Energy Efficient Technologies for the Construction and Buildings Reconstruction

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Abstract. All the integrated approach features to the application of energy-efficient technologies in the buildings and structures reconstruction and construction, which is accompanied by rigorous research, preparation and testing of experimental energy-efficient objects and samples with their further introduction into modern architectural solutions and construction practices are considered. Unlike energy conservation, energy efficiency in construction is aimed at using less energy to satisfy the same level of buildings energy supply or technological processes in production. It is shown that for a qualitative assessment of the improving the energy efficiency of buildings and structures possibility, all areas of energy loss should be assessed. Therefore, priority in technology should be put on improving the thermal insulation efficiency, mounting recovery devices to use exhaust air heat, and also include measures to prevent the warm air infiltration through windows, doors, balconies, and indoors to use instruments to control their internal temperature. Improving energy efficiency should be attributed to the strategic objectives of the state, being at the same time the main method of ensuring energy security.

1. Introduction

Nowadays humanity total energy consumption exceeds 120 billion MWh/year. In energy production for many decades, the annual increase is about 3% [1]. Efficient energy using for the state means saving resources, increasing industrial productivity and competitiveness, for the environment - limiting greenhouse gas emissions to the atmosphere, for the population - a significant reduction in utility costs [2]. In general, energy saving is any activity aimed at reducing the using volume of energy resources without prejudice to the main function of their use, and, in turn, energy efficiency is the rational use of energy resources. That is, unlike energy saving, energy efficiency in construction is aimed on applying less energy to meet the same level of energy buildings supply or technological processes in production.

In the reconstruction and buildings and structures construction, an integrated approach of using energy efficient technologies began to develop in the 1980s, primarily among European countries and in North America. This process was accompanied by research, preparation and testing of experimental energy-efficient objects and samples with their further implementation in architecture and construction. For 20, and in some countries, 30 years, special mechanisms have been used to increase energy efficiency among a number of energy consumption segments, called energy labels (energy consumption classes) and minimum energy performance standards (ITEC). Also, events similar to today's labeling have been developed in different countries. Thus, in the United States, a system was
proposed for estimating the energy intensity of products, called the Energy Guide [3, 4]. According to
this system, 25% of the lowest energy consumption range was selected from the entire energy intensity
range of single-type products, which owners received the prestigious “Energy Star” sign. In Europe,
energy efficiency labeling was initiated by German specialists, but soon became the entire EU system.
The difference between the European model and the American one is in the evaluation of the energy
intensity of products according to 7 classes (A-G). Class A is the most energy-efficient and G is the
most energy-efficient [5].

2. Development of energy saving technology
After the well-known oil crisis of 1974, attention was drawn to the fact that buildings have large
untapped reserves to increase their heat and power efficiency, the possibilities of this direction are
poorly understood, and designers do not know how to optimize heat flows in buildings. For a
qualitative possibility assessment of improving the energy dwellings efficiency, all areas of energy
loss should be evaluated in buildings.

The presence and accounting of internal heat emissions explains houses without heating are
possible, or the so-called "passive" buildings. Indeed, if the heat loss at home is reduced due to good
insulation of the building envelope, then the internal heat release and solar energy input through
translucent structures will be enough to heat it. On the way to the realization of these opportunities, an
energy-efficient house has emerged - a house that has significantly reduced (relative to the average
modern level) energy consumption without losing the living quality. In Europe and the United States,
a trend has emerged to build "energy-active" houses capable of generating electricity and fully
meeting their own needs. The most famous energy-efficient buildings built from 1972 to 2003 are
particularly described in the monograph by Tabunshchikova Yu.A., Brodach M.M. and Shilkina N.V.
For comparison, the first "active" house was built only in Russia, 2011. In ordinary homes, more than
90% of the energy consumed is spent on heating and hot water supply (HWS), with the last spending
from 15 to 30% [6, 7]. Therefore, in energy-efficient homes, technology priority is put on improving
the efficiency of thermal insulation, mounting recovery devices for using exhaust air heat. In addition,
measures are being taken to prevent the infiltration of warm air through windows, doors, balconies,
and apartments to regulate the temperature of the premises are commonly used in apartments. A huge
role is given to the boilers using with increased efficiency [8].

In Europe, particular Scandinavian countries created the necessary legislative norms, paying
attention to the economic interests of homeowners and investors. Energy efficiency gains are achieved
through the use of effective thermal insulation, the heat pumps installation, modern window frames
and doors that prevent losing of the warm air, the use of high-efficiency boiler plants and apartment
temperature control devices. In Germany, more than 1.5 billion Euros was spent on the reconstruction
of houses in order to reduce energy consumption. Moreover, homeowners who want to renovate their
homes are given tax breaks of 20% and low-interest bank loans.

In France, 2005, a tax incentives program was introduced for families wishing to use thermal
energy saving technologies in their own homes [9]. With the housing modernization they are given a
loan, the right to reimbursement up to 50% of the installing thermoregulation systems cost, upgrading
heating and using alternative energy sources: biofuel, solar and wind energy.

Energy-saving policies began in Japan, 1973. Measures are being taken to reduce the houses energy
intensity, improving the buildings design to reduce the cost of heating and air conditioning. Particular
attention is paid to the development of solar energy: the use of solar panels can significantly reduce
energy costs, and the installation of solar panels by 1/3 is paid by the government.

Despite the fact that the Russian Federation is one of the leading energy nations in the world and
has large reserves of energy resources, both already open and potential (in the world’s explored
reserves, Russia's share of oil is 13%, natural gas is 36%, coal - 12%), according to statistics from the
International Energy Agency and the American Council of ACEEE, Russia is only in twenty-eighth
place in terms of energy efficiency. Among the 12 largest economies of the world in terms of rational
energy consumption, Russia is in general the last place (see. Fig. 1). In this rating the leading positions were occupied by the United Kingdom, Germany, Italy [10, 11].

![Figure 1. Analysis of rational energy consumption by countries.](image)

In developed countries, about half of all energy is spent on the construction and operation of buildings and structures, and about a 1/3 in developing countries. In the Russian Federation, about 40–45% of the total energy that produced is spent on household needs, while today almost every second ton of fuel burned is spent inefficiently. In Russia in the second half of the 20th century heating in residential buildings built is 350–380 kWh / m² per year, which is 5–7 times higher than in EU countries. At the same time, considerable distances and deterioration of heating networks lead to losses of up to 40% of all the generated energy directed to the heating of buildings [12, 13].

On the Russian Federation territory, energy-saving technologies actually had began to be used in construction since 1996 after the adoption of federal law No. 28-FZ of April 3, 1996, “On Energy Saving”. In accordance with the provisions of this law, the decisions of the Russian Construction Ministry No. 18-81 of August 11, 1995 and No. 18-8 of January 19, 1998 approved Amendments No. 3 and No. 4 to SNiP II-3-79 “Construction Heat Engineering” and then a new SNiP 23-02-2003 “Thermal protection of buildings” was put into effect. These documents provided for the tightening of requirements for reduced resistance to heat transfer of building envelopes in two stages - from 1996 and from 01.01.2000, as well as the gradation of buildings and structures for energy efficiency [14]. In general, the term “energy efficiency” in Russian construction was introduced SNiP 23-02-2003 “Thermal protection of buildings”. This document provided for the introduction of the energy efficiency indicator of buildings - the specific heat demand for heating, and also established the classes of energy efficiency of buildings and their rules for evaluating both in design and construction and in operation. Buildings that meet these requirements are called "energy efficient buildings." The developers of regulatory and legal documentation on the energy efficiency of buildings determine the energy building efficiency as a property of an object and its engineering systems to ensure a given level of thermal energy consumption to maintain optimal parameters of the indoor microclimate. In the scientific literature, one can also find the definition of the concept “energy efficient building” as a building with energy consumption indicators lower than those established by standards [15, 16]. Thus, in MGSN 2.01-99, the energy efficiency of a building is defined as a property of an object and its engineering systems to provide a given level of thermal energy consumption to maintain optimal parameters of the indoor microclimate [17]. In the process of formation and development of the concept of “energy-efficient building”, its content expanded from requirements exclusively to the
resistance to heat transfer of enclosing structures to the requirements for minimizing primary energy to provide the necessary microclimate inside the building.

On November 23, 2009, Russia adopted Federal Law No. 261-FZ (as amended on July 13, 2015, amended and added, entered into force on January 1, 2016) “On energy saving and on improving energy efficiency and on introducing changes to legislative acts of the Russian Federation”. This law defined energy efficiency as the effective use of not only thermal energy, but also other types of energy and energy resources [18,19]. At the meeting of the Commission for the Modernization and Technological Development of the Russian Economy and the Presidium of the Council for Science, Technology and Education in the same 2009, 6 projects in the field of energy efficiency were approved:

- "Energy efficient city”;
- “Energy Efficient Social Sector”;
- “Count, save and pay”;
- "Small integrated energy”;
- "New World”;
- "Innovative energy”.

In the spring of 2014, on the order of the Russian Energy Ministry, a specially formed working group carried out work on the implementation of research work “Preparation of proposals for improving energy efficiency in typical public sector facilities, as well as apartment buildings during capital repairs and reconstruction.” In general, the stages of the global development and Russian standards for energy efficiency can be seen in Table 1.

Table 1. Development of world energy efficiency standards.

| Year of issue | Standard’s name |
|---------------|-----------------|
| 1974          | The global energy crisis: an awareness of the need to save energy |
| 1976          | The basic principle of energy saving MIREK |
| 1980-1990     | Development of new standards for reducing energy consumption in construction in Denmark, Sweden, Germany |
| 1993          | European Union CO2 Restriction Directive (SAVE) |
| 1992          | The concept of sustainable development in the world. “Energy Strategy of Russia until 2020” in the Russian Federation: attracting business to energy saving. Law No. 28-FZ of April 3, 1996, on Energy Efficiency |
| 2000          | EU Building Energy Efficiency Assistance Program: New Energy Efficiency Norms and Standards |
| 2002          | EU Directive: general conditions of the methodology for calculating energy efficiency, minimum requirements for buildings, energy certification of buildings (EPBD). Approach to buildings as a single energy system. |
| 2006          | ISO 14040: 2006: product life cycle assessment in terms of energy flow and a systems approach |
| 2008          | Amendments to the EPBD: increase of energy efficiency standards in buildings less than 1000 m2 in Denmark, Norway, the Netherlands, Germany, Hungary, France. "St. Petersburg Plan" of energy efficiency in the Russian Federation |
| 2009          | Adoption of Law No. 261-FZ of 11.23.2009 “On Energy Saving and on Increasing Energy Efficiency” in the Russian Federation |
| 2010          | The new EU Directive within the framework of the Europe 2020 strategy: the integration of methodologies for the rationing of energy characteristics. Increase in standards for buildings up to 1000 m2 RES in buildings |
| Present       | The emergence and a system development of strategic documents on energy efficiency in the Russian Federation, ISO 14041 standards |
3. Results
Thus, improving energy efficiency should be attributed to the strategic objectives of the state, being both the main method of ensuring energy security and the most realistic way to reduce dependence on hydrocarbon exports. The movement launched in this direction will ultimately allow the Russian construction industry to reach a new, competitive level of the rational energy resources using.

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