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METHODS TO IMPROVE ENERGY EFFICIENCY OF LOW-RISE RESIDENTIAL BUILDINGS UNDER CLIMATE CHANGE CONDITIONS

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Abstract

In the context of global warming, increasing extreme temperatures, and rising demand for energy resources, reducing the energy consumption of residential buildings has become a critical task. This paper scientifically analyzes the methods to enhance the energy efficiency of low-rise residential buildings under climate change conditions. The study examines modern architectural and planning solutions, structural and engineering technologies, as well as passive and active energy efficiency measures adapted to local climatic conditions. The results of the study provide scientific and practical recommendations for applying energy-saving solutions in the design and renovation of low-rise residential buildings.

Keywords

climate change, energy efficiency, low-rise residential buildings, passive design, sustainable architecture, energy conservation.

Introduction.

Global climate change is currently reshaping socio-economic and environmental strategies worldwide, as rising atmospheric temperatures, increasing occurrences of extreme weather events, and growing demand for energy resources have elevated energy efficiency to a priority issue in certain sectors. The building sector, in particular, consumes a significant portion of global energy, with operational energy use including heating, cooling, ventilation, and electrical systems, which intensifies under changing climate conditions. International studies indicate that climate change can alter heating and cooling loads in buildings, thereby increasing overall energy consumption. This underscores the growing necessity to adapt buildings to ensure energy efficiency.

Low-rise residential buildings represent the predominant housing type in many countries. Enhancing their energy efficiency not only reduces household energy expenditures but also contributes to the reduction of overall carbon footprints. Developing energy-efficient strategies for these buildings requires the implementation of passive and adaptive design principles, improvement of thermal characteristics through insulation, and judicious use of solar energy. Research shows that climate-adapted building designs, which manage thermal loads effectively, can significantly decrease heat consumption, positively affecting the overall energy performance of the building [1].

Moreover, context-sensitive strategies are crucial in improving building energy performance. For example, rising summer temperatures increase cooling demands, necessitating the effective management of thermal loads through energy-efficient systems in low-rise



residential buildings. Studies indicate that climate-adaptive solutions can reduce energy consumption while increasing the resilience of buildings to extreme conditions [2].

Therefore, this paper analyzes scientifically grounded methods for enhancing the energy efficiency of low-rise residential buildings under climate change conditions. The study examines improving thermal performance, principles of energy-efficient design, and practical design approaches. The analysis provides guidance for designing and retrofitting low-rise residential buildings to be sustainable, energy-efficient, and climate-responsive, offering both scientific and practical directions for implementation.

Methodology.

This study employed a comprehensive scientific approach to investigate methods for enhancing the energy efficiency of low-rise residential buildings and adapting them to changing climate conditions. The research methodology combined quantitative and qualitative analysis, conducted through experimental observations, simulation modeling, and comparative evaluations [4].

The research materials included the current energy consumption of low-rise residential buildings located in various climatic zones of Uzbekistan, their thermal characteristics, and the operational performance of heating and cooling systems. In addition, international scientific studies and recent technological developments were analyzed to identify effective strategies for designing energy-efficient buildings adapted to climate change [3].

The methodological approach incorporated the following key elements:

- Calculating the energy balance of low-rise residential buildings and identifying sources of heat loss;
- Assessing the thermal properties of the building envelope and interior spaces;
- Examining passive and active energy efficiency measures, including insulation materials, natural ventilation, utilization of solar energy, shading, and wind management;
- Simulating variations in building energy consumption under different climate scenarios [6, 4].

Developing scientifically grounded and practically applicable strategies to improve energy efficiency in low-rise residential buildings under climate change conditions is essential. This approach provides precise methodological recommendations for sustainable building development, energy conservation, and enhanced living conditions.

Discussion and Results.

Climate change itself generates both mild and extreme environmental conditions in buildings, which directly affect heating and cooling demands and, consequently, energy consumption. Research indicates that without the implementation of energy efficiency measures, buildings may experience increased overall energy usage under changing climate conditions [7].

Thermal comfort within buildings is a critical consideration when evaluating energy-efficient solutions. Interior air temperature, airflow, and heat retention strategies contribute not only to reduced energy consumption but also to enhanced living comfort. The structural design,



selection of materials, and incorporation of passive elements—such as shading devices or natural ventilation channels—significantly improve the performance of energy-efficient systems [8].

Innovative approaches, including digital transformation and simulation methods, play an important role in building design and evaluating energy efficiency. Specifically, employing digital tools throughout the building's lifecycle simplifies energy performance assessment and enables the selection of optimal strategies [9].

Effective strategies for enhancing energy efficiency under climate change conditions are implemented through integrated solutions across several areas. Climate-adaptive design approaches, which consider extreme weather events and future climate scenarios, can significantly reduce thermal loads, optimize heating and cooling demand, and consequently decrease energy consumption, thus improving overall energy performance [10].

Improving the building envelope and enhancing insulation directly contribute to energy savings. For example, the use of high-performance insulation materials and optimized window-to-wall ratios can significantly reduce energy consumption in buildings. Such measures have proven effective in reducing both construction and operational energy costs during building renovation [11].

The discussion results demonstrate that applying a comprehensive approach to the planning, design, and renovation of low-rise residential buildings allows for substantial energy savings under climate change conditions. These measures optimize building energy performance, support the creation of sustainable living environments, and mitigate potential inefficiencies.

Overall, strategies for improving energy efficiency in low-rise residential buildings represent a key tool for reducing the negative impact of climate change, optimizing energy use, and enhancing living comfort. These measures also provide a practical basis for developing long-term sustainable development strategies for residential buildings.

Conclusion.

The study results indicate that improving the energy efficiency of low-rise residential buildings under climate change conditions is effectively achieved through several integrated approaches. The most effective strategies include enhancing the building envelope, using advanced insulation materials, applying natural ventilation and solar energy, and incorporating passive design elements. These measures reduce heat loss and significantly lower energy consumption. Furthermore, digital simulation and BIM-based energy modeling allow for the selection of optimal solutions during the design stage, thereby improving both energy efficiency and living comfort. Combining these strategies is essential for mitigating the negative effects of climate change and establishing long-term sustainable living environments.

In general, scientifically grounded approaches for adapting low-rise residential buildings to climate change provide measurable results in energy conservation, improved comfort, and reduced building energy demand. Moreover, these research outcomes are highly relevant for developing energy-efficient projects in Uzbekistan and formulating sustainable residential development strategies.



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