy-efficient buildings. An innovative approach to the design of energy-efficient residential buildings should include, along with energy saving, various methods of producing and storing alternative energy through the use of solar and wind energy using special technical devices, the use of "green" construction technologies.

1. Introduction

Construction has traditionally been one of the most conservative sectors of both the Russian and global economies. One of the problems of the global construction industry is the low level of energy efficiency combined with an extremely high level of overall energy consumption. So, according to research, in the US, the construction industry consumes about 70% of the electricity produced in the country. The situation is similar in Europe. In a study conducted in 2009 by order of the European Commission, it was noted that various buildings and structures account for about 40% of the total energy consumption [1,2]. Therefore, the most progressive direction in the field of housing is the application of innovative technologies in the field of energy supply and energy efficiency.

Energy efficient facilities owe their birth to the world energy crisis of 1973. At that time, mankind first thought about the exhaustibility of the energy resources of the planet and energy conservation. At the initial stage, this was a simple search for ways to reduce energy consumption for heat supply to buildings. The first experimental building to test and identify the best technical solutions for energy conservation was built in Manchester (USA). It was an office building, commissioned by the General Services Administration. Energy consumption of the building was reduced due to the effective use of solar radiation, double-layer enclosing structures, heat recuperators and the use of computer control of building engineering equipment [3,4].

The implementation of this project has become the starting point for the construction of energy-efficient buildings around the world. The construction of houses with low energy consumption is successfully conducted in Europe. According to various sources, more than 10,000 such houses have already been built in Western European countries. The leaders of this movement are Germany, Finland and Denmark. In these countries, targeted state programs on energy saving, including the construction of energy efficient buildings, have been adopted and successfully implemented [5-7].
2. Methods

Energy saving is a complex of architectural, constructive and engineering solutions that ensure the reduction of consumption and the rational use of energy consumed during the operation of buildings and the creation of a comfortable microclimate in the premises. The relevance of this direction is determined by the growth of energy consumption of cities in the process of urbanization. Reducing energy consumption can be achieved by using fencing structures with heat engineering characteristics that are optimal for the climate zone, maximizing the use of reserves for natural lighting of rooms and using air recovery systems. This is also facilitated by automated microclimate control systems, which ensure a decrease in air temperature in rooms during the absence of people in the room; night airing during the warm season; use technological heat for heating cold zones and other similar measures [4, 7, 8].

Today, the concept of "energy saving" has expanded and transformed into the concept of "energy efficiency." Energy efficiency is a close interweaving of ecology and economics: people intelligently use natural resources, use renewable energy sources, thereby taking care of the environment and saving their own money [9]. This environmental stage implies, along with energy-saving measures, the use of alternative sources of renewable energy - solar collectors, heat pumps, wind power, thermal energy of the earth, biotechnology, etc. [10-12]. Thus, the building becomes not only a consumer, but also an energy producer.

The world is increasingly introducing systems for assessing the energy and environmental performance of buildings. These systems form the quality standards for the modern construction industry. The most famous are the British BREEAM (Building Research Establishment Environmental Assessment Method), operating since 1990 and the American LEED (Leadership in Energy and Environmental Design) system, introduced in 1998. Both systems are rated, but the difference of approaches is that the LEED system largely evaluates the energy efficiency of buildings, and the BREEAM system is environmentally friendly. Certification occurs at the stages of design, construction and reconstruction [13-15].

3. Results

High-rise construction, as the most progressive direction of construction, is especially focused on the application of innovative technologies. For architects, designers and engineers, high-rise buildings are an ideal experimental platform for testing progressive solutions in the field of technology, building materials and engineering systems [16-20]. Therefore, in order to understand the prospects for introducing innovations in the field of energy efficient technologies into the practice of housing construction, it is interesting to consider the experience of their creation and operation at high-rise construction objects.

A promising vector for the development of energy-efficient technologies at present is the creation of "green" buildings. This term refers to the use of construction technologies that use a variety of natural forms, means and sources to create healthy and comfortable human living conditions. Consider several buildings leading in the field of energy efficiency, which are presented in Figures 1-5.

The Hearst Tower, New York. Architect Norman Foster. The environmental part of the project was completed at the highest level - this is the first building in New York that received LEED Gold accreditation. The steel frame is 80% recycled material. Recycled materials are also used for interior decoration. Triangular shapes on the facade not only create a unique look of the building. The diagonal grid allows reducing the number of steel beams of the contour envelope and increasing the insolation of the premises. The glass on which the facades are lined skips the maximum amount of sunlight and blocks the heat, which allows significant savings in electricity consumption and air conditioning in the daytime. Rainwater collection is organized - a reservoir containing up to 14 thousand gallons of water provides about 50% of the needs of a skyscraper. It is used in cooling systems, for watering plants and for creating unusual water sculptures in the main hall.

Bank of America Tower. 366-meter skyscraper built in New York. The building project was created by the famous architect Robert Fox. The cost of Bank of America Tower is 1.2 billion dollars...
and 3% of the total amount is the cost of ensuring the ecological structure. The Bank of America Tower is the first skyscraper to receive a LEED Platinum Certificate. The constructive material of the tower is slag concrete. As an additive to cement, 45% of slag was used - steelmaking production waste. The material in the future may be recycled. On the roof of the building, there is a rainwater storage and purification system. The collected water will be mixed with the already used and then cleaned. This will save up to 30 million liters of water per year. The glass facade provides maximum natural light. Double-glazed windows reduce heat loss, which reduces energy consumption. Automatic lighting system regulates the consumption of electricity depending on the time of day. The cooling system produces an ice supply at night to use its melting to cool the building in the morning and afternoon. The tower has its own generators, capable of generating 4.6 MW of electricity, providing part of the needs of a skyscraper. This eliminates the loss of electricity that exists during transportation from systems of centralized power supply.

Pearl River Tower (Pearl River Tower, Guangzhou, China). According to lead architect of the project Gordon Gill, this 310-meter 71-story building is a “high-performance tool formed by the sun and wind.” Jill, together with architect Adrian Smith and engineer Roger Frechett, created a structure in which almost all the technologies used in green houses were used. Architects call the building the most energy efficient skyscraper in the world. When creating this ambitious project, it was assumed that the building would sell the excess energy generated by the local power plant. Although it has not become energy positive, it consumes almost 60 percent less energy than traditional buildings of similar size. This is provided by the following set of activities. Four giant wind turbines that generate the energy needed by the building are integrated into the technical floors. Wind entering the holes is used to ventilate the skyscraper. The south facade is equipped with double glazing. Interglass ventilation reduces heating of the building and reduces the cost of air conditioning. Dry hot air from the canals between the double glazing is used by the air dehumidification system in hidden ventilation shafts, where passive dehumidifiers are installed to remove excess moisture without attracting energy resources. Air conditioning is carried out by a system built into the floors, in which cooled liquid circulates. This solution allowed engineers to avoid large networks of forced air cooling. Automatic blinds are rotated depending on the angle of incidence of the rays of the sun. On the facade of the building there are powerful solar panels. Reservoirs for collecting, cleaning and recycling rainwater are installed on the roof. Water in the skyscraper is heated by photovoltaic panels. The area of solar panels is more than 1,500 square meters on each facade, and their total capacity is 300,000 kW. To preserve solar energy, new generation thermal collectors are provided.

The Deutsche Post building was built in Bonn according to the design of Helmut Jan. The International Council on High-Rise Buildings and the Urban Environment awarded him a decade
award for unique energy performance. Compared with similar-sized buildings, this 163-meter skyscraper consumes 79% less energy. This was made possible thanks to a competent and carefully thought-out orientation regarding the prevailing direction of the winds and cardinal points, which saves on artificial lighting and ventilation. A special underground pump is able to remove excess heat from the building in the summer, accumulate it, and give it back during the cold season. Energy is produced and solar panels installed on the roof. The building uses groundwater to supply the heating and cooling system. This reduces energy costs by almost a third.

Figure 3. Pearl River Tower, Guangzhou, China.  Figure 4. Deutsche Post Building, Bonn, Germany.  Figure 5. Agora Garden Tower, Taipei, Taiwan.

The creation of green in the direct and figurative sense of buildings is another modern trend of energy efficient construction. A recent example of this architectural direction is a residential building built in 2018 according to the design of Vincent Calleau in Taipei, Taiwan. The architect’s design was inspired by a DNA model for a residential building project. The skyscraper is, according to the author, a symbol of reconciliation between man and nature. During the construction of this “symbol”, only environmentally friendly building materials were used to confirm the idea. About 23 thousand live trees sprouted around the skyscraper. Agora Garden Tower is the embodiment of the concept of symbiosis of man and nature. The design of the tower was developed with careful consideration of the conditions of the construction site: the movement of the sun, thermal and wind climate to optimize natural lighting and ventilation. On the roof and visors mounted photovoltaic solar panels that produce electricity. The constructive central core of the building is equipped with a system providing passive climate control and vertical air circulation in the interior. Ecological innovations of the tower include rainwater recirculation system, energy-saving elevators and automatic energy-saving monitors that adapt to climatic conditions. In addition, large "green" areas will allow the building to absorb about 130 tons of carbon dioxide annually. This fantastically beautiful structure is an example of a successful project of a friendly attitude to nature and the rational use of resources. The project occupies a leading position in a number of prestigious international prizes - the LEED Gold + level from the US Green Building Council and the Diamond level from the Low Carbon Building Alliance (minimizing carbon dioxide emissions).
4. Discussion
The considered buildings provide excellent examples of the use of "green" technologies in construction and illustrate the possibilities of efficient use of energy resources. This is a living guide on how to build “friendly” human buildings, create a comfortable environment and reduce operating costs. Technologies in such facilities are focused on reducing the harmful effects of a building on human health and the environment during the entire cycle of its existence. This is achieved by selecting the best construction site, thoughtful design and construction solutions, competent development of systems of operation, maintenance and disposal of waste.

5. Conclusions
Energy-efficient strategies and technologies used in the construction of high-rise buildings are being developed and improved. The optimized and effective methods tested at these sites should become part of the practice of mass housing construction. Innovative systems of bioclimatic design of high-rise buildings are designed to create more comfortable conditions for people, ideally, even without the use of complex and expensive technological solutions. The use of renewable energy is a symbol of the developing technologies of the future.

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