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Passive individual residential building overview and concept for a continental temperate climate

Abstract. The research relevance is determined by the need to develop energy-efficient and climate-resilient living spaces to ensure sustainable development and reduce environmental impact. The study aimed to analyse the integrated concept of a passive individual residential building specially adapted to the conditions of the continental temperate climate, with a focus on maximum energy efficiency and ensuring a high level of comfort for residents. While the research, analytical, classification, functional, synthesis and other methods were employed. The article examines the trend of improving the energy efficiency and environmental friendliness of individual residential buildings that meet the requirements of carbon neutrality and sustainability. The use of modern thermal insulation materials and optimisation of the concept of minimising heat-conducting inclusions has helped to dramatically reduce the building's heat transfer losses. The result is an integrated design that uses high-quality insulation materials, optimally positioned windows to maximise solar energy and efficient ventilation systems with heat recovery. However, infiltration losses remain

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significant, and improving the efficiency of ventilation system recovery and regeneration is a key area of research. To reduce transmission losses, it is important to consider internal and external heat gains in individual buildings. Organising aspects that consider the house as a biosphere-compatible and energy-efficient structure is an urgent task, and the study is aimed at developing an engineering and applied project concept. The practical significance of this research is determined by the creation of an innovative housing solution that not only optimises energy consumption and ensures environmental friendliness, but also meets the specific requirements of the continental temperate climate, contributing to the sustainability and efficiency of the construction sector

Keywords: energy efficiency; comfort; thermal insulation materials; heat recovery; integrated design

INTRODUCTION

Studying passive individual residential buildings for continental temperate climates is relevant in terms of the current challenges associated with climate change and sustainable development. The growing awareness of energy efficiency and the environmental impact of construction requires innovative approaches to the design of living spaces. Passive houses, specifically adapted to temperate climates, have the potential not only to significantly reduce energy use but also to create a comfortable environment for residents. Individual residential buildings show a trend towards greater energy efficiency and environmental friendliness, which aligns with global requirements for carbon neutrality, environmental sustainability, and energy autonomy, while the use of advanced thermal insulation materials and improved concepts for minimising heat-conducting inclusions significantly reduce the amount of heat loss through the building envelope. It is worth noting that infiltration losses continue to be significant, and it is important to maintain a balance so that their minimisation does not lead to a reduction in ventilation, which is a key parameter for the formation of sanitary and hygienic comfort.

The research problem is determined by the need to improve the energy efficiency and climate change resilience of residential buildings for continental temperate climates. Climate change and increased awareness of environmental issues are challenging the construction industry to create living spaces that not only reduce energy consumption but are also adapted to specific climate conditions. Challenges include the need to find optimal structural and energy-efficient solutions, consider the impact of external factors on building performance, and develop integrated concepts aimed at creating housing that uses resources efficiently while ensuring comfort and sustainability in a rapidly changing climate.

B. Dykiy & A. Hlushchenko (2023) emphasise the need to improve the energy efficiency and climate resilience of residential buildings in continental temperate climates, but the study does not consider the possibility of using alternative energy sources. Ye. Borodin & M. Myrhorodska (2022) emphasise the importance of ensuring comfortable living conditions in buildings while minimising environmental impact, and I. Arutiunian *et al*. (2023) highlight the relevance of developing integrated concepts for passive individual residential buildings.

Aspects of using high-quality insulation materials require detailed consideration, and therefore are analysed in many modern studies. N. Bolharova *et al*. (2020) emphasise the important issue of optimising thermal insulation materials and efficient heat recovery ventilation systems, which makes the possibility of improving the efficiency of ventilation systems in the context of providing clean air in buildings. A. Rogovyi & M. Dubina (2023) highlight a significant contribution to the development of innovative and long-term solutions in the field of housing construction and the use of green technologies to optimise heat loss. This topic is also considered in the study by V. Chala *et al*. (2023), where researchers emphasise the importance of green building and environmental compatibility in the concept of a passive house.

V. Deshko *et al*. (2022) raise the issue of internal and external heat gain in individual houses, which is important to consider when creating climate-resilient living spaces, but the study does not address the socio-cultural aspects of sustainability and the perception of innovations in housing construction. At the same time, M. Savytskyi *et al*. (2021) recommend the use of high-quality insulation materials and efficient windows to retain heat in winter and remove it in summer. D. Isaienko & V. Scochko (2019) formulate general approaches to modelling processes that affect the microclimate conditions of energy-efficient buildings.

The study aimed to analyse the integrated concept of a residential building operating on the principles of passive architecture and specially adapted to the conditions of a continental temperate climate.

MATERIALS AND METHODS

The analytical method was used to investigate the effectiveness of innovative thermal insulation materials, reveal trends in the development of the concept of minimising heat-conducting inclusions and determine their impact on the overall heat loss of the building. The method was also used to determine the optimal balance between reducing infiltration losses and ensuring the necessary level of air exchange to ensure the health and comfort of the occupants.

The functional method was used to identify the main functions and requirements that a passive individual residential building should fulfil in continental temperate climates. This method was used to conduct a comprehensive review of internal and external factors affecting energy efficiency and indoor comfort. In particular, the functional method was used to determine the optimal location of windows and doors to maximise solar energy and minimise heat loss, and to consider smart heating and ventilation control systems to ensure optimal conditions in the building during different periods of the year.

The deduction method was used to identify the main principles and strategies for the development of a passive individual dwelling house for a continental temperate climate and to organise scientific and technical knowledge to logically derive the key principles that form the basis of the concept. The method was also used to develop a conceptual model that considers the interaction between the various elements of the building and its environment.

Comprehensive and optimally coordinated solutions for the creation of an individual residential building were developed using the synthesis method. This method involved a comprehensive combination of various elements, considering their interaction to achieve maximum energy efficiency and comfort for residents. The synthesis method was used to combine advanced technologies in the field of thermal insulation and ventilation, rational use of solar energy and the introduction of smart control systems and to consider the influence of environmental factors, local characteristics, and the individual needs of the residents, creating a harmonious combination between technical solutions and sustainability requirements.

The classification method was used to categorise architectural and engineering solutions according to various criteria, such as optimal use of natural light, thermal insulation, ventilation systems. This method was used to identify the key elements that determine the efficiency and sustainability of living spaces and to identify the typologies of buildings that best suit the conditions of the continental temperate climate and to incorporate them into the concept development.

A range of software tools were used in the process of creating the graphic representations for this study to ensure a high degree of quality and representativeness of the visuals. Starting with AutoCAD, used for the development of architectural and technical schemes, drawings and 2D plans, to SketchUp, which provided the possibility of three-dimensional modelling of building structures. The selected software is distinguished by its high efficiency, ability to accurately reproduce complex architectural structures and ease of use to achieve the research objective. The use of these tools made it possible to obtain detailed and realistic graphical representations of the research objects, illustrating key study aspects.

RESULTS

Architectural Solutions. The correct positioning of the building concerning the cardinal points ensures that the amount of solar heat energy gained and lost through translucent structures such as glazed windows and doors is accurately measured. Planning solutions for the building's volumetric layout include placing the most heavily used rooms, such as bedrooms and guest rooms, on the south side, while less used and technical rooms, such as corridors, engineering rooms, kitchen, and bathrooms, are located on the north side.

The area of the windows on the southern facade is designed to compensate for the heat gain from solar radiation to ensure that the heat required to provide a comfortable microclimate in all rooms is not lost. The area of the windows on the north, east and west facades was determined to minimise heat loss and at the same time ensure the required level of illumination in the premises. This is important to ensure that all premises meet the comfort standards for living, working and recreation, considering the sanitary and hygienic requirements for the level of illumination for the health of vision. The house has an additional structure in the form of a combined sun protection, which includes a pergola and an outdoor terrace for relaxation (Spanjar *et al.*, 2022). Furthermore, the part of the roof overhang above the southern façade creates a canopy that connects to the pergola, providing effective sun protection for the southern facade. This avoids overheating during the warmer months and reduces visual discomfort caused by too much light, especially when the sun is higher at its zenith.

The height of the window sills on the southern façade regulates the transmission of only the amount of solar heat energy that is necessary to ensure comfortable indoor conditions. Thus, these window sills partially perform the function of sun protection. The dimensions of each window, both in width and height, are carefully calculated to maintain an optimal balance of heat gain and heat loss within each room, between rooms and within the building as a whole. In particular, the windows on the southern facade are the widest and their window sills are higher compared to the other facades. The windows on the north, east and west facades are narrow and are positioned to provide localised lighting for technical and other rooms. Additionally, some windows on the north façade extend from floor to ceiling to improve the light hygiene of the corridors and kitchen. The windows on the south and north facades are located mainly along conventional axes that are perpendicular to the respective facades. This creates intersecting natural light, which avoids insufficient illumination of work areas in the building's premises during periods when sun protection causes a shadow effect on the southern facade.

The internal walls and partitions separating the living areas from the common and technical areas have translucent door leaves and windows above them. This ensures that natural light can be received on the worktops through the transparent elements of the doors and windows. Internal partitions with doors placed between living rooms, corridors and technical rooms effectively limit and control excessive air exchange between rooms in the north and south directions. This prevents intensive mixing of air of different temperatures, which in turn leads to a reduction in heat loss during the cold season and avoids overheating in summer. In addition, the separation of the staircase from other rooms by additional partitions with doors helps to reduce heat loss through the opening and closing of external entrance doors to the street and the terrace of the second floor of the building.

The staircase of the building has a single flight of stairs with the use of traction devices and three running steps in the upper part (near the ceiling of the second floor). At the same time, the space near all the entrance doors is preserved to the maximum extent possible, which makes it possible to place cabinets, shelves, and other interior items in this area. To further preserve the feeling of openness in the entrance area, the staircase is made without stoppers behind the steps, creating the effect of a "transparent staircase" and allowing for natural light on both sides. The second floor (superstructure) above the staircase is designed in such a way that, without interfering with the movement of people going up or down, it preserves the maximum usable area for the possibility of arranging a work area, study, library, or a combination of these.

The roof slope is oriented from south to north. This solution leads to an increase in the area of the southern facade, which should receive the most solar irradiation and heat energy during the cold season, and a decrease in the area of the northern facades, where heat losses are most intense and should be minimised (Mutani & Todeschi, 2021). In addition, such a roof pitch helps avoid overheating in the warm season and contributes to the additional accumulation of thermal energy in the air masses in the residential (southern) part of the building during the cold season. A single-pitched roof allows for the reduction of the heated volume of the premises at the full height from floor to ceiling, which coincides with the bottom of the roof structure. The slope of the roof above the stairwell is oriented in the opposite direction to the rest of the roof to reduce the volume of the room served by heating.

In the bathroom and sanitary room, which do not have a direct connection to the exterior walls, translucent doors and additional windows above the doors are provided to provide natural light, additional insolation and reduce the electricity used for lighting. The bathroom adjacent to the northern façade also has a window with the same considerations. At the same time, the north-facing orientation of this bathroom helps to avoid the development of harmful fungi and microorganisms. In addition to its sun protection, the terrace on the second-floor extension serves as an additional place for relaxation and entertainment and provides a place for atmospheric exterior elements and ornamental plants. The pergola structure on the superstructure helps to partially keep the load from snow in winter, which improves the operating conditions and extends the service life of the roof. It is important to note that such a superstructure allows us to preserve the artificially used area on the territory around the house. The continuation of the pergola structure to the east creates an ideal place for car parking. The convergence of the car park with the stairwell, which acts as a thermal buffer, allows for an additional entrance door (emergency entrance) to be placed near the car park, and a significant shadow zone from the stairwell façade protects cars from excessive colour fading. The plants that predominate on the site are exclusively local species that do not require significant watering. The trees and shrubs planted on the southern façade are mainly deciduous, while the northern facade is predominantly coniferous.

Construction Solutions. The exterior walls are made of energy-efficient ceramic blocks with a multi-cavity structure. In addition to its high thermal insulation, this material is environmentally friendly, safe, and durable, and provides effective moisture exchange with the environment, which is similar to the moisture exchange in the human body (Turakulovna & Pulatovich, 2023). This increases the comfort of living in the building and improves the emotional state of a person. The interior walls are made of standard ceramic bricks, which are also considered a reliable and environmentally friendly material. The increased density of the bricks of the internal walls ensures high heat storage properties of the building.

The building's insulation is designed with vertical, inclined, and horizontal parts of the insulation materials closely and inseparably connected. High-density mineral wool boards are used to insulate the exterior walls, as the insulation system has an increased thickness. Polyurethane boards are used under the floor. The wall structures are separated from the foundation slab and rafter structures by foam glass inserts. The roof is insulated with sprayed open-cell polyurethane foam at the pore level to provide a "breathable building" effect. To reduce heat loss, all vertical, horizontal, and sloping joints are designed to minimise or eliminate heat conductive inclusions and vulnerable fragments of complex geometry that could become cold bridges (Mallick & Gayen, 2023). A single-pitched roof also helps to reduce heat loss, as it does not have additional zigzags and protrusions. An important technical solution aimed at reducing the number of cold bridges is the almost complete separation of the pergola terrace of the second-floor extension from the building envelope. The superstructure is in contact with the building only at two points on the pillar supports, which are mounted on the internal load-bearing walls. In this case, the load is transferred through the minimum required contact area, and the main part of both pillars is separated from the internal load-bearing walls by effective foam glass iWnsulation. All other superstructure supports are independently located columns that are not connected to the building.

To minimise heat loss caused by cold air infiltration or warm air leakage during the cold season, and vice versa – by warm air inflow or cooled air leakage during the warm season, all internal joints of the building envelope (walls, roofing, foundation slab, windows, and external doors) are equipped with a windproof membrane insulated from accidental air drafts. The project provides for the effective separation of the internal load-bearing walls made of ceramic bricks from the external envelope structures employing layers of high-strength foam glass insulation.

Additionally, the internal walls in contact with the engineering room are not connected to the external walls at all. All internal load-bearing walls act as heat accumulators, the main purpose of which is to localise the heat in the central part of the building. This leads to an increased thermal mass of the building, ensuring longer retention of thermal energy in the cold season and slower heating in the warm season. This, in turn, results in lower energy consumption for heating and cooling. On the other hand, the materials of the stairwell and the staircase itself are designed with wooden structural elements that do not accumulate significant thermal energy (Cabral & Blanchet, 2021). This is because this part of the building, in particular, is the "coldest" during the cold season and the "hottest" during the warm season, due to the presence of four entrance doors, and therefore does not require the use of heat storage materials.

All window structures of the building are designed with double elements, using modern multi-chamber profiles and double-glazed windows to significantly increase the heat transfer coefficient of window systems. The door structures are also made with double elements, which allows them to be opened both inside and outside the building. The layout of the ground and first floor of a biosphere-compatible and energy-efficient individual dwelling house is determined by several key aspects (Fig. 1; Fig. 2). First, it is necessary to consider the optimal location of the house to maximise solar thermal energy (Mostafaeipour *et al.*, 2021). Large windows on the southern facade contribute to light and heat gain. An important aspect is the use of energy-efficient heating systems, such as geothermal heating, and ventilation systems for optimal heat management in the building. High-quality insulation materials help reduce heat loss. The layout of interior spaces should be logical and convenient for occupants. It is necessary to consider the zoning and use of space according to its functionality. Efficient use of water supply and lighting, as well as an effective rainwater harvesting system, contribute to an environmentally friendly environment. The creation of courtyards and recreation areas improves natural ventilation and provides an opportunity to enjoy fresh air. The layout should also consider the maximum use of space to ensure the comfort and aesthetic appearance of the building. In general, the combination of these aspects contributes to the creation of an efficient and biosphere-compatible living space that provides comfort and a balanced relationship with the natural environment.

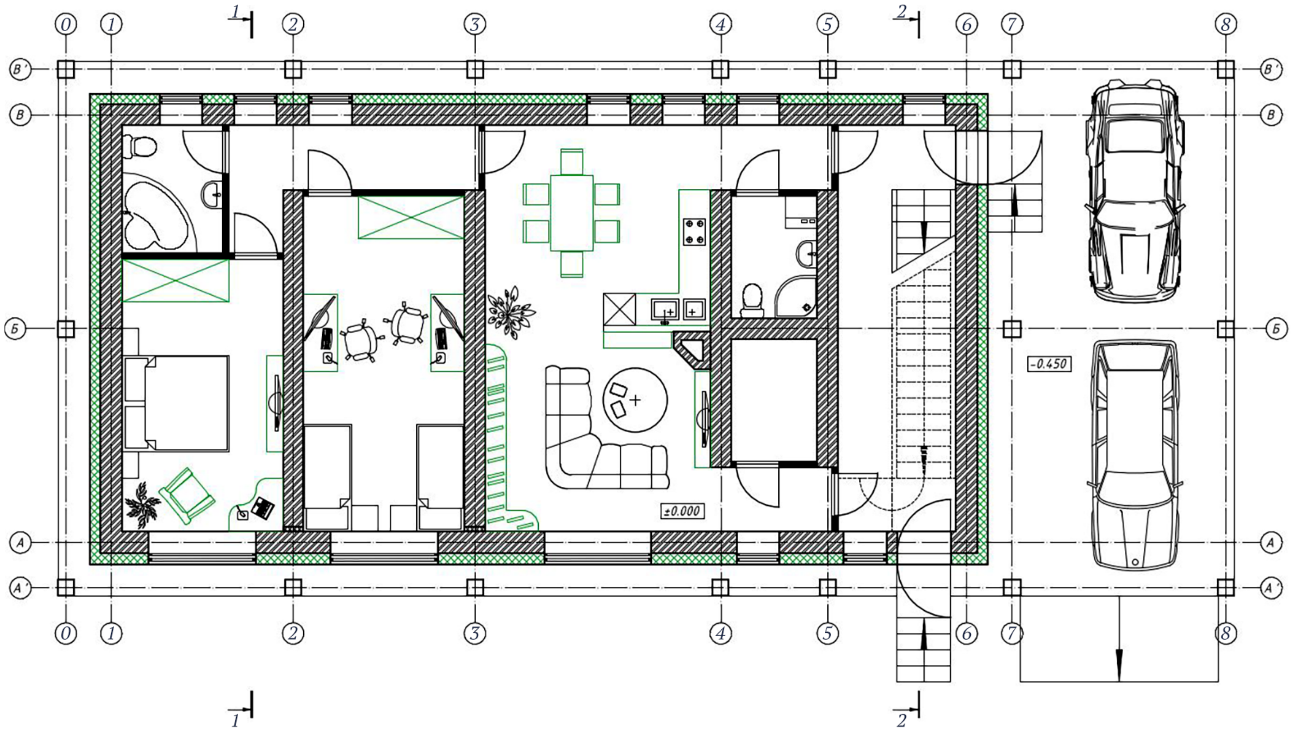

Figure 1. Planning solutions for the first floor of a biosphere-compatible and energy-efficient individual residential building

Source: compiled by the authors

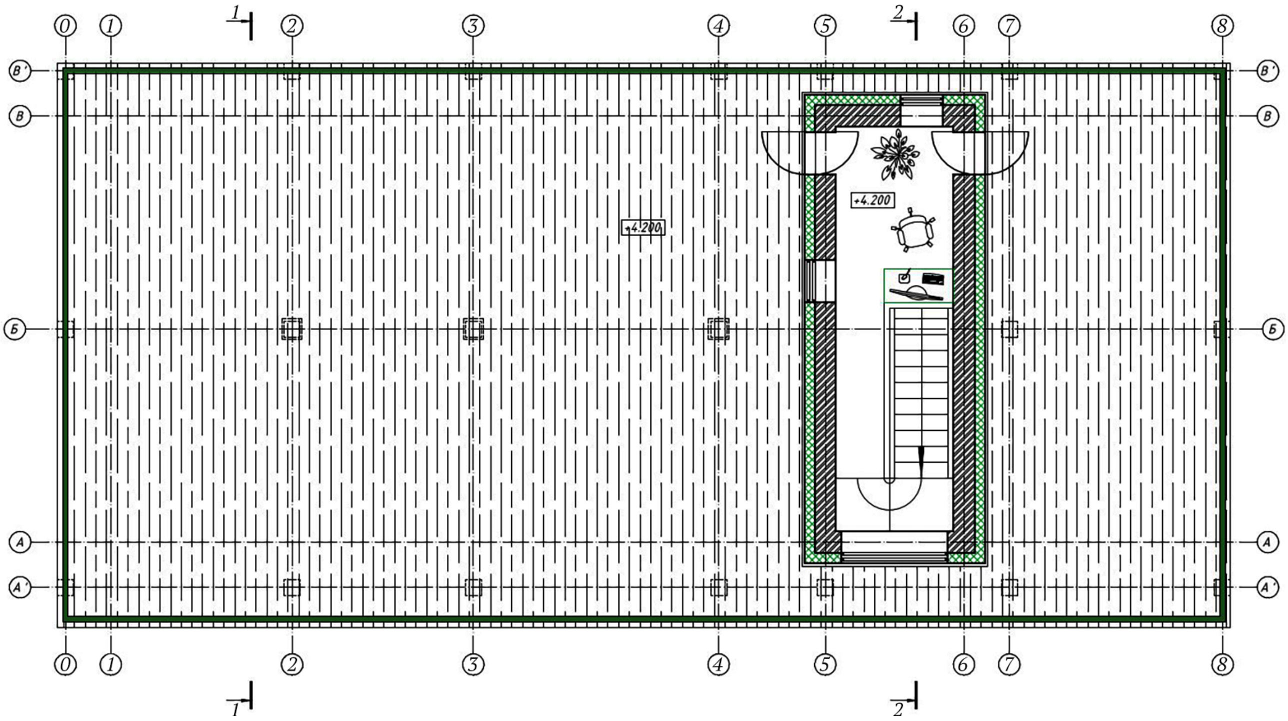

Figure 2. Planning solutions for the second floor
and terrace of a biosphere-compatible and energy-efficient individual residential building
Source: compiled by the authors

The exterior of the central façade of a biosphere-compatible and energy-efficient individual residential building is determined by several key aspects that combine aesthetic and functional considerations (Fig. 3; Fig. 4). The architectural style is chosen to be in harmony with the natural environment (Orhan & Yilmazer, 2021).

Figure 3. Exterior of the central facade
of a biosphere-compatible and energy-efficient
individual residential building
Source: compiled by the authors

Figure 4. Exterior of the central facade
of a biosphere-compatible and energy-efficient
individual residential building
Source: compiled by the authors

The use of natural materials, such as wood or stone, emphasises the principles of biosphere compatibility. Integrating solar cells into the facade design will not only add aesthetics but also become a source of additional energy. Projections and canopies can serve not only an aesthetic purpose but also a functional one, providing sun protection and comfort in the house. Pond elements and vegetation add biosphere interaction and natural beauty. The design of the lighting elements gives the house a day and night look, emphasising its shapes. By incorporating these aspects, the exterior of the central façade can reflect the aesthetic preferences of the owners, while also meeting the principles of energy efficiency and biosphere compatibility, creating a harmonious image with the natural environment.

Design Solutions. Repair and finishing inside the house are done in the minimalist style, with the interior associated with a loft. The finishing of wall surfaces involves painting or varnishing for interior brick and exterior ceramic block walls. All technical rooms, corridors, bathrooms, the entrance section, and the kitchen are equipped with ceramic tiles, and the floors in the living rooms are laminate. Given the use of wind barrier membranes, the junctions are hidden by wooden overlays. Local LED (light-emitting diode) lighting around the premises is used to create a design effect. The lighting fixtures are mainly equipped with energy-efficient thermal LED lamps. The living room is combined with the kitchen to visually enlarge the space. The living room has a fireplace to create cosiness and improve energy independence. The flooring has a specific pattern, and the colour is in harmony with insolation calculations. The interior walls are decorated with thematic wall paintings. The ceiling is made in light colours for maximum light reflection. The bathrooms are decorated in light colours to maximise natural light. The premises are decorated with many home plants. Environmentally friendly materials were used for construction. The interior is complemented by designer furniture and lighting fixtures.

The entrance and living room interiors of the biosphere-compatible and energy-efficient building are striking in their functionality and convenience, reflecting the concept of an eco-friendly and stylish space (Druta & Ronald, 2021). The entrance group is designed in a minimalist and natural style (Fig. 5; Fig. 6).

Figure 5. Living room interior
of a biosphere-compatible
and energy-efficient individual house
Source: compiled by the authors

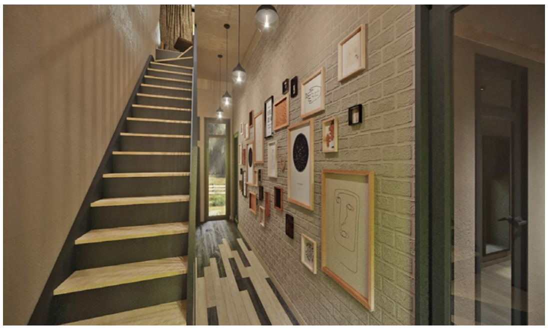

Figure 6. The interior of the entrance group
of a biosphere-compatible
and energy-efficient individual residential building
Source: compiled by the authors

The use of natural materials, such as wood and stone, gives the room a natural warmth. The light colours of the walls and floor visually expand the space, and the lighting creates an atmosphere of comfort and convenience. The living room, which is connected to the entrance hall, creates an impression of modernity and elegance. The furniture and décor favourably combine natural materials with stylish design. Large windows make the room open and fill it with natural light. The spatial plan is designed to create functional areas, considering the needs of the residents. The overall appearance of the entrance and living room impresses with its aesthetics and harmony, complementing the concept of a biosphere-compatible and energy-efficient building.

Engineering And Technological Solutions. In the new construction approach, an important element is passive adaptation to the environment, which can be achieved through the integration of the latest technologies and careful design. It is specified that the house should be connected to the electricity grid with an input power of 10 kW, acting as a partial backup source. This indicates a strategic approach to ensuring the reliability of the power supply in the face of possible interruptions. However, the key factor that attracts attention is the assessment of the total energy consumption of the building. It is noted that this passive individual house can reach a level of approximately 20 kWh/m^2 per year, considering all aspects, from heating and cooling to hot water supply. This figure indicates an impressive potential for energy efficiency and demonstrates that with the right design and technological solutions, high standards of energy savings can be achieved. The additional emphasis on sustainable interaction with climatic conditions not only ensures interior comfort but also minimises energy consumption for heating and cooling. Based on energy efficiency and ecological principles, this passive house sets a new standard for sustainable housing construction. All of this shows that high-performance housing can be not only innovative but also achievable. Considering the needs of modern society and climate change, such passive houses are becoming a model of sustainable living, where comfort and efficiency merge into a single harmonious space.

The heat supply system uses geothermal probes designed according to modern approaches to optimise energy extraction from a 90-metre-deep borehole for heating and hot water supply (Kulinko *et al.*, 2019). The heat pump operates in compressor mode in winter and reverse mode in summer. The energy-efficient system uses 4-pipe convectors for heating and cooling, and underfloor convectors are installed in the living room, children's room, and bedroom. Hot water is provided by a bivalent boiler. A recuperative ventilation system uses fresh air intake through a green area and tunnel to supply it to the air handling unit. The ecological water supply is obtained from a well of the second aquifer, and the wastewater is treated in individual treatment plants for further use in plant irrigation. The microclimate system in the building includes air purification and humidification functions. Lighting is provided by natural and artificial light using LED lamps. An automated control system allows residents to monitor all the building's engineering systems through a central processor that can receive commands locally or remotely via the Internet.

DISCUSSION

In the continental temperate climate zone, extreme temperature fluctuations and other weather conditions are important to consider. Passive houses are characterised by a high level of thermal insulation and an efficient ventilation system, which ensures a comfortable life for residents with minimal energy consumption. This is important both for reducing energy costs and for reducing the environmental impact of buildings. One of the key concepts is the use of modern renewable energy technologies, such as solar panels. This not only reduces the dependence on traditional energy sources but also contributes to the creation of energy-independent homes. Passive house designs also emphasise the importance of integrating environmental considerations into design and construction. This can include elements such as rainwater harvesting and utilisation systems, efficient use of natural light and other environmentally friendly solutions. So, the overview and concept of a passive individual dwelling house for a continental temperate climate indicate the need to combine innovation, energy efficiency and sustainability in construction to provide optimal living conditions with minimal environmental impact.

According to the results of research by L. Pajek & M. Košir (2021), the strategy of achieving long-term energy efficiency in European single-family buildings through passive climate adaptation is a promising direction in the field of sustainable construction. With its high population density and diverse climatic conditions, Europe is proving to be an ideal laboratory for introducing passive strategies into the building industry. Passive climate adaptation involves the careful design and construction of buildings that are designed to use natural resources efficiently and make the most of climatic features. The use of high-quality insulation materials, building orientation, optimised ventilation systems and the use of solar energy are key elements of this strategy. This strategy is not only aimed at reducing energy consumption and emissions but also at creating a comfortable environment for the occupants. Optimal temperature, good lighting and the best possible ventilation conditions help to ensure healthy and environmentally friendly housing. These findings are in line with the points made in the previous section. The Passive Climate Adaptation Strategy for Energy Efficiency in European Single-Family Buildings sets a new standard for sustainable residential construction, promoting environmental awareness and sustainability in the building industry (Kovalyshyn *et al*., 2023).

Referring to the definition of T. Yang *et al.* (2023), a review of the climate adaptation of phase transition materials incorporated into the building envelope for passive energy conservation reveals promising opportunities in the field of sustainable construction and energy efficiency optimisation. Phase transition materials have unique properties that allow them to deepen and release thermal energy during the phase transition, ensuring efficient thermal regulation in the building (Tsapko *et al*., 2022). The inclusion of such materials in building envelopes helps to stabilise the temperature regime of the premises, which is of great importance for passive energy saving. Their role in regulating the heat balance in the room is especially important, reducing the load on heating and air conditioning systems. It is worth noting that this approach contributes to the creation of buildings that effectively use natural processes to conserve energy while reducing heating and cooling costs. In addition, it reduces the ecological footprint of construction and contributes to sustainable development.

Y. Elaouzy & A. El Fadar (2022) determined that the integration of passive design strategies into buildings offers significant energy, economic and environmental benefits, making this approach a key focus in modern construction. From an energy point of view, the passive design maximises the use of natural resources and climatic conditions to regulate the temperature and lighting in a building. The use of wind energy, optimal solar orientation and thermal insulation materials helps to reduce energy consumption and ensure temperature stability. From an economic perspective, the implementation of passive strategies leads to a significant reduction in energy costs, which becomes a key factor in the cost of operating buildings (Baidrakhmanova *et al*., 2023). Significant savings on heating and air conditioning bills make such buildings financially viable for owners and occupants over the long term. Environmental benefits include reduced emissions of carbon dioxide and other pollutants due to lower energy consumption. Passive design contributes to the creation of energy-efficient, environmentally friendly buildings that meet the requirements of sustainable development and contribute to the conservation of natural resources. These results confirm the study findings, as the integration of passive design strategies into the construction process proves to be important not only in terms of energy conservation but also in terms of cost-effectiveness and positive environmental impact.

M. Hu *et al.* (2023) demonstrated that the impact of passive design on indoor thermal comfort and energy savings in residential buildings in hot climates is setting new standards for resource efficiency and sustainable living. A systematic review of this impact reveals several key aspects aimed at ensuring optimal conditions for occupants and minimising energy costs. One of the most important characteristics is the ability of passive design to effectively manage the heat balance in a building. The use of heat-insulating materials, intelligent thermal modelling and proper ventilation make it possible to maintain comfortable indoor temperature conditions, even at high ambient temperatures (Antypov *et al*., 2023). Saving energy in hot climates becomes critical, and passive design is a key tool to achieve this goal. Using natural energy sources, such as solar radiation to generate electricity and ventilation systems to optimise air circulation, makes buildings more energy-efficient and environmentally friendly. It is possible to agree with this opinion that passive design in hot climates not only improves thermal comfort but also accelerates the transition to sustainable living by reducing the negative impact of buildings on the environment and creating more efficient living conditions for residents.

As noted by A. Staszczuk & T. Kuczyński (2021), studying the impact of wall and roofing materials on the summer thermal performance of a building in a temperate climate defines key aspects of energy-efficient construction and a comfortable environment for occupants. Choosing the right materials is important to ensure optimal thermal insulation and response to the external environment. Wall material affects the distribution of heat in a building and can have a significant impact on its thermal performance. Materials with high thermal conductivity can lead to unpredictable heat distribution, while insulated materials can help to maintain a comfortable temperature inside the building (Tsapko *et al.*, 2020). Roofing materials are also important because they interact with solar radiation and determine the degree of thermal penetration. In temperate climates, where temperatures can fluctuate significantly, it is important to consider not only the thermal insulation properties but also the material's ability to regulate humidity and ventilation. Analysing the results and conclusions obtained, the impact of wall and roofing materials on summer thermal performance requires a comprehensive approach, considering the climatic conditions and the building's energy efficiency and comfort needs.

N. Fereidani *et al.* (2021) determined that a review of the energy implications of passive building design and active measures in the face of climate change reveals important aspects for sustainable development and ensuring efficient energy use in construction. Passive design is becoming a key tool in climate change adaptation strategies, as it allows for comfortable building conditions with minimal energy use. Climate change conditions require active measures to ensure energy efficiency and resilience of buildings to extreme weather conditions. Incorporating elements that reduce heat loads, such as solar panels and thermal insulation materials, into architectural solutions is becoming an important step in ensuring the long-term sustainability of building structures. Active measures, such as the use of renewable energy sources and efficient energy management systems, not only help to reduce the building's impact on climate change but also provide economic benefits and reduced utility costs. Furthermore, the energy implications of passive design and active measures in the face of climate change define a new paradigmatic approach to construction that promotes both sustainable development and adaptation to the challenges of a constantly changing environment.

CONCLUSIONS

In light of current trends in construction and the environment, it is important to consider passive individual houses as an effective option for continental temperate climates. An overview of such houses shows innovative solutions and technologies aimed at providing maximum comfort with minimum energy consumption. One of the key elements of the passive house concept is the use of high-quality insulation materials and techniques aimed at retaining heat in the room. Well-designed architecture and an efficient ventilation system allow for the necessary air exchange without significant energy loss. The use of solar panels for electricity generation and efficient use of natural light is also an important element. The integration of energy-saving systems and the use of renewable energy sources makes a passive house not only cost-effective but also environmentally friendly. Other benefits include resistance to extreme weather conditions and reduced heating and air conditioning costs. This creates a comfortable and cost-effective environment for the building's occupants.

This study presents a structured set of aspects and solutions related to the concept of designing and building an individual residential building that is biosphere-compatible and energy-efficient. It is noted that the house should be connected to the electrical grid with an input power of 10 kW, functioning as a partial backup source. At the same time, the assessment of the total consumption of the house demonstrates the possibility of reaching a level of approximately 20 kWh/m^2 per year, considering the needs for heating, cooling, and hot water supply. To summarise, a passive house for a continental temperate climate is an effective combination of innovative technologies, environmental friendliness, and comfort. It opens up new opportunities for sustainable development in construction and contributes to the formation of energy-efficient and environmentally conscious housing. To gain a deeper understanding of passive individual houses for continental temperate climates, optimal thermal protection methods, efficient ventilation models and the integration of modern energy management technologies should be investigated, which, in turn, provides prospects for further research in this area.

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CONFLICT OF INTEREST

None.

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Огляд та концепція пасивного індивідуального житлового будинку для умов континентального помірного клімату

Анотація. Актуальність дослідження полягає в необхідності розробки енергоефективних та стійких до змін клімату житлових просторів для забезпечення сталого розвитку та зменшення впливу на навколишнє середовище. Метою даного дослідження був аналіз інтегрованого концепту пасивного індивідуального житлового будинку, спеціально адаптованого до умов континентального помірного клімату, з акцентом на максимальну енергоефективність та забезпечення високого рівня комфорту для мешканців. У процесі дослідження використано аналітичний, класифікаційний, функціональний, синтез та інші методи. У статті розглянуто тенденцію підвищення енергоефективності та екологічності індивідуальних житлових будинків, що відповідає вимогам вуглецевої нейтральності та сталості. З використанням сучасних теплоізоляційних матеріалів та оптимізації концепції мінімізації теплопровідних включень вдалося різко зменшити трансмісійні тепловтрати будівлі. Результатом є інтегрований дизайн, що використовує високоякісні ізоляційні матеріали, оптимально розташовані вікна для максимального використання сонячної енергії та ефективні системи вентиляції з рекуперацією тепла. Однак інфільтраційні втрати залишаються суттєвими, і підвищення ефективності рекуперації та регенерації вентиляційних систем є ключовим напрямком досліджень. З урахуванням зниження трансмісійних втрат важливо розглядати внутрішні та зовнішні теплонадходження в індивідуальних будинках. Організація аспектів, що розглядає будинок як біосферно-сумісну та енергоефективну структуру, представляє собою актуальне завдання, і дослідження спрямоване на розробку інженерно-прикладної концепції проекту. Практичне значення даного дослідження полягає в створенні інноваційного житлового рішення, яке не лише оптимізує споживання енергії та забезпечує екологічність, але й відповідає конкретним вимогам континентального помірного клімату, сприяючи підвищенню сталості та ефективності будівельного сектору

Ключові слова: енергоефективність; комфорт; теплоізоляційні матеріали; рекуперація тепла; інтегрований дизайн