



GLASS FAÇADES AS A COMPONENT OF SUSTAINABLE ARCHITECTURE – ANALYSIS OF SELECTED CASES

FASADY SZKLANE JAKO ELEMENT ARCHITEKTURY ZRÓWNOWAŻONEJ – ANALIZA WYBRANYCH PRZYPADKÓW

Sylvia Mochocka*, Małgorzata Wijas, Weronika Kaczmarczyk
Kielce University of Technology, Poland

Abstract

The governance of sustainable energy represents one of the principal concerns in the current era. The escalation of global warming and the depletion of natural resources have become progressively pertinent issues, underscoring the crucial role of sustainable architecture in addressing these pressing concerns. In the context of advancing sustainable development and environmental preservation, contemporary construction processes hold significant importance. Sustainable design in architectural practices plays a crucial role in strategizing the construction of buildings to curtail their energy consumption and utilization of natural resources. In the context of escalating standards for energy conservation, twin-layered façades are gaining significant traction. This paper aims to substantiate that incorporating a double façade in structures is not just a trend, but a critical component in the execution of sustainable growth. These façades play a key role in improving energy management and enhancing the quality of urban life, by yielding quantifiable ecological and energy outcomes.

Keywords: glass façade, sustainable development, sustainable design, friendly city, bioclimatic comfort.

Streszczenie

Zrównoważone zarządzanie energią stanowi jedną z kluczowych kwestii współczesnych czasów. Wraz ze zmianami zachodzącymi na świecie zmieniają się również potrzeby i pojawiają się nowe wyzwania, którym musimy sprostać. Nowoczesne budownictwo odgrywa istotną rolę we wspieraniu zrównoważonego rozwoju. Elementy zrównoważonego projektowania w architekturze obejmują m.in. planowanie budynków w taki sposób, aby minimalizować ich zużycie energii i zasobów naturalnych. W związku z rosnącymi standardami energooszczędności coraz większą popularność zyskują fasady dwupowłokowe, znane również jako fasady z „podwójną skórą”. Są to tradycyjne fasady, na które nałożono dodatkową, zewnętrzną warstwę, zazwyczaj wykonaną ze szkła. Celem artykułu jest wykazanie, że wprowadzenie podwójnej fasady do budynków jest istotnym elementem realizacji zrównoważonego rozwoju, umożliwiającym efektywniejsze zarządzanie energią. Korzyści wynikające z realizacji takich obiektów, dzięki zastosowaniu odpowiednich technologii i metod budowlanych, mają kluczowe znaczenie dla jakości życia w mieście. Wpływają one na poprawę właściwości termoizolacyjnych budynków, komfortu cieplnego oraz mikroklimatycznego, a także przynoszą wymierne efekty ekologiczne i energetyczne.

Słowa kluczowe: fasada szklana, zrównoważony rozwój, projektowanie zrównoważone, miasto przyjazne, komfort bioklimatyczny.

1. INTRODUCTION. SUSTAINABLE ARCHITECTURE

Sustainable development combines socio-economic advancement with political, economic, and social initiatives, ensuring the preservation of

natural equilibrium and the durability of essential environmental procedures. These initiatives are conceived to fulfil the requirements of contemporary society in a manner that does not infringe upon

*Kielce University of Technology, Poland, e-mail: smochocka@tu.kielce.pl

the capacities of future generations to satisfy their individual needs [1].

Sustainable design, a crucial constituent in implementing the Sustainable Development Goals, responds to challenges encompassing “urban sprawl”, the contraction of non-renewable energy resources, excessive water discharge, and territory desertification. By addressing these challenges, sustainable architecture significantly enhances the quality of life, inspiring us to continue our efforts in this field [2].

The evolution of sustainable development discourse concerning architecture or construction can be traced back to the 1990s. References such as “A Primer on Sustainable Building” [3] and “Handbook of Sustainable Building” [4] can be cited in this context. The existing corpus of investigation concerning sustainable development is exceptionally comprehensive. In her research, M. Stawicka-Wałkowska has elucidated the fundamental tenets of sustainable development concerning the construction industry [5]. Concurrently, A. Baranowski, through his scholarly work, has explained the concept of sustainable design and endeavoured to formulate a sustainable design methodology within the discipline of architecture [6]. The issue of creating sustainable architectural designs and their evaluation is discussed in the works of S. Wehle-Strzelecka, who investigates solar architecture and its relation to residential environmental quality [7]. Similarly, E. Niezabitowska and D. Masły explore the evaluation of built environment quality and its importance in advancing sustainable building concepts in their research [8]. M. Jagiełło-Kowalczyk [9] and L. Kamionka [10] also embark on detailed research concerning the sustainable design of living environments in their works, with the latter delineating a strategy for addressing architectural design issues from the perspective of sustainable development.

The proliferation of research on sustainable design is unquestionably fuelled by designers’ escalating consciousness about the irreversible repercussions of global warming, such as rising sea levels, extreme weather events, and loss of biodiversity. The construction industry is projected to contribute significantly to these environmental and societal implications, accounting for an estimated 40% of global energy consumption and 36% of greenhouse gas emissions.

According to World Economic Forum data, the improvement and use of structures contribute 38% of CO₂ discharges and are responsible for approximately 30% of worldwide waste [11]. The data emphasises

the substantial role of the modern architect, whose endeavours should aim to reduce energy use and prudently manage natural resources, thereby impacting human life quality [12].

The endeavour to establish sustainable architecture is intrinsically tied to selecting technical methods, which indisputably influence the shape of the planned and implemented structures.

Materials such as wood and natural stone are generally considered to be eco-friendly. In contrast, others, like concrete, which contributes to CO₂ emissions; plastics, which lead to global littering; and glass, which results in building overheating during summer and heat loss during winter, are viewed as detrimental to the environment.

The paradigm of construction and its associated technologies has been reevaluated due to climate change. Manufacturers of materials are striving to enhance and diminish their ecological impact, such as fabricating concrete with a lowered carbon footprint or amalgamating photovoltaic components embedded in the façade with dynamic façade systems. The implementation of sustainable development principles necessitates substantial alterations in the methodology of architectural planning. Opting for an appropriate building façade provides an array of possibilities in this context, acting not merely as the interface between the interior and the external environment, demarcating thermal sectors and shielding against unfavourable meteorological conditions, but also influencing the energy efficacy of the structure. An appropriately engineered glass façade exhibits multifunctionality, shaping both the aesthetic appeal and architectural shape of the structure while establishing a synergy between the interior and exterior and facilitating efficient room ventilation [13]. This type of façade can be exemplified by the “double-skin façade”.

2. AIM OF THE STUDY

The aim of this study is to discuss the potential of double-skin façades for improving energy efficiency, enhancing thermal comfort, and contributing to sustainable development in architecture.

The documented advantages of implementing such building façade typologies significantly influence the standard of living while delivering satisfactory outcomes in terms of ecological and energy efficiency.

A crucial component of this analysis involves delineating the advantages of utilising glass façades as an alternative to conventional building exteriors. By highlighting them as innovative solutions that

harness contemporary technological capabilities, we can inspire excitement about the future of sustainable architecture.

3. METHODOLOGY

The research applies a descriptive analysis based on selected case studies. The adopted criteria for analysis are derived from the diagram presented in Figure 1, which outlines key aspects of double-skin façades systems in the context of sustainable design. The main evaluation criteria include:

- energy efficiency – potential for reducing energy consumption;
- thermal insulation – ability to improve building insulation;
- indoor comfort – enhancement of thermal comfort and indoor air quality;

- natural ventilation – possibility of using passive or mechanical ventilation systems;
- architectural and urban integration – contribution to the aesthetic and functional quality of the building and its urban surroundings.

These criteria were used to analyse the selected examples presented in the case study section.

4. “SECOND SKIN” FAÇADE

From an architectural perspective, windows constitute a crucial component of the building envelope. They establish the physical demarcation between the interior and exterior while safeguarding the interior from the influence of the external environment. Furthermore, they perform a significant function in the energy efficiency of structures, owing to their capability to permeate daylight and solar warmth (Fig. 2).

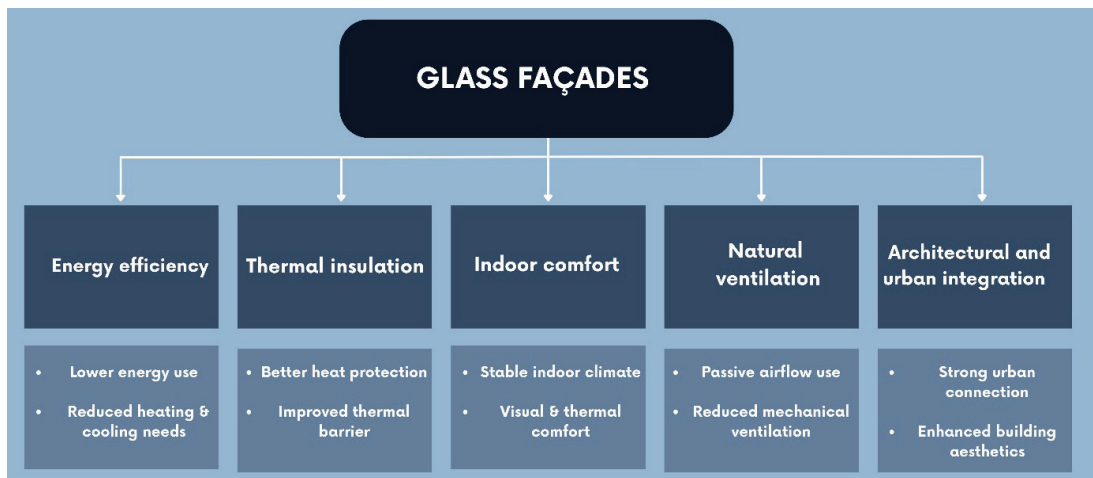


Fig. 1. Benefits of double-skin façade systems. Diagram summarizing the analytical criteria applied in the case study evaluation (study by S. Mochocka)

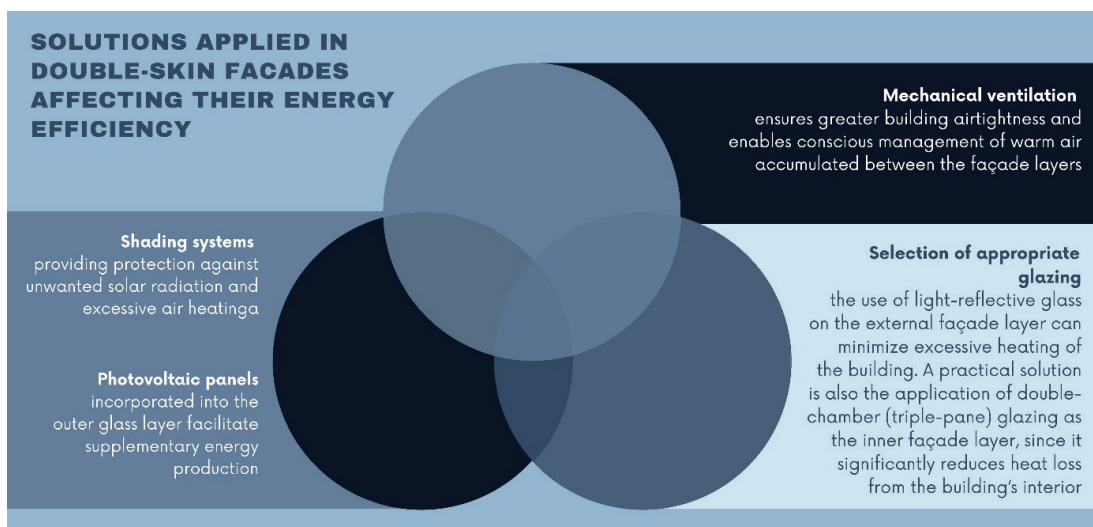


Fig. 2. Technological solutions in glass façade systems. Conceptual diagrams summarizing the design considerations discussed in the study (study by W. Kaczmarczyk)

Glass is one of the most prevalent materials, significantly influencing structure and aesthetic appeal and delineating the connectivity of a building with its external surroundings. The beginning of contemporary glass and steel infrastructures can be traced back to The Crystal Palace, which was erected in 1851 in London, following the architectural blueprint of Joseph Paxton [14]. After this period, there have been substantial advancements in materials technology, with objectives encompassing mitigating their detrimental environmental effects. Contemporary fenestration technologies are centred on enhancing the thermal insulating properties and inhabitant convenience while curtailing the energy consumption of structures. An instance can be observed in the so-called “double skin” façade, representing a conventional façade supplemented with an additional exterior layer, frequently made of glass. The first known example of using a “double skin” façade is the Steiff Corporation’s machine hall building from 1903. The dual glass sheathing primarily facilitated acoustic insulation while functioning as a thermal buffer and ventilation conduit. One instance of the pioneering application of this technology is embodied by the building of the Faculty of History at the University of Cambridge, erected from 1964 to 1968 under the supervision of James Sterling. This initiative incorporated novel strategies based on a dual-layered glass structure, wherein the exterior layer comprised dynamic components such as ventilators, whilst the interior layer was constituted by sandblasted glass. The substantial influence of Polish initiatives dating back over four decades warrants emphasis. Examples such as the Double Shell Glass Façade in Zachęta II by O. Hansen, L. Tomaszewski and St. Zamecznik, or the Houses of the Centre in Warsaw by Z. Karpiński, E. Waclawek and J. Jakubowicz (with the technical development of the wall by Borowski) remain an inspiration for today’s advanced projects [15].

A vital component of the double façade system is the air gap between the two barriers, offering additional operational space, such as for terraces. Depending on their design, these can serve as leisure areas that enhance the building’s reception by its occupants or as installation zones for ventilation systems without detriment to the building’s aesthetic appeal. Furthermore, this area facilitates indirect air circulation via the buffer zone, typically accessed through dedicated ventilation openings in the outer façade [16]. The air is disseminated within the buffer zone, infiltrating spaces with operable windows.

The exterior glass layer attenuates wind blasts at significant elevations, enabling the application of gravitational ventilation even at the level of multiple tens of floors. The double façade can be subject to natural or mechanical ventilation, contingent on the employed system, and it enables the implementation of supplementary installations within the inter-skin space to channel the accumulated air into the building’s energy regulation system, which could profoundly influence the operational expenditures of the entire building [17].

An appropriate selection of glass combination is pivotal to maximise the advantages derived from using a double façade [18, 19]. Furthermore, the strategic placement of windows and doors on the façade and incorporating additional components like awnings, shutters, sun breakers, or louvres is of great significance [20]. All these elements considerably influence the comfort of building users, are associated with appropriate temperature, humidity, and indoor air quality, and are associated with the structure’s energy performance [21]. From a broader perspective, they affect the comprehensive quality of life within the urban setting [22].

5. CASE STUDY 1 – UBER WORLD HEADQUARTERS, SAN FRANCISCO (FIG. 3)

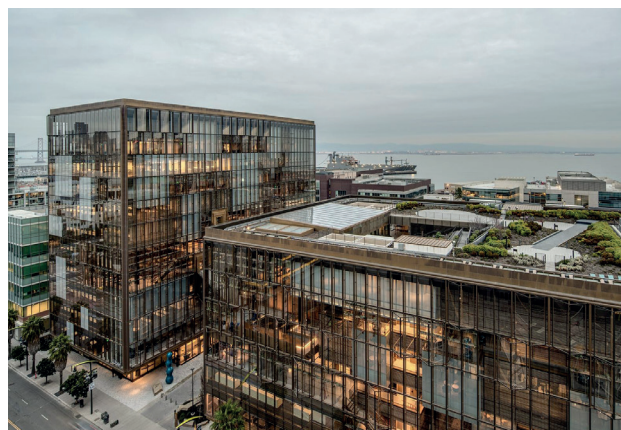


Fig. 3. Uber Technologies headquarters in San Francisco. Source: <https://www.qa-us.com/project/uber-world-head-quarters> (accessed: 01 July 2024)

The seat of Uber Technologies in San Francisco, situated centrally in Mission Bay, encompasses two towers—a structure of six levels and another of eleven—interconnected via perspicuous overpasses above Pierpoint Lane. Both buildings feature technologically advanced façades, equipped with systems enabling the regulation of openings for natural ventilation and

daylight control. The permeable façades link interior and exterior environments via full-dimension atria (Fig. 4).



Fig. 4. Uber Technologies headquarters, bridges connecting buildings. Source: <https://www.qa-us.com/project/uber-world-headquarters> (accessed: 01 July 2024)

The headquarters of Uber Technologies is not merely practical but also technologically superior, integrating architectural design with cutting-edge façade strategies. Within the functional programme's scope are offices, cafés, childcare provisions and retail outlets situated on the ground level [23]. Applying a dual façade in the building facilitated impressive architectural formation and more efficient exploitation of solar energy for internal illumination. It enhanced the inhabitants' welfare by integrating interior atriums, supplementary leisure areas (Fig. 5).



Fig. 5. Uber Technologies headquarters, view of exterior façade. Source: <https://www.qa-us.com/project/uber-world-headquarters> (accessed: 01 July 2024)

Double-skin façade technology contributes to higher energy efficiency by optimizing solar gains and reducing the need for artificial illumination. It contributes to thermal insulation by introducing

a buffer zone for the two façade skin to reduce heat loss and improve thermal performance in buildings. The façade design also contributes to indoor comfort by stabilizing the interior temperatures, providing natural daylighting, and sufficient air quality through integrated natural ventilation systems.

The presented case was analyzed according to the criteria in Figure 1, demonstrating its potential in terms of energy performance, indoor comfort, and architectural integration.

6. CASE STUDY 2 – CULTURAL CENTRE AS A LOCAL CREATIVE SPACE (FIG. 6)

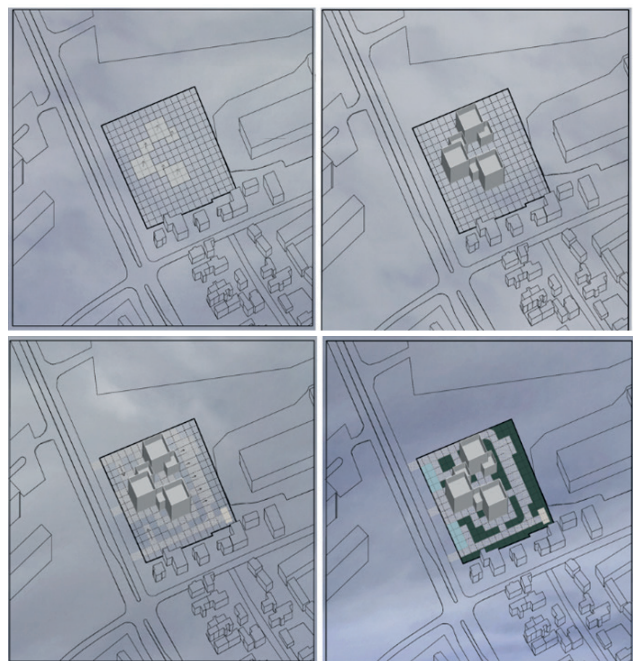


Fig. 6. Diagram illustrating the shaping of the building's form, by the author: W. Kaczmarczyk

An intriguing application of a glass façade as a “second skin” is demonstrated in the conceptual project of the cultural centre situated in a scenic area of Kielce. The dissertation's primary objective was to devise a multifunctional establishment that serves as a “hospitable” building, appealing to children, adolescents, and adults. It is intended to be open and accessible to various societal groups, provide comfort, facilitate active time expenditure, and, crucially, enhance human relationships. A further proposition entailed the construction of an entity capable of simulating human conduct. The uncomplicated and amenable architecture of the structure transforms it into a sort of communal domain and an accessible locale, thereby fostering a more “congenial” ambience within the urban environment.

The building's architectural design and structural configuration facilitated the versatile moulding of functional areas. The culture centre is made up of six cubes of two different heights. The building is partitioned into three operational segments, interconnected via a linkage, each provisioned with an independent entrance and an individual stairwell. The lucid functional arrangement contributed to effortless spatial and interior navigation, concurrently enhancing the accessibility of the infrastructure. The building has an underground car park with three stairwells, providing access to the critical sections of the structure. The application of an external façade and the strategy of elevating it beyond the height of the structure's walls has facilitated the incorporation

of practical, whilst not disrupting the aesthetics of the building. These roofs serve as shared areas for sports and leisure activities.

This exemplifies a glazed building designed to represent an intelligent structure with considerable energy conservation through enhanced efficiency. The distinctive, simple design achieved by using a double glass façade has strengthened the object's connection with the urban context. On the other hand, the curvilinear arrangement of the razors, in addition to its aesthetic function, acts as an effective shading system, improving thermal insulation and reducing unwanted solar heat gains. The result is a dynamic façade surrounding the centre, filtering daylight to improve indoor comfort and visual quality (Fig. 7).



Fig. 7. Cultural centre as local creative space, engineering design (conceptual design, author: W. Kaczmarczyk)

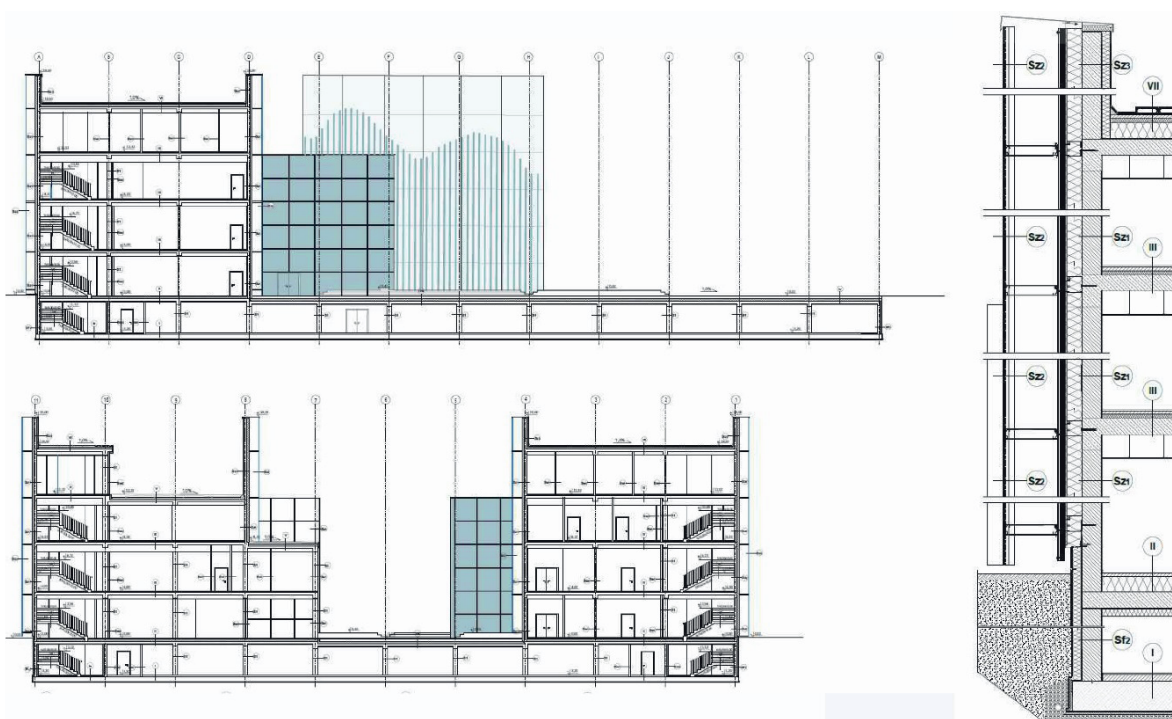


Fig. 8. Cultural Centre – cross-section and detail, engineering design (conceptual design, author: W. Kaczmarczyk)

The distance between the two façades permitted the construction of additional terraces. Implementing intelligent systems has resulted in a notable reduction in energy consumption. The project employed a mechanical (active) ventilation system, supporting natural ventilation strategies during transitional seasons and improving air quality, which is particularly advantageous during winter. The energy expended in heating the building can be conserved through recovery, which can notably impact the building's operating costs. Furthermore, utilising suitable systems facilitates efficient ventilation, directly enhancing indoor comfort and maintaining a stable indoor climate [24]. Using appropriate construction technologies and methodologies within a facility is paramount to the quality of life of the facility's users and, subsequently, the city's quality of life (Fig. 8).

The cultural centre design project reflects the application of double-skin façades systems with consideration of the analysis criteria. The project highlights the potential for energy savings, improved thermal insulation, enhanced indoor comfort, and positive architectural contribution to the urban context.

7. SUMMARY

Incorporating sustainable design principles into the design and implementation process is contingent upon, among other things, the level of awareness of the irreversible effects of global warming among all participants in the investment process. The consequences of irreversible climate change prompt consideration of the courses of action to be taken in constructing the building and its most prominent feature, the façade.

The façade that separates the inner and outer worlds must respond to the challenges posed by the energy

crisis. The appropriate form of the façade, the size and configuration of windows, and other elements such as blinds and sun-breakers significantly impact the reduction of the building's energy demand.

In developing energy-efficient and sustainable buildings, adopting an integrated approach to material selection and technological solutions is essential. The choice of an appropriate type and glass parameters is a crucial aspect in designing a thermal barrier, such as a façade. As with other solutions within the facility, the objective should be to minimise energy consumption.

The popularity of façades with a double skin is increasing, as they provide thermal insulation for buildings and offer enhanced ventilation for rooms, preventing heat accumulation and facilitating energy recovery through appropriate systems. These highly efficient systems reduce energy consumption and represent a significant component of sustainable architectural design. Sustainable architecture aims to enhance the thermal insulation properties of buildings, improve bioclimatic and thermal comfort, minimise condensation and manage energy economically. This benefits the users of the buildings and, more generally, the quality of life in the city.

The analyzed case studies confirm the relevance of double-skin façades as an architectural solution addressing key aspects of sustainable design. Both cases meet the analysis criteria, demonstrating their effectiveness in improving energy performance, thermal comfort, indoor air quality, and architectural integration.

Although further empirical studies are needed to fully assess their effectiveness, the presented cases illustrate the potential of double-skin façades in supporting sustainable architecture.

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