

Architectural strategies for energy-efficient housing: Analysis of student design proposals

Research Article

Jerzy Wojewódka* , Julia Więckowska* 

Faculty of Architecture, The Silesian University of Technology, Akademicka 7, 44-100, Gliwice, Poland

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Abstract: This study explores the contemporary strategies for designing energy-efficient multi-family residential architecture, emphasizing the integration of functional, technological, and environmental considerations. It highlights how compact spatial layouts, appropriate material selection, and innovative building solutions can reduce energy consumption while maintaining occupant comfort and aesthetic quality. The study examines approaches for optimizing natural lighting, thermal insulation, and ventilation, as well as the use of flexible apartment layouts to accommodate diverse user needs. Emphasis is placed on the importance of combining design creativity with sustainable solutions to achieve energy savings at both micro- and macro-scales. The findings underscore that modern residential architecture can successfully harmonize functionality, aesthetics, and energy efficiency, providing a framework for sustainable urban development.

Keywords: Ecology • Energy-efficiency • Multi-family housing • Optimization • Sustainability

1. Introduction

Contemporary principles of designing multi-family residential architecture, regardless of whether they pertain to an individual building or an entire housing complex, emphasize the paramount importance of incorporating energy-efficient elements into both functional and structural solutions. Rationality in the design of architectural objects indicates that, irrespective of various regulations or directives issued by political or corporate bodies, energy-efficient design strategies should constitute a priority in the education of future architecture professionals. Within academic work conducted with students of the Faculty of Architecture at the Silesian University of Technology in Gliwice, substantial attention is devoted to issues of energy use, ecology, and energy efficiency as fundamental factors in sustainable design.

A deliberate undertaking of architects is the need to raise societal awareness regarding energy-efficiency issues – not only in the context of individual housing but also, and perhaps even more importantly, in the architectural solutions applied to multi-family residential buildings. This

should be achieved through the implementation of new material and technological solutions in design, as well as through the introduction of appropriate design strategies that promote contemporary spatial layouts. These include not only the organization of urban spaces within residential complexes and the design of shared spaces but also the configuration of apartments within buildings and the internal arrangement of the apartments themselves.

A contemporary apartment should allow flexible shaping of individual room spaces and the interchangeability of certain functions. The spatial relationships between the various zones within the dwelling should be designed to accommodate functional variability. These strategies should be implemented on the basis of proven energy-efficient solutions and technologies, employing ecological or environmentally friendly materials that can be subjected to recycling processes. Contemporary architecture is fundamentally grounded in the close interaction between art and advanced technologies.

2. Research methodology

Several selected student design projects completed within the course *Design of Multi-Family Housing Complexes* (fifth

* E-mail: jerzy.wojewodka@polsl.pl, j.wieckowska02@gmail.com

semester, Faculty of Architecture, Silesian University of Technology in Gliwice) were subjected to analysis. For the purpose of comparison, buildings with similar formal structures and functional assumptions were chosen. One such example is a multi-family housing complex located in Ruda Śląska. Another analyzed project is a complex situated on the same plot, yet developed on the basis of different functional and spatial guidelines. Both housing complexes represent non-standard architectural types that adopt individualized functional-programmatic, visual, and spatial solutions as their conceptual foundation. Material solutions applied in each project were also individualized, depending on the specific design model adopted for the development.

The guidelines included, among other factors, the placement of the buildings on plots with identical initial parameters such as solar exposure, humidity, climate, prevailing winds, noise levels, and other environmental conditions [1,2]. In both cases, the predominant type of dwelling consists of units with a usable floor area of approximately 60–75 m², intended for families of three to four persons. This parameter was established on the basis of market demand analyses, which indicate that apartments of type M-3 or M-4 constitute 60–70% of future users' expectations. Smaller apartments, such as type M-2 (approximately 40–50 m²), account for around 20–25% of demand, whereas type M-5 units and larger represent approximately 5–10% [3]. The trend toward choosing smaller apartments is observed in nearly all major cities and is primarily related to the real costs of maintenance [4], as well as the limited supply and housing needs of individuals becoming independent [5].

Therefore, aside from other equally important aspects associated with environmental protection, climate considerations, and global-scale energy efficiency, the design exercise deliberately narrowed the issue of efficiency to a micro scale – namely, the needs of the immediate user of the apartment and residential building. This approach is grounded in the assumption that properly resolved elements at the micro scale are capable of generating positive outcomes and impacts at higher levels, ultimately extending to the macro scale.

3. Course of the research process

The first example under discussion is a medium-rise multi-family residential building with the possibility of a mixed access system combining staircase and gallery circulation. This aspect constitutes a significant factor positively influencing the building's overall energy balance. In most residential block designs, staircases serve solely as vertical communication spaces. They require the maintenance of appropriate thermal standards and ventilation while minimizing energy losses; however, it must be recognized that they will always function as elements that draw heat from the building as a whole, and consequently also from individual apartments.

The proposed mixed circulation system, in which the staircase functions only as a vertical communication core supplemented by enclosed galleries leading to individual dwellings, is not an innovative solution *per se*. Its aim is merely to reduce the extent of heat loss resulting from the natural “chimney effect” inherent to vertical stairwells. Mixed-access solutions are commonly employed in Dutch and British architecture. It should be noted that in many Western societies, apartments in such residential blocks frequently serve as social housing, where the cost of building maintenance must remain low, as responsibility for upkeep often lies with local municipalities or other local authorities [6].

The building (or its individual segments) is characterized by a compact form, simple volumetric parameters aligned with the building frontage, and the presence of so-called buffer zones, which significantly limit heat loss (Figure 1).

The layered structural arrangement of the building, illustrated below, demonstrates how elements responsible for the greatest energy losses were “encapsulated” with a curtain wall featuring minimal window openings – providing only the required amount of daylight for the horizontal gallery circulation spaces. This solution reduces heat loss and allows for the near-total elimination of heating in this part of the building. Such an approach is feasible due to the galleries' location, which effectively places them within an “insulating cocoon.”



Figure 1. The compact spatial configuration enables the optimization of heat loss within individual buildings. (Author's own elaboration based on an academic design project completed as part of the course *Design of Multi-Family Residential Complexes*; project author: Adam Myczkowski; design studio supervisor: Associate Prof., Eng. Arch. Jerzy Wojewódka; course instructor: Associate Prof., Eng. Arch. Grzegorz Nawrot).

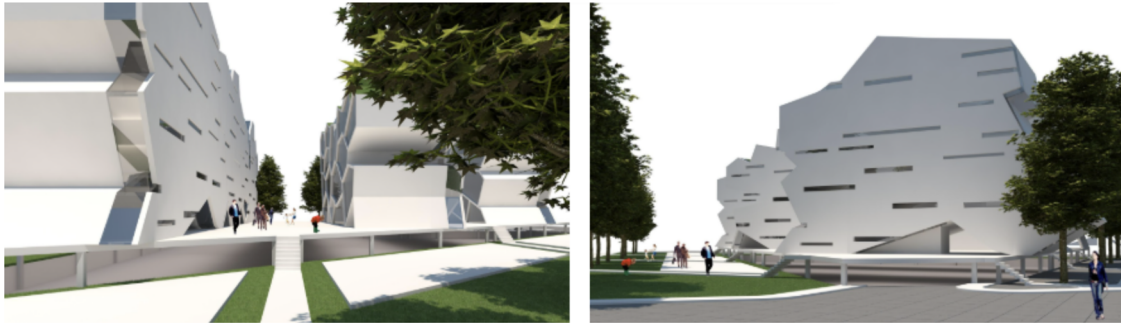


Figure 2. The compact spatial arrangement does not induce a sense of claustrophobia due to the sculptural character imparted to the façades and individual buildings (project author: Adam Myczkowski; design studio supervisor: Associate Prof., Eng. Arch. Jerzy Wojewódka; course instructor: Associate Prof., Eng. Arch. Grzegorz Nawrot).

The compactness of each building segment is maintained despite the necessity of employing a dense grid of structural expansion joints, dictated by geological conditions present at the site. The area in which the residential buildings were designed is subject to substantial mining-induced ground deformations (categories II and III), requiring a dense system of expansion joints whenever a structure exceeds a length of 25 m [7] (Figures 2 and 3).

Furthermore, the placement of staircases in recesses separated from the main building structure ensures minimal energy losses in zones that traditionally constitute thermal weak points in residential buildings. A staircase surrounded longitudinally by a thermal buffer formed by adjacent apartments not only reduces heat loss but also provides effective natural illumination of the circulation space, thereby limiting the need for artificial lighting. In terms of the overall energy demand, such a reduction may yield substantial savings.

Attention should also be drawn to the fact that the arrangement of “thermal buffer” rooms – such as wardrobes, sanitary facilities, and similar spaces – in the immediate vicinity of staircases contributes significantly to the building’s overall energy performance (Figure 4).

A highly important factor influencing the building’s energy efficiency, alongside obvious considerations such as the use of appropriate structural and finishing materials, is the application of additional elements and design strategies that enhance energy performance. In the project under discussion, several supplementary solutions were implemented which, apart from improving functionality, can contribute to enhanced user comfort (Figure 5).

When examining the longitudinal section of the building, the arrangement of apartments within the individual “cells” may initially appear complex. This spatial concept stems from a sociological approach to residents’ expectations regarding dwelling size, the number of

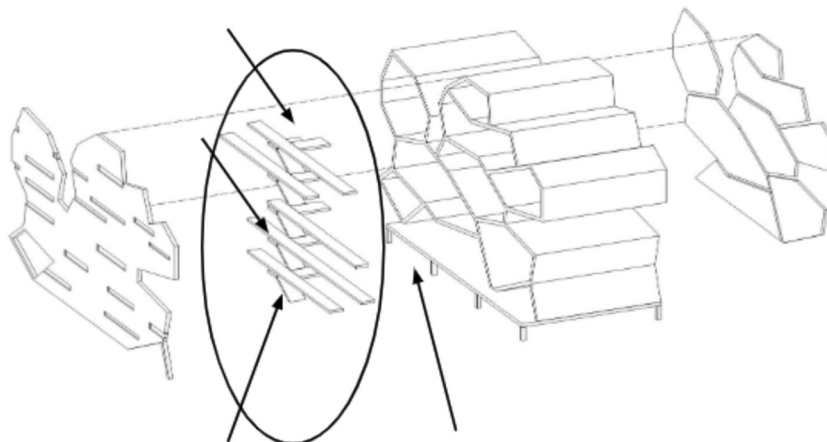


Figure 3. A diagram of the building layout indicating the elements that require particular energy-related attention in order to minimize heat loss. Own elaboration based on an academic design project (project author: Adam Myczkowski; design studio supervisor: Associate Prof., Eng. Arch. Jerzy Wojewódka; course instructor: Associate Prof., Eng. Arch. Grzegorz Nawrot).

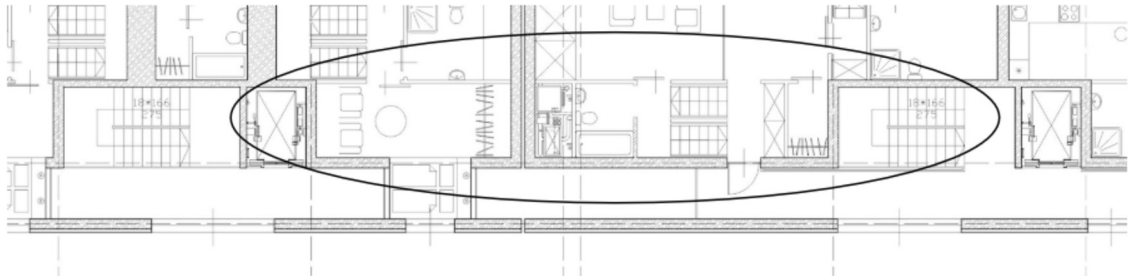


Figure 4. The placement of staircases within “thermal buffer” zones enables additional energy-saving effects to be achieved in the overall energy balance of the building. Moreover, the direct exposure of stairwells to natural daylight provides further savings by reducing the need for artificial lighting. Own elaboration based on an academic design project (project author: Adam Myczkowski; design studio supervisor: Associate Prof., Eng. Arch. Jerzy Wojewódka; course instructor: Associate Prof., Eng. Arch. Grzegorz Nawrot).

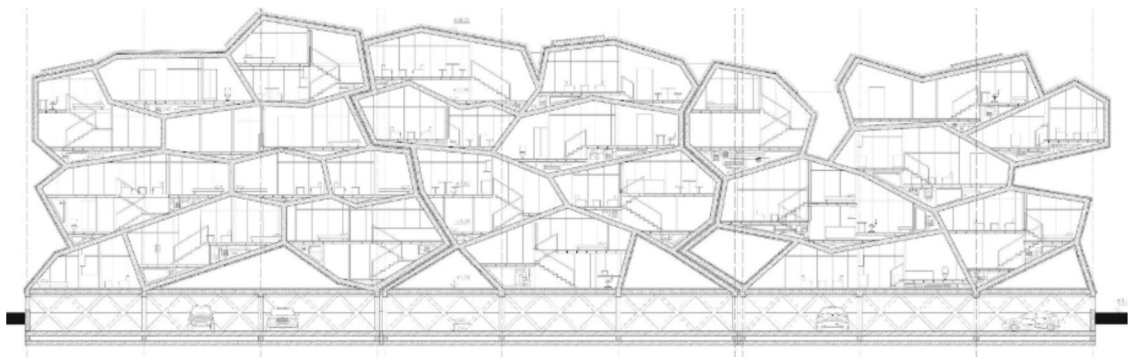


Figure 5. The flexible shaping of individual apartments within a compact spatial arrangement allows for effective energy balancing (project author: Adam Myczkowski; design studio supervisor: Associate Prof., Eng. Arch. Jerzy Wojewódka; course instructor: Associate Prof., Eng. Arch. Grzegorz Nawrot).

functional rooms, and the possibility of full individualization of each apartment according to the occupants’ preferences [4]. This model of shaping the spatial structure of the residential block allows the building to maintain appropriate energy-efficiency parameters despite the freely

sculpted external form – this is achieved through the highly compact configuration of the apartments themselves, irrespective of their size.

Moreover, the design of individual rooms is based on maintaining an appropriate balance between energy-



Figure 6. The apartments function as heat exchangers, working together with buffer zones to form a thermal accumulator model. Own elaboration based on an academic design project (project author: Adam Myczkowski; design studio supervisor: Associate Prof., Eng. Arch. Jerzy Wojewódka; course instructor: Associate Prof., Eng. Arch. Grzegorz Nawrot).

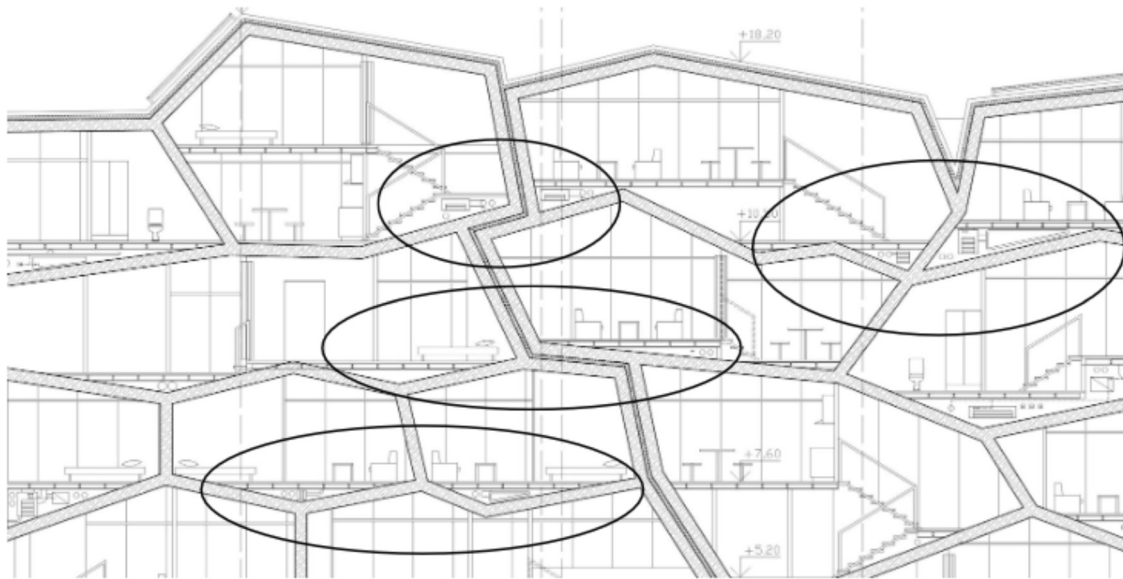


Figure 7. The raised technical floor, which levels the shapes of individual apartment “cells,” serves technological, insulating, and gravity-ventilation functions. Own elaboration based on an academic design project (project author: Adam Myczkowski; design studio supervisor: Associate Prof., Eng. Arch. Jerzy Wojewódka; course instructor: Associate Prof., Eng. Arch. Grzegorz Nawrot).

gaining spaces and thermal buffer zones such as bathrooms, toilets, and wardrobes. These auxiliary rooms are consistently located in areas with the smallest temperature fluctuations; thus, they may be regarded as a type of heat accumulator. During the day, they absorb heat from sunlit areas – such as living rooms, kitchens, dining rooms, and bedrooms – and subsequently sustain optimal climatic conditions during the night by releasing the stored heat back into the residential spaces (Figure 6).

The vertical arrangement of the individual residential “cells,” made possible by the building’s freely sculpted form, enables the use of interstitial spaces created by floor-level adjustments for housing infrastructure elements and utility technologies such as electrical systems and fiber-optic installations. Simultaneously, these spaces, due to their positioning between apartments and interior rooms, function as thermal and acoustic insulators. When equipped with appropriately designed ventilation openings accessible from the gallery side, they ensure efficient internal–external air exchange, effectively functioning as a form of passive heat recovery (Figure 7).

The appropriate design of the exterior layered walls filled with insulating materials ensures proper thermal and acoustic insulation between individual apartments [8]. The application of this solution also enhances the architectural aesthetic quality, which holds significant educational value – architecture, after all, should convey

lessons about form, technology, and environmental responsibility.

The final result, presented in the subsequent illustrations, reveals a residence functioning as an “energy machine” suited to the demands of the twenty-first century (Figure 8).

Another example of a residential building complex that aligns with the search for alternative perspectives on energy-efficient and pro-energetic approaches is the project developed by Piotr Juzwa. As in Adam Myczkowski’s design, the primary objective was to create an unconventional residential unit that would meet not only the visual expectations of a contemporary building but also the highest standards in terms of energy performance. The conceptual foundation of the project refers to characteristic elements of the Silesian landscape – namely, mining shafts. Individual residential units were attached to a central reinforced-concrete and steel core, within which the vertical circulation was designed, comprising a staircase and a passenger–freight elevator shaft [10]. Each unit, differing in usable floor area, was to be prefabricated at ground level and subsequently lifted to its designated attachment point using a technology analogous to that employed in mining hoist shafts.

Although the method of shaping the overall form of the residential building appears, at first glance, to be highly energy-inefficient due to the nature of the design – based on “suspending” apartments from the central core – the

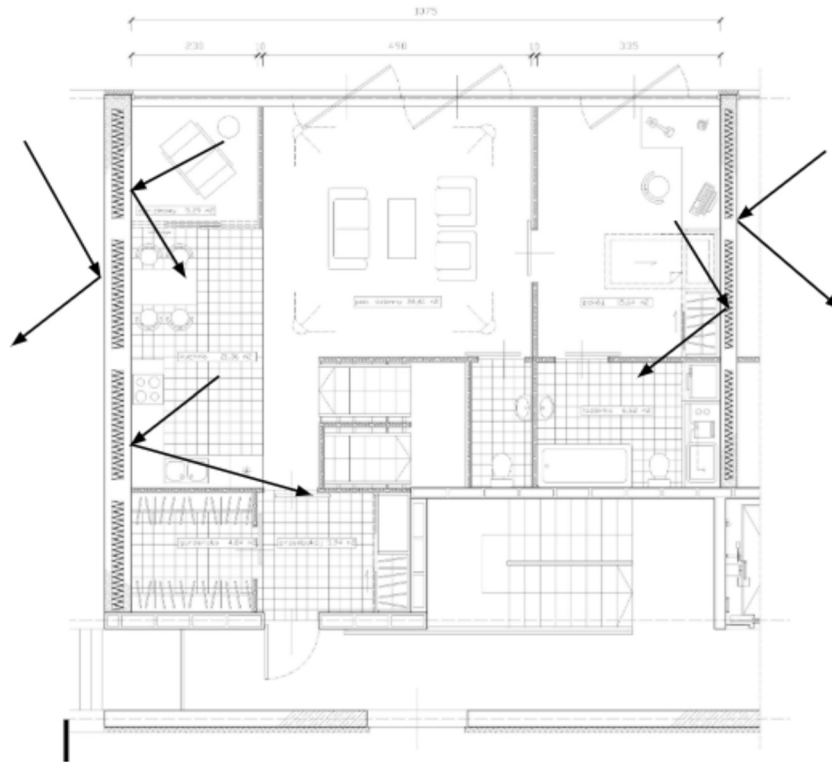


Figure 8. The appropriate design of layered walls filled with insulating material ensures adequate thermal and acoustic insulation between individual apartments [9]. Own elaboration based on an academic design project (project author: Adam Myczkowski; design studio supervisor: Associate Prof., Eng. Arch. Jerzy Wojewódka; course instructor: Associate Prof., Eng. Arch. Grzegorz Nawrot).

building nonetheless meets rigorous energy-efficiency requirements owing to the materials used in the construction of the individual residential “modules.” Each module

consists of a skeletal structure made from composite materials forming the load-bearing floor and ceiling elements [11]. The external walls were made of fiberglass,



Figure 9. The symbolism of the mining shaft references the traditional Silesian landscape. Individual residential units suspended from a shared circulation core provide appropriate functional conditions, acoustic comfort, and a sense of privacy. All of these functional aspects are supported by energy-efficient solutions that enhance user comfort (project author: Piotr Juzwa; design studio supervisor: Associate Prof., Eng. Arch. Jerzy Wojewódka; course instructor: Associate Prof., Eng. Arch. Grzegorz Nawrot).

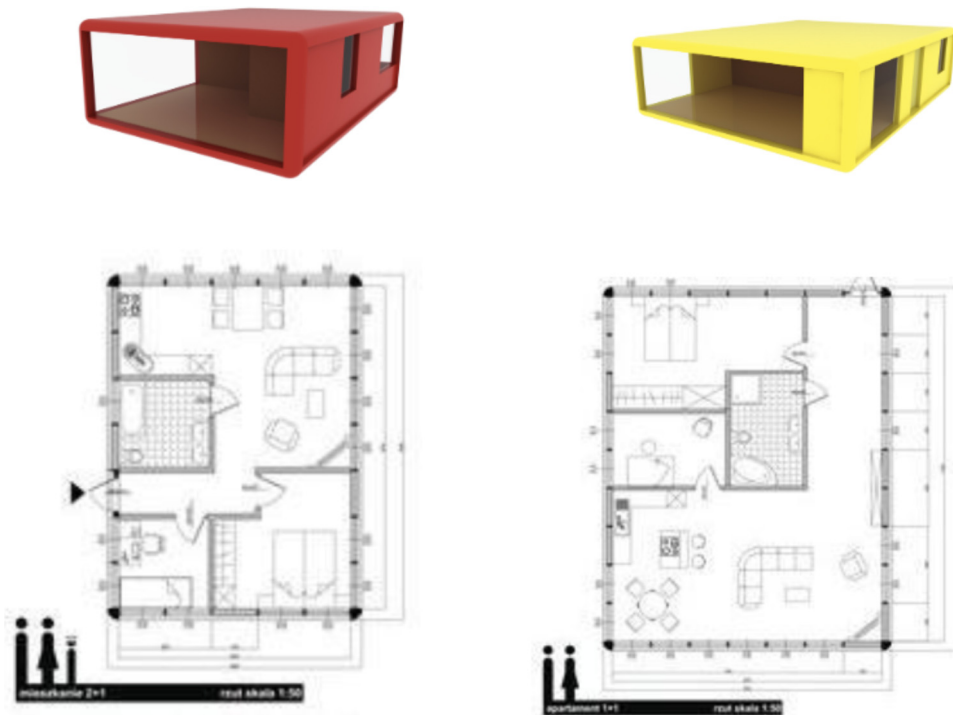


Figure 10. Example residential units adapted to the diverse needs and expectations of occupants. The illustration shows an M-3 apartment (left) and an M-2 apartment (right) (project author: Piotr Juzwa; design studio supervisor: Associate Prof., Eng. Arch. Jerzy Wojewódka; course instructor: Associate Prof., Eng. Arch. Grzegorz Nawrot).

functioning as infill frames within the inter-window structural grid. The internal cavities of this grid consist of chambers filled with insulating materials (e.g., polyurethane foam), ensuring an adequate level of thermal insulation.

The project also incorporates low-emissivity, polymer, and organic glazing, which provides the required insulation for interior spaces. Furthermore, these materials

effectively protect occupants from adverse atmospheric conditions – preventing excessive overheating during the summer and avoiding heat loss during the winter. The entire structure is equipped with a suitably designed gravity ventilation system (Figures 9–12).

A fundamental feature contributing to the energy efficiency of the proposed residential units is the complete

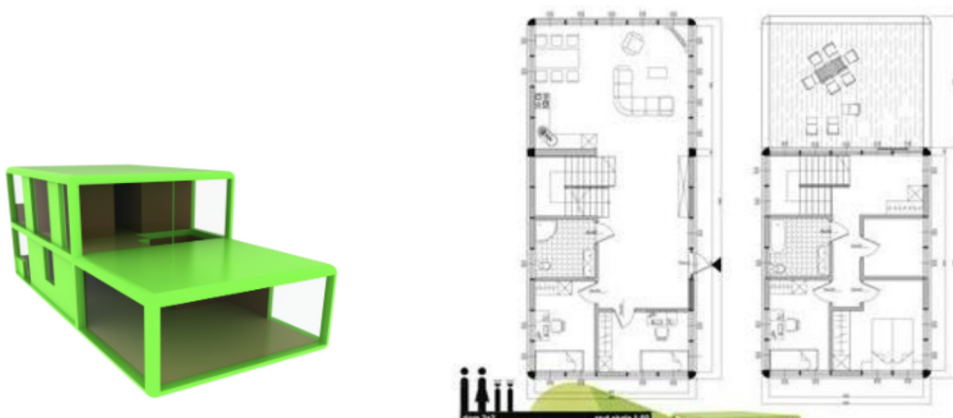


Figure 11. Example of a residential unit in a duplex configuration. The illustration shows an M-4/M-5 apartment, created by combining smaller independent units (project author: Piotr Juzwa; design studio supervisor: Associate Prof., Eng. Arch. Jerzy Wojewódka; course instructor: Associate Prof., Eng. Arch. Grzegorz Nawrot).

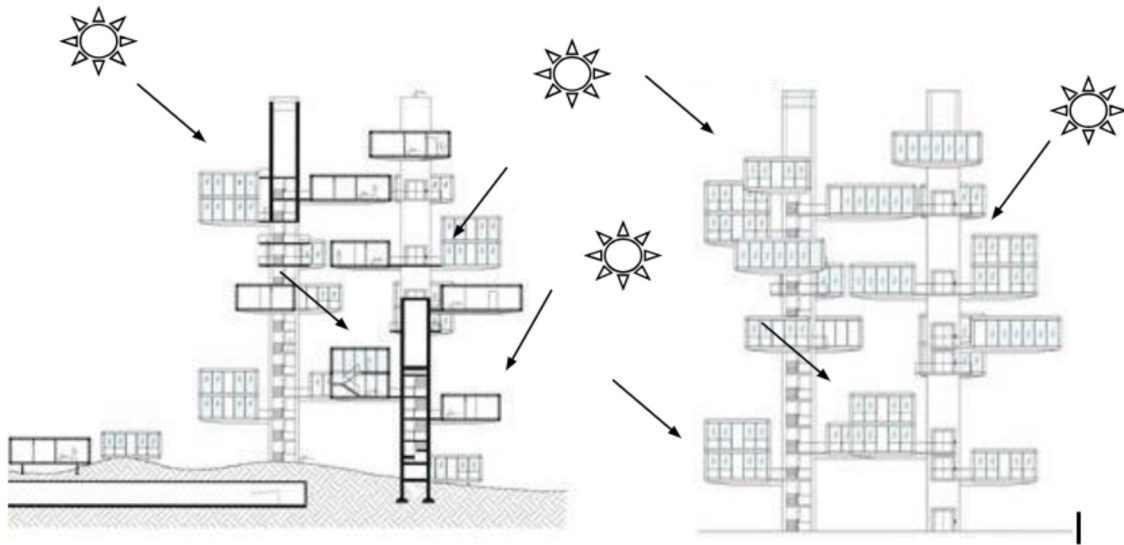


Figure 12. Example of a residential unit composition: cross-section of a double core and elevations. The spatial arrangement allows for optimal daylighting of individual apartments, enhancing the overall energy balance (project author: Piotr Juzwa; design studio supervisor: Associate Prof., Eng. Arch. Jerzy Wojewódka; course instructor: Associate Prof., Eng. Arch. Grzegorz Nawrot).

absence of thermal bridges at connection points, lintels, and inter-window mullions – common issues in traditional masonry constructions. Another advantage is that all elements of internal infrastructure present within the dwellings are shielded from atmospheric influences, as their preparation during controlled prefabrication ensures an appropriate level of insulation [8].

3. Conclusion

The presented examples of alternative approaches for shaping residential units clearly demonstrate that architecture of high aesthetic value and contemporary form can simultaneously meet the requirements imposed on energy-efficient and environmentally sustainable buildings. While the use of appropriate materials with high insulating properties is naturally a key factor in achieving suitable energy-saving parameters, it does not, in itself, ensure the overall quality of a building, which also depends on its functional and aesthetic attributes. The overarching objective is to draw attention to all aspects of the design process, including issues of micro-scale efficiency – namely, the needs of the direct user of the apartment and the residential block. The underlying premise is that a correctly conceived set of micro-scale components can generate appropriate outcomes and effects across larger scales, ultimately extending to the macro scale. Seemingly minor energy-

saving measures implemented at the level of individual buildings and residential complexes contribute meaningfully to the improvement of our environment, and their success depends on architects, investors, and the users themselves.

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Conflict of interest statement

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