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The correlation between biophilic strategies and the energy performance of buildings

Corelația dintre strategiile biofilice și performanța energetică a clădirilor

Alexandra Rusen

RU-LU WORK EXPRES WEST SRL
9 May Street, No. 41, Moldova Noua, Caras Severin, Romania
E-mail: rusenalexandra97@gmail.com

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Abstract: *This article analyzes the relationship between the integration of biophilic design principles in architecture and the energy performance of buildings. Strategies such as natural lighting, natural ventilation, and the integration of vegetation are evaluated, highlighting their impact on energy consumption and indoor comfort. The study demonstrates that biophilic design is not only an aesthetic approach, but also an effective tool for optimizing the energy performance of the built environment.*

Key words: *biophilic design, natural ventilation, materiality, vegetation, stack effect (natural draft), skylight, orientation.*

1. Introduction

The concept of biophilia was introduced and developed by Edward O. Wilson, who defined it as “the innate tendency of humans to seek connections with nature and other forms of life.”

This idea is based on the fact that, from an evolutionary perspective, humans developed in direct contact with the natural environment, and this relationship has remained deeply rooted in human psychology and physiology. This predisposition has evolutionary origins and significantly influences mental state, health, and human behavior. In the context of the built environment, biophilia forms the theoretical foundation of biophilic design, which aims to integrate natural elements into architecture in order to improve quality of life and spatial performance.

In the current context of climate change and the increasing energy consumption in the construction sector—accounting for approximately 40% of total global energy use-there is a growing interest in sustainable design strategies. Within this framework, the concept of biophilia, introduced by Edward O. Wilson, has become an important theoretical reference, defining the innate human tendency to seek connections with nature.

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Recent research highlights that the integration of biophilic principles in architecture not only benefits users' health and well-being, but also has a significant impact on the energy performance of buildings. Studies conducted by Stephen R. Kellert emphasize the role of biophilic design in creating sustainable built environments, while reports published by the World Green Building Council underline the connection between passive strategies (such as natural lighting and natural ventilation) and reduced energy consumption.

Furthermore, specialized literature indicates that the use of natural elements—such as integrated vegetation, natural materials, and the optimization of the indoor–outdoor relationship—contributes to improving the indoor microclimate and reducing the energy demand for heating, cooling, and artificial lighting. However, there is still a lack of studies that directly quantify the correlation between biophilic strategies and energy performance, particularly in the context of single-family housing in Eastern Europe.

2. Strategies applicable in architecture

This study aims to investigate the correlation between biophilic strategies and the energy performance of buildings by addressing the following main research directions: the identification and systematization of the conceptual framework and the main biophilic strategies applicable in architecture; the evaluation of the impact of these strategies on building energy consumption; the analysis of the relationship between indoor comfort parameters and the energy efficiency of built spaces; the development of a case study on semi-detached house dwelling in order to highlight the practical applicability of biophilic principles; and the formulation of well-founded recommendations for integrating biophilic strategies into the architectural design process.

- ***Identification and Systematization of the Conceptual Framework and Main Biophilic Strategies Applicable in Architecture***

The identification and systematization of the conceptual framework of biophilia, as well as of the main biophilic strategies applicable in architecture, represent an essential step in establishing the theoretical foundation of this research. The concept of biophilia, introduced by Edward O. Wilson, describes the innate human predisposition to develop a connection with nature, with significant implications for human health and behavior [1].

In the field of architecture, this concept was further developed and operationalized by Stephen R. Kellert, who defines biophilic design as an approach aimed at integrating nature into the built environment, contributing to the creation of healthy and sustainable spaces [2]. Subsequently, research has been expanded through a clearer structuring of biophilic strategies, particularly in the work of Browning et al., which proposes a model based on three main categories: nature in the space, natural analogues, and nature of the space [3].

According to these studies, the direct integration of nature (nature in the space) includes elements such as vegetation, natural light, water, and natural ventilation, being associated with improved environmental comfort and reduced energy consumption through passive strategies [3]. Indirect integration (natural analogues) involves the use of natural materials, forms, and textures inspired by nature, contributing to the creation of a psychologically supportive indoor environment [2].

The third category, nature of the space, refers to spatial configurations inspired by the natural environment, including features such as open perspectives, gradual transitions between interior and exterior, and variations in light and volume. These characteristics enhance user experience and contribute to the creation of a built environment adapted to fundamental human needs [3].

Furthermore, reports published by the World Green Building Council highlight that biophilic strategies can have a significant impact on building performance, particularly by reducing energy consumption and improving indoor environmental quality [4].

Therefore, the systematization of these strategies provides a coherent framework for analyzing the relationship between biophilic design and energy performance, demonstrating that biophilia is not only a theoretical concept but also a practical tool for optimizing building performance.

- ***Evaluation of the impact of these strategies on building energy consumption***

The analysis of the energy impact of biophilic strategies highlights that they are not merely aesthetic or psychological interventions, but effective mechanisms for optimizing building energy consumption. The specialized literature indicates a direct correlation between the integration of natural elements and the reduction of energy demand for lighting, heating, and cooling.

The optimized use of natural light represents one of the most effective biophilic strategies with a direct energy impact. Studies show that the integration of daylighting can reduce energy consumption for artificial lighting by approximately 20% to 60%, depending on building typology and the adopted design solutions [5].

Moreover, solar gains contribute to the passive heating of spaces during the cold season, reducing the energy demand for heating. However, the lack of solar control measures may lead to overheating during the warm season, highlighting the need for complementary solutions such as shading devices or high-performance glazing [6].

Natural ventilation significantly contributes to reducing the energy consumption associated with mechanical cooling systems. Its use can decrease cooling energy demand by up to 30% under certain climatic conditions [7].

At the same time, natural ventilation improves indoor air quality and helps maintain adequate thermal comfort, reducing dependence on HVAC systems [8].

The integration of vegetation into architecture has a direct impact on the microclimate and on building energy performance. Vegetation contributes to lowering outdoor temperatures through shading and evapotranspiration processes, thereby reducing cooling demand [9].

Green roofs can reduce heat flux through the building envelope and may lower indoor temperatures by approximately 1–3°C during summer periods [10].

The use of natural materials contributes to regulating indoor comfort conditions through their hygrothermal properties. Materials with high thermal mass can reduce temperature fluctuations and the energy demand for heating and cooling [6].

The energy impact of biophilic strategies is maximized when they are integrated within a holistic approach. The combination of daylighting, natural ventilation, and integrated vegetation can lead to a significant reduction in the overall energy consumption of buildings [3].

- ***Analysis of the relationship between indoor comfort parameters and the energy efficiency of built spaces***

The analysis of the relationship between indoor comfort parameters and the energy efficiency of built spaces highlights the interdependence between the environmental conditions perceived by users and the energy consumption required to maintain these conditions within optimal limits. Indoor comfort parameters—such as air temperature, relative humidity, air quality, and daylight levels—directly influence the energy performance of buildings, as their regulation involves the use of heating, cooling, ventilation, and artificial lighting systems [6].

The specialized literature emphasizes that optimizing these parameters through passive strategies, characteristics of biophilic design, can lead to a significant reduction in energy consumption without compromising user comfort. For instance, the use of natural lighting and natural ventilation reduces dependence on mechanical systems [5], [7], while the integration of materials with high thermal mass contributes to stabilizing indoor conditions and reducing temperature fluctuations [6].

At the same time, studies on passive climate control highlight that maintaining thermal comfort can be achieved by harnessing natural resources such as solar radiation, air movement, and the thermal mass of materials, thereby reducing the demand for conventional energy [8]. In this context, biophilic strategies—such as the integration of vegetation and the optimization of the indoor–outdoor relationship—contribute to improving the indoor microclimate and increasing the energy efficiency of buildings [9], [10].

Thus, a direct relationship can be observed between the enhancement of indoor environmental quality and energy efficiency, provided that design solutions are coherently integrated from the conceptual stage. In this regard, biophilic design can be considered an integrated approach that not only improves indoor comfort but also optimizes the energy performance of built spaces by leveraging natural resources and reducing dependence on active systems [3].

3. Case study: application of biophilic principles in a single-family dwelling

The development of a case study on a semi-detached house dwelling aims to highlight the practical applicability of biophilic principles and to analyze their impact on energy performance and indoor comfort. The case study represents a commonly used method in architectural research, allowing the correlation of the theoretical framework with concrete design solutions [2].

The analyzed dwelling is configured in accordance with biophilic design principles, through the integration of strategies such as optimal orientation relative to cardinal directions, maximization of natural lighting, implementation of natural ventilation by positioning openings on opposite facades, and the use of natural materials. These interventions contribute to reducing energy consumption and improving indoor environmental quality, being consistent with passive design strategies described in the specialized literature [6], [7].

At the same time, the natural variation of light within the interior space supports the principles of biophilic design by reproducing natural rhythms and enhancing the visual and psychological comfort of users [3]. Thus, the integration of daylight becomes not only a functional element but also an essential component in shaping a qualitative and sustainable spatial experience.

The analyzed case study focuses on a duplex residential building (semi-detached house) with a height regime of ground floor + one upper floor (P+1), characterized by a simple, compact volumetry and an architectural expression based on the use of natural materials and a direct relationship with the outdoor environment.

Fig. 1. Architectural rendering of the duplex as a case study

The overall configuration of the building highlights a contemporary approach in which biophilic principles are integrated both at a functional and at a compositional level.

The analyzed floor plans highlight a coherent functional organization, in which spaces are configured in an efficient, compact, and ergonomic manner, adapted to users' needs and aligned with the principles of biophilic design. Their dimensions are established in such a way as to avoid unnecessary surfaces, optimizing circulation flows and the use of interior space.

The daytime area, located on the ground floor, is conceived as an open-plan space integrating living, dining, and kitchen functions, promoting both visual and functional continuity. This configuration allows for a direct relationship with the exterior through large openings towards green spaces, facilitating the penetration of natural light and creating a constant connection with the natural environment.

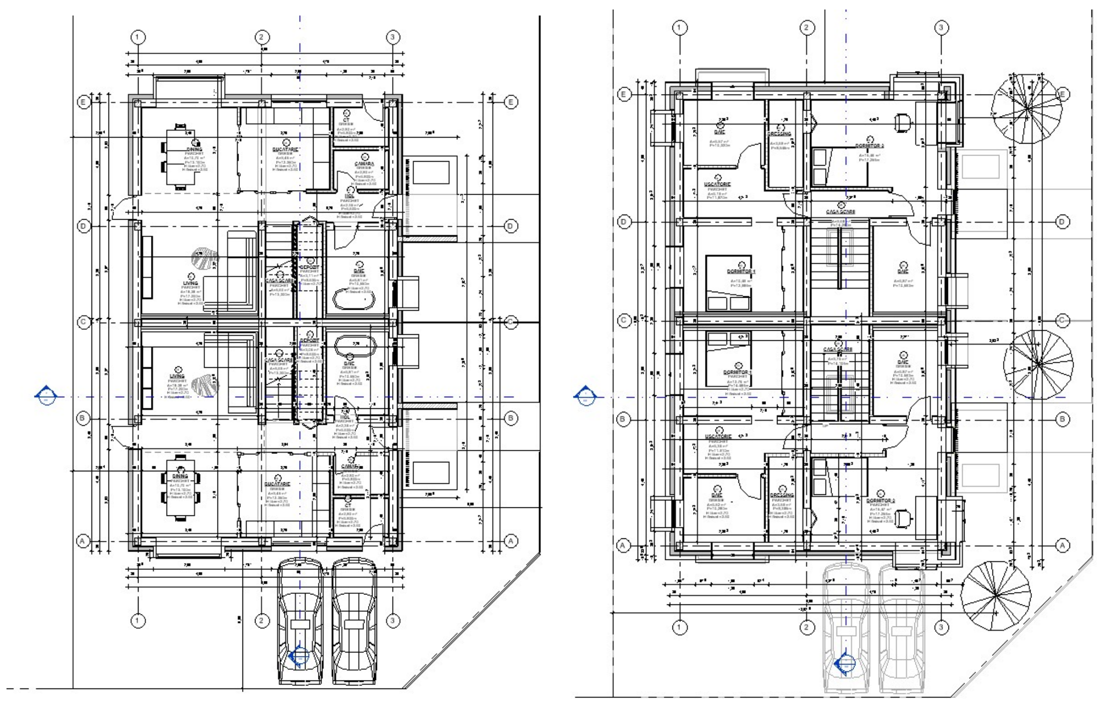


Fig. 2. Ground floor plan and first floor plan of the duplex

On the upper floor, the night-time spaces are organized to ensure privacy while maintaining a direct relationship with the exterior, through the orientation of rooms towards the green areas of the site. Each room is ergonomically dimensioned, ensuring a balance between functionality and comfort without overcrowding the space.

A central element of the spatial organization is the staircase, which functions not only as a vertical circulation element but also as a biophilic and climatic core of the dwelling. It facilitates natural ventilation and the integration of vegetation, contributing to the creation of a favorable indoor microclimate.

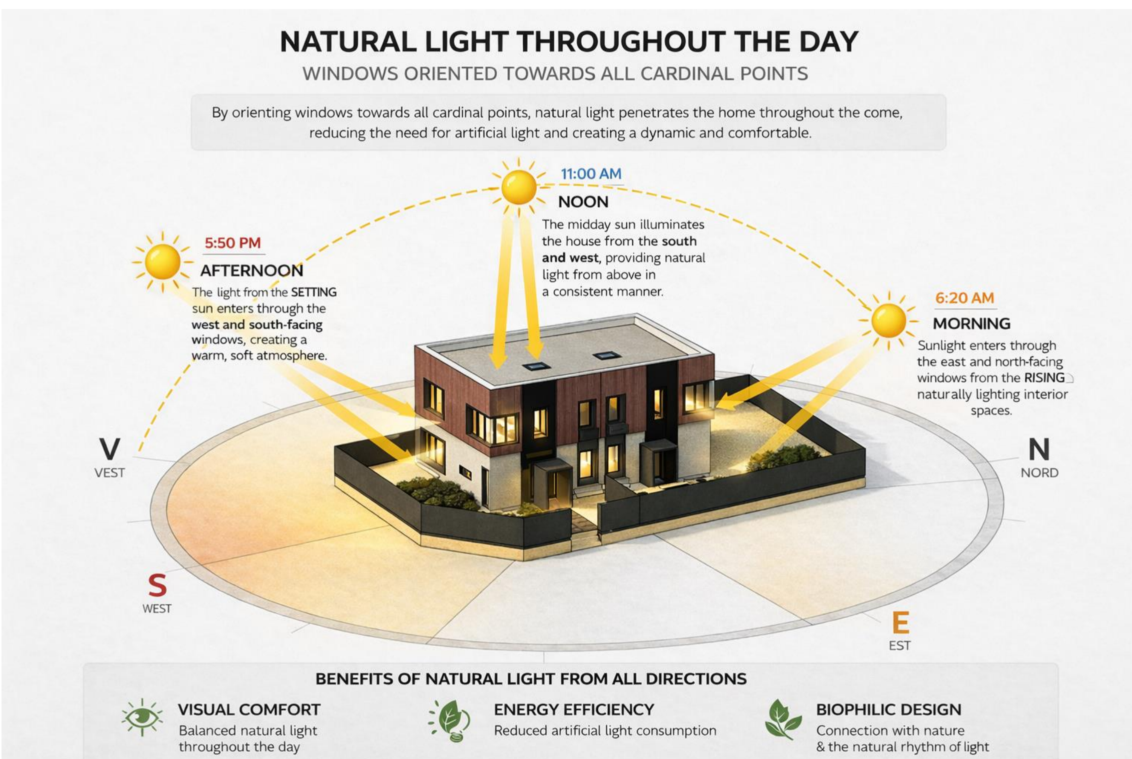
The interconnection of spaces is achieved in a fluid manner, without major discontinuities, allowing for a unified perception of the dwelling and a continuous relationship with nature. The placement of the building within a natural setting is enhanced through the orientation of openings towards the exterior, providing visual connections to vegetation and ensuring direct exposure to the natural environment. The space is not merely inhabited, but experienced in direct relation to nature.

Thus, the planimetric organization reflects a contemporary approach in which spatial efficiency, ergonomics, and the integration of nature are correlated, generating a balanced, sustainable living environment adapted to current needs [3].

The distribution and sizing of façade openings have been designed to ensure a constant supply of natural light throughout the day, by orienting windows towards all cardinal directions. As a result, natural light gradually penetrates interior spaces depending on the position of the sun, contributing to the creation of a dynamic and visually balanced environment.

The southeast and southwest orientations favor solar gains during morning and afternoon periods, while openings towards other directions complement daylighting throughout the entire day. This strategy reduces dependence on artificial lighting and contributes to optimizing the building's energy consumption [5].

An essential element of the case study is the relationship between the interior space and the external environment, achieved through large glazed surfaces, terraces, and the integration of vegetation in the immediate proximity of the building. These solutions facilitate natural lighting, support natural ventilation, and generate a favorable microclimate, with a positive impact on energy consumption [3], [9].



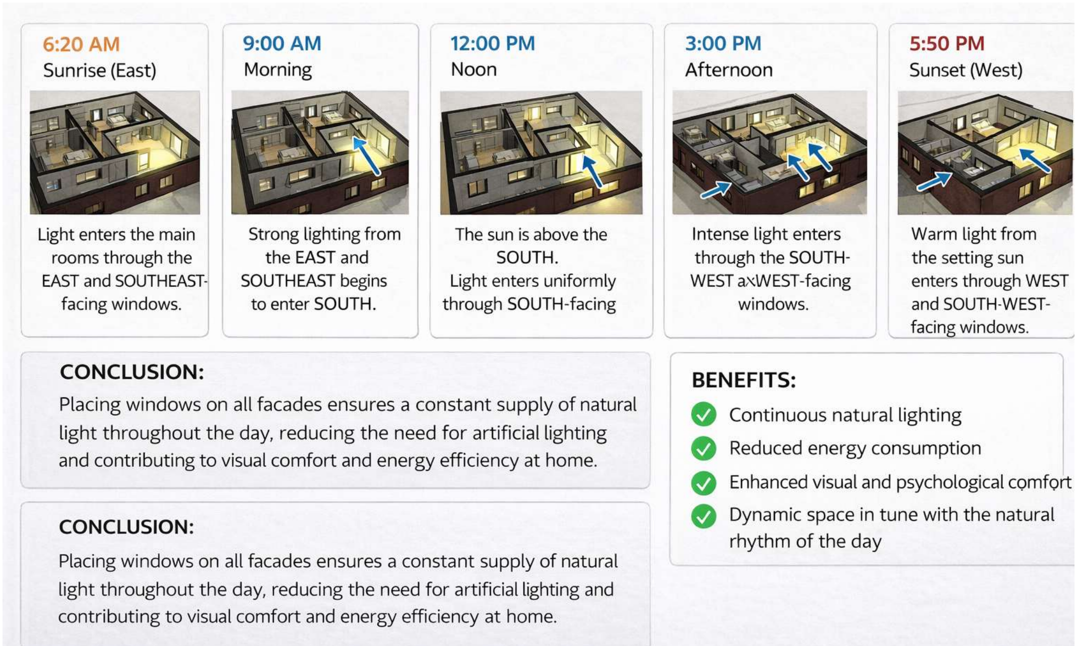


Fig. 3. Sunlight study – highlighting the contribution of natural light throughout the day

Furthermore, the integration of vegetation and materials with hygrothermal properties contributes to stabilizing indoor conditions and reducing temperature fluctuations, thereby decreasing the energy demand for heating and cooling [6], [10]. Thus, the analyzed dwelling demonstrates how biophilic strategies can be coherently implemented, generating benefits both in terms of energy performance and user comfort.

An essential aspect of optimizing natural ventilation in the analyzed dwelling is the use of the stack effect, generated by temperature and pressure differences between the lower and upper areas of the building. A hybrid ventilation system is therefore proposed, combining natural ventilation during the warm season with mechanical ventilation with heat recovery during the cold season. Fresh air enters through windows located on the southern façade, is drawn through the interior spaces, and is subsequently exhausted through a roof window (Velux type) positioned above the staircase, in the northern area. This configuration promotes the creation of an upward airflow, driven by the natural tendency of warm air to rise, achieving efficient natural ventilation without additional energy consumption [7].

Through this mechanism, continuous renewal of indoor air is ensured, contributing to maintaining air quality and reducing the need for mechanical ventilation. At the same time, this passive ventilation system facilitates the removal of overheated air during the warm season, playing an important role in the building's natural cooling strategy [8]. The integration of such a solution highlights a coherent application of biophilic and bioclimatic principles, by harnessing available natural resources and reducing dependence on active HVAC systems.

An innovative element proposed within the analyzed dwelling is the integration of a vertical greenery system located in the staircase, correlated with the natural ventilation mechanism based on the stack effect. In this area, a green wall composed of potted plants arranged on metal supports is proposed, characterized by a substantial vegetal volume that contributes to creating a favorable indoor microclimate. The system is complemented by a sprinkler assembly that sprays water onto the vegetation, facilitating evapotranspiration processes and the natural cooling of the air.

The fresh air introduced through the lower facades of the building passes through this vegetated zone, where it is partially cooled and humidified, and is subsequently exhausted through the upper roof window positioned above the staircase. Thus, the staircase functions as an active “ventilation chimney,” where the interaction between vegetation, water, and airflow contributes to improving indoor air quality and reducing air temperature, in accordance with the principles of passive evaporative cooling [8], [9].

The sprayed water is collected at the base of the green wall through a drainage grid and directed to an external reservoir, allowing its recirculation and reducing resource consumption. This integrated system highlights a sustainable approach in which biophilic elements are correlated with building services solutions, contributing both to energy efficiency and to the creation of a healthy and comfortable indoor environment [3].

The natural ventilation system based on the stack effect, integrated with the green wall and evaporative cooling elements, demonstrates high efficiency during the warm season, contributing to the reduction of overheating and the improvement of indoor thermal comfort.

Under high temperature conditions, warm air inside the dwelling accumulates in the upper part of the staircase and is evacuated through the roof window (Velux type). This process generates an intensified natural draft, which induces the intake of fresh outdoor air through openings located at the lower levels, particularly on the southern façade. Thus, a continuous airflow is created, contributing to the cooling of interior spaces without the use of mechanical air-conditioning systems [7].

During the cold season, natural ventilation through the stack effect is limited by keeping the roof window closed, in order to avoid heat losses. Under these conditions, the ventilation system is adapted through the integration of controlled solutions that maintain indoor air quality without compromising energy efficiency.

An effective solution consists in the use of a mechanical ventilation system with heat recovery (HRV – Heat Recovery Ventilation), integrated within the staircase area. The stale air extracted from the upper part of the dwelling passes through a heat exchanger, where it transfers thermal energy to the incoming fresh air from outside. In this way, indoor air renewal is ensured with minimal energy losses [6].

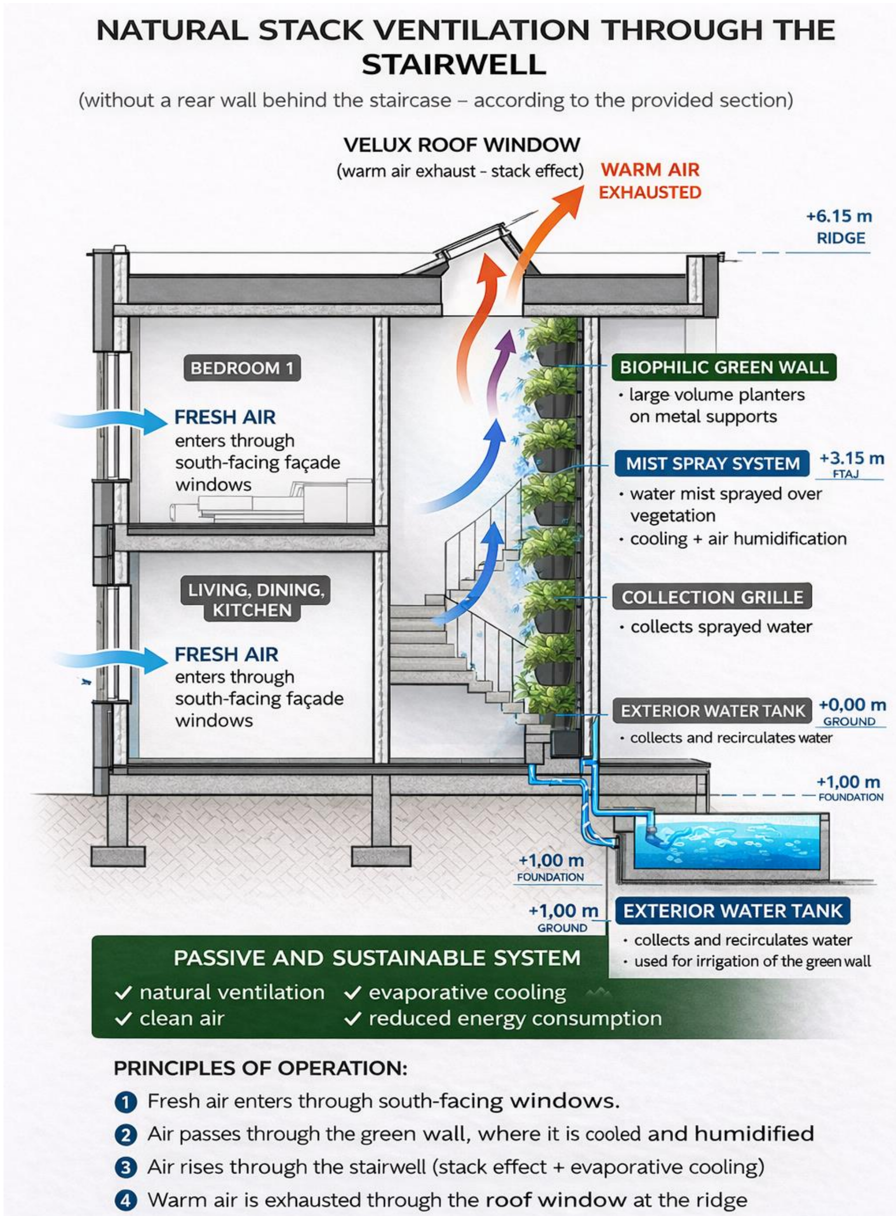


Fig. 4. Natural ventilation scheme based on the stack effect and integration of the biophilic green wall

Within the proposed system, the staircase functions as a warm air collection zone, without allowing direct exhaust to the exterior. The air is captured through extraction grilles and directed to the heat recovery unit, where thermal energy is reused. This solution maintains the principle of vertical air circulation, characteristic of biophilic design, but in a controlled and energy-efficient manner.

The green wall maintains its role during the cold season; however, the operation of the sprinkler system is reduced or adjusted to avoid excessive humidity. The vegetation continues to contribute to improving air quality and stabilizing the indoor microclimate.

Therefore, the proposed system operates differently depending on the season: in summer, natural ventilation through the stack effect ensures passive cooling of the building, while in winter, ventilation is controlled and based on heat recovery, reducing energy losses and maintaining indoor comfort [3], [6].

Consequently, the case study demonstrates that the application of biophilic principles in the design of single-family dwellings represents a viable solution for increasing energy efficiency and improving the quality of the built environment, confirming their relevance in contemporary architectural practice.

3. Conclusions

The conducted analysis highlights that the integration of biophilic principles into architectural design significantly contributes to improving both energy performance and indoor environmental quality. Through the use of passive strategies—such as natural ventilation, optimized daylighting, and the integration of vegetation—the dependence on mechanical systems is reduced, thereby lowering the overall energy consumption of the building.

The analyzed case study demonstrates the practical applicability of these principles in a contemporary single-family dwelling, in which spatial organization, orientation, and materiality are closely correlated with natural factors. The compact and ergonomic plan configuration enables efficient space utilization, while openings oriented towards all cardinal directions ensure a consistent supply of natural light throughout the day, contributing to visual comfort and reducing the need for artificial lighting.

A key element in the building's performance is the staircase, which becomes an active component of the natural ventilation system, functioning as a ventilation chimney based on the stack effect. The integration of the green wall, combined with a sprinkler system and water recirculation, enhances the efficiency of this mechanism through evaporative cooling processes and the improvement of indoor air quality.

Furthermore, the seasonal operation of the system—natural ventilation during the warm season and controlled ventilation with heat recovery during the cold season—highlights the adaptability and sustainability of the proposed solution. The integration of building services systems in correlation with biophilic strategies allows for the optimization of energy consumption without compromising user comfort.

The use of natural materials such as stone, wood, and fired ceramics contributes to the regulation of hygrothermal conditions and to the creation of a healthy indoor environment, while color schemes and the variation of natural light support a dynamic spatial experience aligned with natural rhythms.

In conclusion, the analyzed project demonstrates that biophilic design is not merely an aesthetic direction, but an integrated design strategy capable of addressing contemporary requirements related to energy efficiency, sustainability, and quality of living. The coherent implementation of these principles leads to the creation of balanced, efficient architectural spaces that are deeply connected to the natural environment.

References

[1] E.O. Wilson, Biophilia, Harvard University Press, Cambridge, 1984.

[2] S.R. Kellert, Biophilic Design: The Theory, Science and Practice of Bringing Buildings to Life, Wiley, New York, 2008.

[3] W. Browning, C. Ryan, J. Clancy, 14 Patterns of Biophilic Design: Improving Health & Well-Being in the Built Environment, Terrapin Bright Green, New York, 2014.

[4] World Green Building Council, Health, Wellbeing and Productivity in Offices, World Green Building Council, London, 2014.

[5] C.F. Reinhart, K. Voss, "Monitoring manual control of electric lighting and blinds", Lighting Research & Technology, nr. 3, 35, 2003, pp. 243–260.

[6] N. Lechner, Heating, Cooling, Lighting: Sustainable Design Methods for Architects, Wiley, Hoboken, 2015.

[7] F. Allard, Natural Ventilation in Buildings: A Design Handbook, James & James, London, 1998.

[8] M. Santamouris, D. Asimakopoulos, Passive Cooling of Buildings, James & James, London, 1996.

[9] E. Alexandri, P. Jones, "Temperature decreases in an urban canyon due to green walls and green roofs", Building and Environment, nr. 4, 43, 2008, pp. 480–493.

[10] K.L. Getter, D.B. Rowe, "The role of extensive green roofs in sustainable development", HortScience, nr. 5, 41, 2006, pp. 1276–1285.