buildings

MDPI

Article

The Santa María Micaela Residential Complex in Valencia (Spain) Study of the Original Design to Assess Its Bioclimatic Potentials for Energy Upgrading

Giuseppe Angileri [1], Graziella Bernardo [2], Giuseppina Currò [1], Ornella Fiandaca [1], Fabio Minutoli [1,*], Luis Manuel Palmero Iglesias [3] and Giovanni Francesco Russo [1]

[1] Dipartimento di Ingegneria, Università di Messina, 98100 Messina, Italy; giuseppe.angileri@studenti.unime.it (G.A.); giuseppina.curro@studenti.unime.it (G.C.); ornella.fiandaca@unime.it (O.F.); giovanni.russo6@studenti.unime.it (G.F.R.)

[2] Dipartimento delle Culture Europee e del Mediterraneo, Università degli Studi della Basilicata, 75100 Matera, Italy; graziella.bernardo@unibas.it

[3] Escuela Técnica Superior de Ingeniería de Edificación, Universitat Politècnica de València, 46000 Valencia, Spain; lpalmero@csa.upv.es

* Correspondence: minutoli.fabio@unime.it; Tel.: +39-3208656124

Abstract: The existing built heritage is excessively energy intensive compared to the standards required by European policies that promote zero- or near-zero-energy buildings. Hence the need to promote a radical energy requalification of the existing stock through ad hoc solutions. In the modelling of buildings undergoing redevelopment, the boundary conditions considered by the designer are often underestimated, resulting in a digital model that does not perfectly adhere to reality, due to a lack of historical and documentary knowledge. The present work—which concerns the Santa Maria Micaela residential complex built in Valencia by architect Santiago Artal Ríos, a representative work of Spanish Modernism—aims to overcome this vulnus with modelling that also takes into account historical and archive information. The housing complex was studied using a multidisciplinary approach with historical–archival analyses and site surveys that allowed BIM modelling and localisation in a WEB-GIS platform. The modelling took into account the peculiarities of the original design (exposure, windiness, and shading) and data from historical research (stratigraphy of building elements, dimensions, types of materials). The energy simulation, on the other hand, referred to a representative dwelling unit of the complex, and using SolidWorks software the ventilation flows were evaluated, which made it possible to create a model that was more in keeping with reality and to more correctly identify the performance upgrading proposal. The energy improvement was then evaluated according to the hypothesised interventions using two different analysis methodologies, TerMus and CE3X, for direct comparison. The transposition into WebGIS then made it possible to assess the potential of a digital platform to enhance information sharing.

Keywords: Santiago Artal Ríos; Santa Maria Micaela building complex; social housing; Spanish Modernism; H-BIM; WEB-GIS platform; energy requalification

Citation: Angileri, G.; Bernardo, G.; Currò, G.; Fiandaca, O.; Minutoli, F.; Palmero Iglesias, L.M.; Russo, G.F. The Santa María Micaela Residential Complex in Valencia (Spain) Study of the Original Design to Assess Its Bioclimatic Potentials for Energy Upgrading. *Buildings* **2024**, *14*, 3819. https://doi.org/10.3390/buildings14123819

Academic Editors: Laura Gabrielli and Ruggeri Aurora Greta

Received: 31 October 2024
Revised: 14 November 2024
Accepted: 19 November 2024
Published: 28 November 2024

1. Introduction

Recent European policies (EU/2024/1275) once again promote the need for energy retrofitting of the existing building stock, responsible for 40% of the EU's total energy consumption [1]. Statistics point out that 45% are buildings constructed between 1945 and 1990 [2]. Energy Conservation Measures (ECMs) are proposed, such as envelope nsulation, more efficient windows, solar shading, etc., which can increase market value but often neglect the preservation of aesthetic integrity to meet the standards required by the directives for nearly-zero energy and zero-emission buildings.

In a context where the recognition of Modernist building heritage is at the center of European initiatives [3], it is particularly interesting to understand how to approach these buildings and what actions to take. Energy modelling often underestimates or ignores important boundary conditions (wind, sunlight, and exposure) that were considered by the building's designer, focusing almost exclusively—and too simplistically—on iconic components of thermal losses: glazing, walls, and roofs. The accurate assessment of the actual energy performance is a key factor in preventing unbalanced, incorrect, or unnecessary interventions [4]. For this reason, energy modelling and thermal simulation are essential phases to outline the most appropriate retrofitting scenarios, but they must necessarily require a historical and documentary understanding of the building to determine if actions in this regard were already undertaken by the designer during its conception. The lack of knowledge leads to uncertainties in input data, with significant discrepancies between simulated and actual performance. Simplified models are often the cause of substantial energy gaps, which are extremely dangerous in the field of conservation, where the authenticity of materials and minimal intervention are two guiding concepts. However, the performance gap continues to be a significant issue in current practice [5], and the methods for achieving high accuracy in thermal modelling cannot disregard the cooperation of different simulation and performance evaluation systems. Few scientific papers focus on the calibration of models for post-war historic buildings, and when it is carried out, it is often poorly related to reality due to the difficulty in recognizing the performance values already possessed by heritage buildings.

Different approaches have been proposed in the literature. Lidelöw et al. outlined the need to share knowledge regarding good practices specific to historic buildings [6]. Some researchers, like Buda et al. and Rieser et al. [7,8], focused on finding specific solutions on a case-by-case basis; others have developed methodologies attentive to the efficiency-conservation compromise [9,10]; others have defined scenarios [11] or given greater weight to environmental aspects [12] or the use of digital technologies such as BIM [13].

Finally, it is worth noting that the IEA project SHC Task 59 (Renovating Historic Buildings Towards Zero Energy) [14] and the Interreg Alpine Space ATLAS [15] have jointly developed a tool for the dissemination of non-invasive solutions for improving the energy efficiency of the historical-architectural heritage, (thus, not comparable in terms of construction characteristics to modern buildings, but undoubtedly a useful starting point for interventions on buildings of different eras), known as HiBERatlas (Historical Building Energy Retrofit Atlas), [16]. Despite its limitations, the database provided presents best practice examples of how a historic building can be retrofitted to achieve high levels of energy efficiency while respecting and protecting its heritage significance.

The goal of this research is to minimise the risk of inappropriate interventions on Modern heritage buildings, considering the Santa Maria Micaela complex in Valencia (Spain) a representative example of social housing with authorial characteristics.

2. Materials and Methods

The research presented in this study is the result of a collaborative effort conducted by a research group united by a shared disciplinary background but distinguished by different knowledge and professional skills (archival, technological, energy, and information sciences).

Over approximately one year, information on the Santa Maria Micaela building complex (Valencia, Spain) were collected combining traditional investigations with a digital transition approach. This dual approach applied to a representative work of Spanish Modernism generated an information system where the 3D model was enriched with data from historical research, technological system classification, and energy simulations. This was carried out to support the knowledge phase, performance awareness, scenarios necessary for hypotheses of energy efficiency, and building management possibilities. Additionally, the transposition into GIS allowed for evaluating the potential of a digital platform more suitable at the urban scale.

The implemented methodology considered the specific competencies of the research group to define a workflow consistent with the study's objectives: to contribute to the knowledge of modern architecture, determine the peculiarities to preserve in view of any energy modernization interventions, and allow easy access for any type of user.

The outlined process was structured into the following phases (Figure 1):

- Searching for archival and bibliographic documentation to identify the construction and performance characteristics of architectural components from a historical perspective;
- Examining the most suitable computer systems for parametric, geometric, and informational modelling, as well as for energy simulation, comparing Italian and Spanish protocols with reference to the work to be digitized, its specificities, historical period, and possible simplifications;
- Assessing interoperability issues and choosing software to minimize information loss (level of reliability);
- Refining an urban container in a GIS environment to hold the data of the building under examination and, prospectively, to accommodate those in the investigated area that may become subject to the same analyses.

Figure 1. Representation of the knowledge and digitization steps carried out for the project. © 2024, authors.

The workflow organized for the Santa Maria Micaela complex in Valencia, chosen as case study, included the following activities:

- Historical research related to the geographical and chronological context of the work;
- Site inspections to identify and classify the construction techniques in use;
- Assessing the performance model correlated to the microclimate, using data from meteorological stations;
- Producing a Heritage Building Information Modelling (HBIM) model using proprietary software also evaluated in terms of interoperability;
- Enriching the HBIM model with heterogeneous information derived from archival/bibliographic data, materials, climatology, and performance data;
- Performing energy simulations with software defined for Italy and Spain and comparing normative and operational procedures;
- Psychrometric analyses to estimate performance comfort in the hot and cold seasons;
- Evaluating scenarios for energy efficiency compatible with the historical-architectural quality of the work through pre- and post-intervention simulations;
- Creating a Web Geographic Information System (WebGIS) platform to input the outcomes in order to enhance the potential of the research.

The research of sources, based on collating archival documents, construction projects, and previous studies, and familiarization with the sites through an inspection of a representative apartment of the architectural complex, was conducted to identify its technical characteristics and performance specificities and to understand the architectural and geopolitical context.

The primary and secondary sources consulted were cross-referenced to define their accuracy and relevance. This investigation was necessary to realize the digital twin of the entire examined building complex to allow:

- The visualization of formal characteristics, spatial and constructive specificities, and attributes of the materials used;
- The analysis of energy performance through computer simulations.

The transposition into BIM was carried out using ACCA programmes, selected mainly because the company offers a suite that includes specific tools for the different required functionalities: the 3D model was created with Edificius software, while the subsequent definition of the energy model was performed with TerMus. However, a cumbersome interoperability practice was noted in acquiring information from purely parametric modelling software, resulting in the repetition of numerous steps already performed initially for model generation. The use of Italian software led to a comparison with a Spanish programme, conducting a parallel energy analysis also through the use of the Iberian software CE3X, produced by Efinovatic—listed on the official website of the *Ministerio para la transición ecológica y el reto demográfico* among the software compliant with calculating the energy needs of buildings according to Spanish regulations which, unlike parametric modelling in a BIM environment, employs a simplified calculation method. This choice allowed for comparing two different methodologies for energy analysis and rehabilitation of the building heritage, referring to the regulations of the two different nations, with the aim of comparing the results obtained and evaluating their effectiveness and compliance with specific European energy regulations.

The energy analysis of the selected housing unit was complemented by a study on the perception of residential comfort in the city of Valencia, conducted using the functions of the Weather Tool software (an Autodesk application). This allowed for the development of a psychrometric diagram and an in-depth analysis of the intensity, direction, and hourly frequency of winds affecting the area under investigation. The method does not focus on the analysed building itself but provides fundamental indications on the thermal-hygrometric comfort of the average inhabitant of the studied city, starting from the only input data consisting of the climatic file in .epw format produced by Meteonorm software, based on data collected hourly from the reference meteorological station.

The assistance of specific information obtained through the simulation of ventilation flows inside the studied unit using SolidWorks software allowed completion of the collection of elements to enrich the methodology with data to accompany the results expressed by the energy classification derived from calculations run on the analysis software.

Integrating the energy data from the thermal state analysis—performed with two different methods: BIM and simplified—with the insights from climatic diagrams, comfort parameters, and wind regimes ultimately allows approaching the performance rehabilitation proposal phase of the case study with a more complete vision. This aims to maximize the valorisation of the designer's original idea without altering what was wisely foreseen by the authors, by proposing interventions with minimal impact on the existing structure. Ultimately, the rehabilitation proposal is still subjected to the same procedure applied for the current state, evaluating the improvement of the post-intervention energy class through the two different methods of analysis, via TerMus and CE3X.

The data enrichment phase involved the HBIM model but, in addition, to maximize the use of cognitive material containing the research results, a WebGIS platform was developed using ESRI's ArcGIS. This hosts georeferenced data, allowing users to visualize the building in its geographical context and explore information related to its historical, constructional, and energy aspects, as well as all analytical information that can be integrated later. Thus, in this study, the WebGIS served as a digital tool to boost the sharing information.

3. The Modern Complex Social Housing in Spain and in Valencia

The evolution of social housing in Spain, although marked by a delay compared to other European countries, followed a unique path that reflects the intersection between political conditions and the architectural and urban transformations of the 20th century. In this context, Spanish architects were able to combine innovative design experiments and cutting-edge technological solutions, contributing to the development of an architectural heritage that still constitutes an integral part of the urban landscape today (Figure 2) [17].

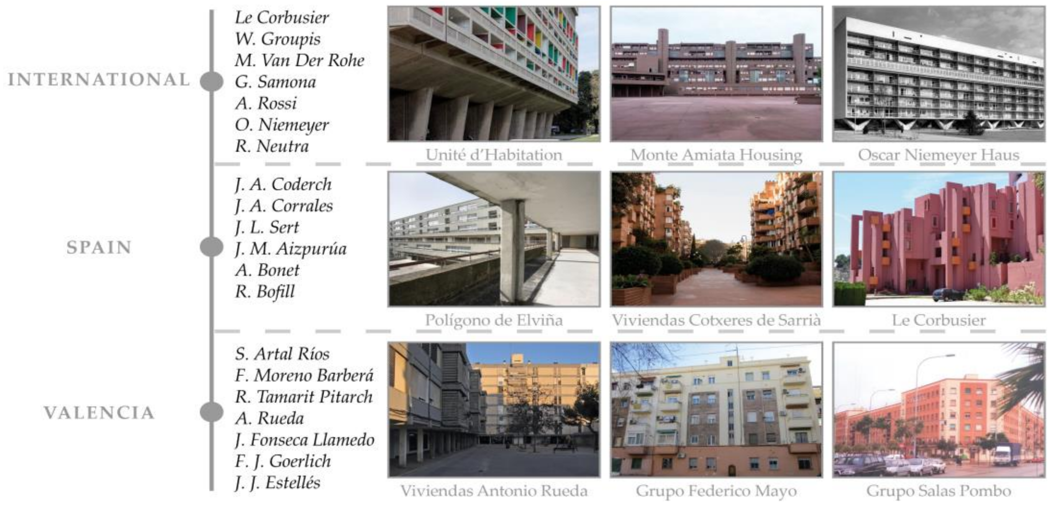

Figure 2. Some examples of important exponents of modern architecture of international, Spanish and Valencian fame and some examples of their works. © 2024, author's elaboration.

A key moment in this trajectory was the founding, in 1930, of the *Grupo de Artistas y Técnicos Españoles para el Progreso de la Arquitectura Contemporánea* (GATEPAC), a group of architects and technicians aimed at promoting the principles of the Modern Movement in Spain. This group was part of the broader international context of the *Congrès Internationaux d'Architecture Moderne* (CIAM), an organization that sought to disseminate the principles of architectural rationalism globally. GATEPAC became a pivotal center for avant-garde architectural debates in Spain, publishing the journal *AC. Documentos de Actividad Contemporánea* (1931–1937)—one of the main vehicles for the dissemination of rationalist architectural principles [18].

Architectural rationalism, inspired by the theories of the Modern Movement and influenced by the German Bauhaus and European avant-gardes, was based on the pursuit of a functional aesthetic, the elimination of all superfluous ornamentation, and the application of innovative technical solutions. In Spain, this approach found fertile ground in the design of social housing, with particular attention given to improving the living conditions of the working classes. Rationalist principles were applied not only to architectural form but also to urban planning, focusing on the creation of functional, well-ventilated, and well-lit spaces, in line with the theories of the hygienist movement, which had been widely disseminated in Europe since the early 20th century [19].

Among the most emblematic works of Spanish rationalism in the field of social housing is the *Casa Bloc* project (1932–1936) in Barcelona, designed by Josep Lluís Sert and his collaborators from GATCPAC, the Catalan version of GATEPAC. The *Casa Bloc* is considered one of the first expressions of rationalist social housing in Spain and represents a pioneering attempt to create dignified and functional housing for the working class, in line with contemporary European models [20,21].

The building embodies a unique synthesis of functionality and aesthetics, integrating elements such as ample natural light, the design of open spaces, and the reduction of superfluous ornamentation. These features reflect the theoretical foundations of rationalism, according to which architecture should not merely create beautiful or monumental forms, but should instead address the concrete needs of society, particularly by improving the housing conditions of the less privileged classes (Figure 3) [22].

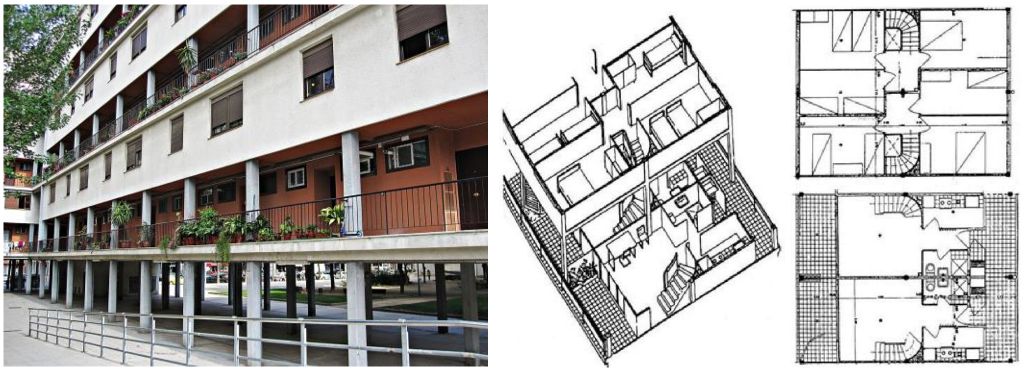

Figure 3. Casa Bloc: (**left**), image of the elevation; (**right**), axonometric cutaway and floor plans. © https://www.amatimmobiliaris.com (accessed on 20 September 2024).

Francisco Franco's dictatorship in 1939 marked a sudden halt for avant-garde architecture in Spain. The authoritarian and nationalist regime imposed a traditionalist and monumental architectural style, inspired by the ideals of the "eternal Spain" and aimed at exalting the authority and power of the State. In this context, modernity was replaced by a return to vernacular and regionalist styles for residential housing, and by neoclassical monumentalism for public buildings [23]. Only in the 1950s, with the start of Spain's modernization under Franco's regime, were the ideas of the Modern Movement partially revived, particularly in the field of social housing [24–26].

In the 1950s, in response to the growing demand for affordable housing, the Franco regime undertook a series of urban and architectural reforms, establishing the *Ministerio de la Vivienda* (1957) and the *Instituto Nacional de la Vivienda*, which oversaw the planning and implementation of programs for social housing. A key moment was the enactment of the *Ley de Viviendas de Renta Limitada* (1954), which regulated the rents and duration of leases for public housing, introducing criteria of economic accessibility based on family income [27,28].

The *Poblados Dirigidos* (1956–1966), experimental social housing settlements, were among the most significant projects of this period. These interventions aimed to solve the housing shortage and reduce land consumption while maintaining high standards of comfort and well-being for residents. The design of these new neighbourhoods followed strict principles in terms of orientation, solar exposure, natural ventilation, and the use of industrialized materials such as reinforced concrete, reflecting an increasing awareness of sanitary conditions and housing well-being [29].

The evolution of social housing in Spain, marked by phases of innovation, repression, and revival, represents a significant case within the context of modern European architecture. The contributions of rationalist architects and the resurgence of experimentation during the Francoist period of the 1950s highlight the importance of the dialogue between technological innovation, functional aesthetics, and social policies. The design models developed during this period influenced urban planning in Spain and in other European nations, leaving us heritage buildings in the field of residential architecture [30].

In the context of the evolution of modernist architecture in Spain, the city of Valencia played a significant role, standing out for its innovative approach to social housing. Although often overshadowed by the more famous experiences of Madrid and Barcelona, Valencia embraced modernist principles and translated them into concrete responses to the housing challenges facing the city's social fabric during that period. Modernist architecture, characterized by a strong connection to the use of new technologies and materials, as well as an aesthetic centered on organic and decorative forms, found fertile ground for experimentation in Valencia. The city successfully combined modernist aesthetics with a strong focus on social issues, developing housing projects aimed at improving the living conditions of the working classes.

Local authorities and architects worked together to address the city's housing shortage, leading to the development of projects that reflected the functionalist and rationalist ideals of CIAM and GATEPAC. The *Grupo Residencial Virgen del Carmen* (1954–1956), for instance, exemplified this approach, featuring open courtyards, simple forms, and practical layouts that facilitated natural ventilation and sunlight. The project, spearheaded by architects such as Cayetano Borso di Carminati and Javier Goerlich Lleó, sought to provide dignified housing for the city's working-class residents, while also reinforcing a modern urban identity for Valencia [31].

Valencia's engagement with social housing continued in the 1960s with experimental developments aimed at relieving urban density and creating new living environments for low-income families. Projects like the *Poblado Dirigido de Valencia* (1958–1960) integrated green spaces, community facilities, and accessible services into their design, reflecting a broader understanding of housing as a social infrastructure. These developments followed rationalist principles in their use of materials—such as reinforced concrete—and focused on practical considerations like solar orientation and natural ventilation. By emphasizing the importance of public spaces and community cohesion, architects in Valencia reinforced the idea that housing should not only provide shelter but also foster social interaction and well-being (Figure 4) [32,33].

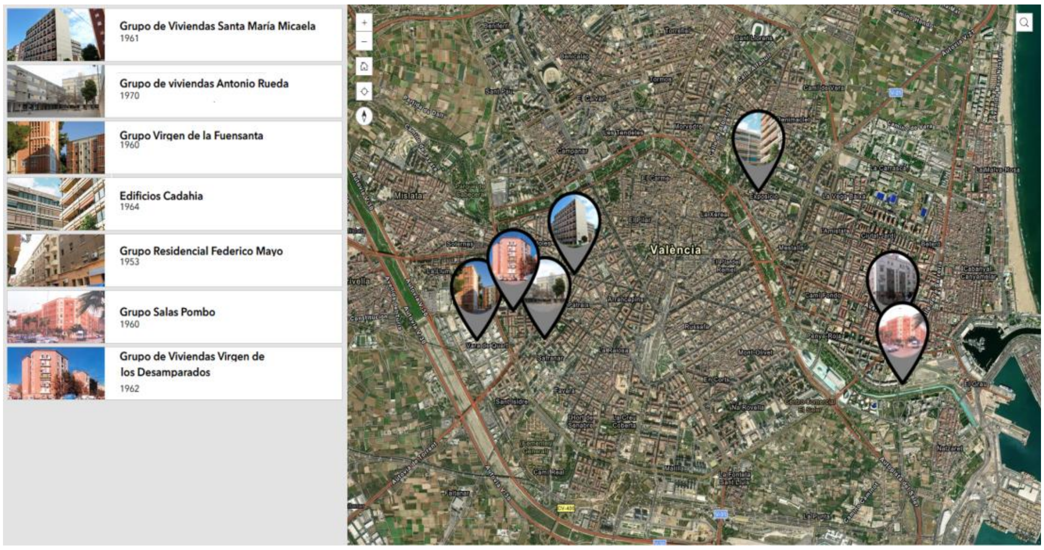

Figure 4. WebGIS representation of the Modern Architecture complex in Valencia. © 2024, authors.

In these projects, Valencia's architects displayed a commitment to functionalist principles, while also adapting modernist ideas to meet the specific needs of the city's population. Their work contributed to a broader Spanish architectural movement that sought to harmonize innovative design with social purpose. Today, Valencia's mid-20th-century social housing developments remain significant as enduring examples of the Modern Movement's influence on Spain's urban fabric. They highlight the role of architecture in addressing housing shortages and improving urban quality of life through rational design. Valencia's contributions, alongside those of other Spanish cities, underscore the relevance of modernist principles in tackling contemporary urban challenges, leaving a legacy in the field of social housing [34].

4. The Santa Maria Micaela Building Complex in Valencia (Spain)

The residential complex of Santa Maria Micaela, known as the *Cooperativa de Agentes Comerciales*, designed by architect Santiago Artal Ríos in 1958 and completed in 1961, stands as one of the most innovative and influential examples of modern architecture in Valencia. Situated at the corner of *Santa María Micaela* Street and *Pérez Galdós* Avenue in the *Petxina* neighborhood, this complex distinguishes itself not only through its formal and technical solutions but also through its impact on the social and urban fabric of its time (Figures 5 and 6) [35].

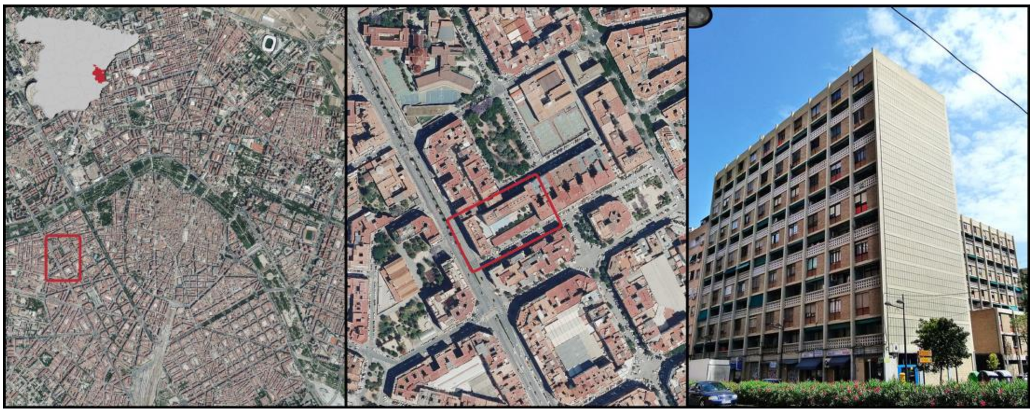

Figure 5. Identification of the complex in the city of Valencia. (Red box) © 2024, author's elaboration.

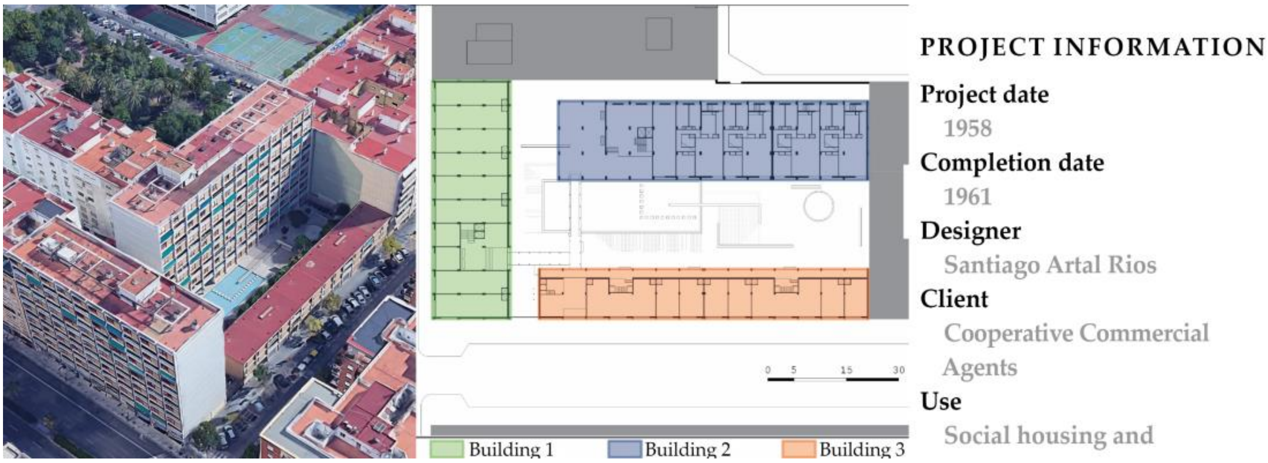

Figure 6. Top view and overall plan of the complex. © 2024, author's elaboration.

Artal Ríos conceived this project during a period of significant architectural and urban change in Spain, when the principles of the Modern Movement, already firmly established internationally, began to find application in residential projects aimed at the burgeoning urban middle class. Designed in accordance with the *Ley de Viviendas Subvencionadas* of 1957, the complex sought to provide dignified, affordable housing to a middle-class demographic. In this way, it reflects an evolving conception of urban living, where functional and aesthetic choices were tightly interwoven with the socioeconomic context of the era [36].

The building complex is raised on a rectangular plot measuring 45.50 × 83.40 m. It is organized around a large central space dedicated to recreational activities, gardens, and water features. The layout, articulated into three main blocks, follows a clear rationalist intent. Two blocks, each thirteen stories high, are arranged in an "L" shape and house duplex units, while a third, lower block (three stories), located at the entrance on Santa María Micaela Street, serves as a connecting element between the taller structures, ensuring proper lighting and ventilation for the internal spaces (Figure 7).

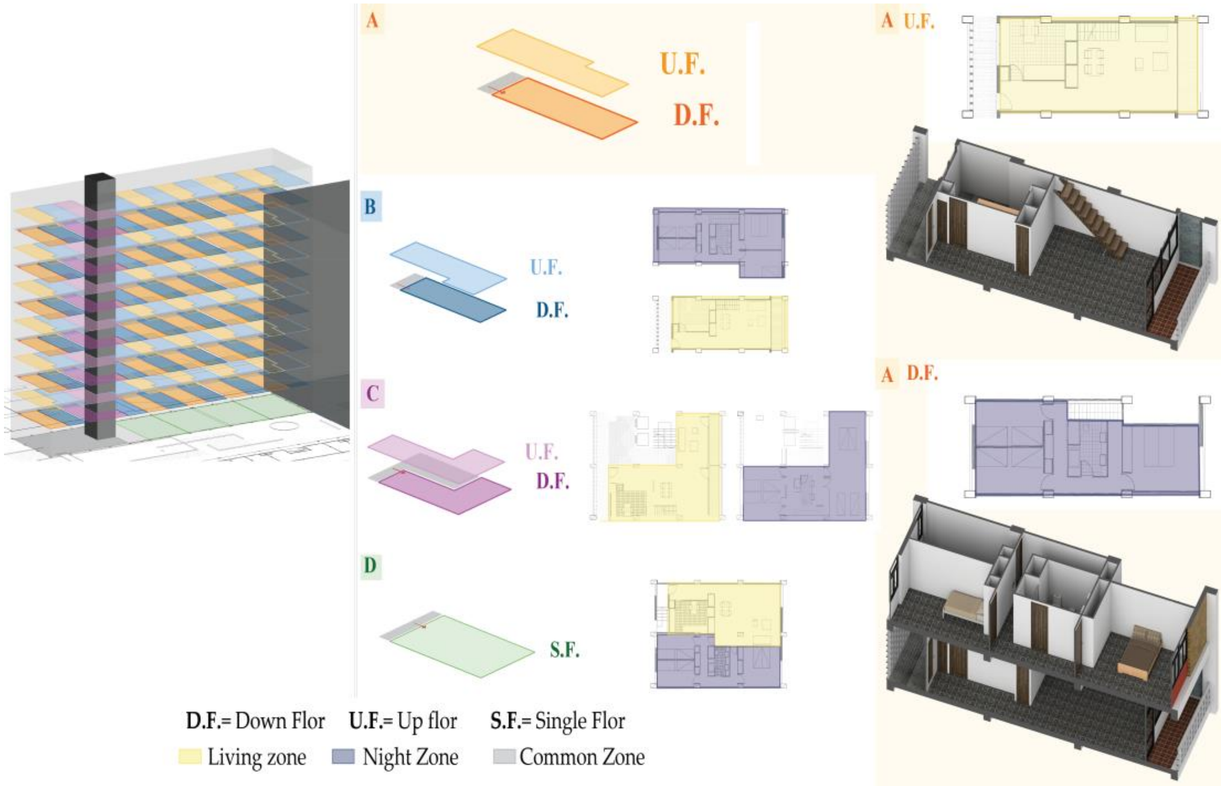

Figure 7. Housing types in building no. 2 and distinction between living and night zones: Type A, duplex dwelling with terrace with three rooms; Type B, duplex dwelling with terrace and four rooms; Type C, duplex dwelling with terrace with three rooms; Type D, One floor dwelling with three rooms. Axonometric cross-sections of unit 27 representing the type A building 2, duplex, 120 m^2. © 2024, authors.

The decision to use two different heights of blocks highlights Artal Ríos's attention to the balance between built volumes and open spaces, ensuring that the inner common areas are well-lit and ventilated, which is essential for residential comfort.

The apartments, with floor areas ranging from 120 to 159 m^2, are designed in six different types, demonstrating a flexible approach intended to accommodate the varying housing needs of the middle class (Figure 7) [37].

One of the most innovative aspects of the project is the use of exposed reinforced concrete, a stylistic choice aligned with the rationalist tendencies of the Modern Movement. The structural frame, made of reinforced concrete, imparts a strong plastic impact to the entire complex. The rhythmic composition of the façades is defined by the regular repetition of concrete pillars and beams, which form a modular grid of 4.80 $\times$ 4.80 m. Within this grid, alternating solid surfaces of exposed yellow brick and glazed sections with black iron frames are incorporated.

The latter, arranged at full height, includes a balustrade made of wired glass with opaque red panels, creating a chromatic contrast that lends dynamism and movement to the architectural composition [38,39].

The use of innovative materials is one of the distinguishing features of the project. Artal Ríos adopts solutions that reflect particular attention to quality and durability, without neglecting aesthetics. The steel-framed windows prefabricated white concrete screens (known as *cobogó*, typical of Brazilian architecture of the 1920s [40]), and polychrome vitreous mosaic cladding, used both on exterior surfaces and in common internal spaces, all demonstrate the architect's design skill.

These decorative and technological details not only serve functional purposes—such as natural ventilation and light control—but also contribute to defining the building's aesthetic identity (Figure 8C) [41].

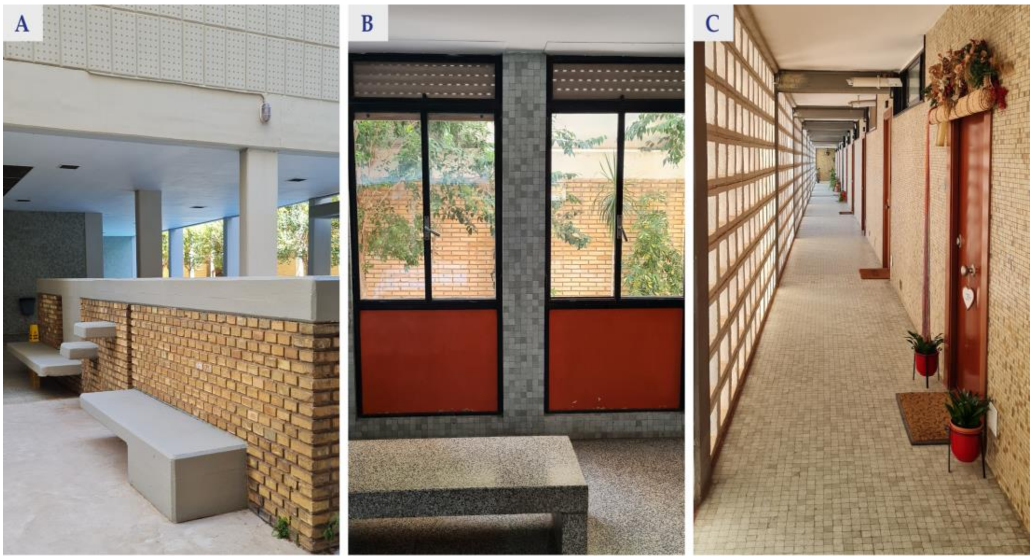

Figure 8. Some decorative and functional elements. (**A**): Common spaces in the courtyard. (**B**): Detail of windows. (**C**): External gallery for access in the housing units. © 2024, authors.

One of the most noteworthy aspects of the complex is the management of common spaces and the technological solutions adopted. The inner courtyard, with its gardens and ponds, functions not only as a recreational area but also as a climatic mediator. The presence of water features aids in the natural cooling of the area, mitigating the effects of the summer heat typical of Valencia's Mediterranean climate. Suspended walkways, made of reinforced concrete and clad in mosaic, traverse the water and connect the various residential blocks, offering a unique spatial experience that departs from the traditional housing models of the time (Figure 9A–C).

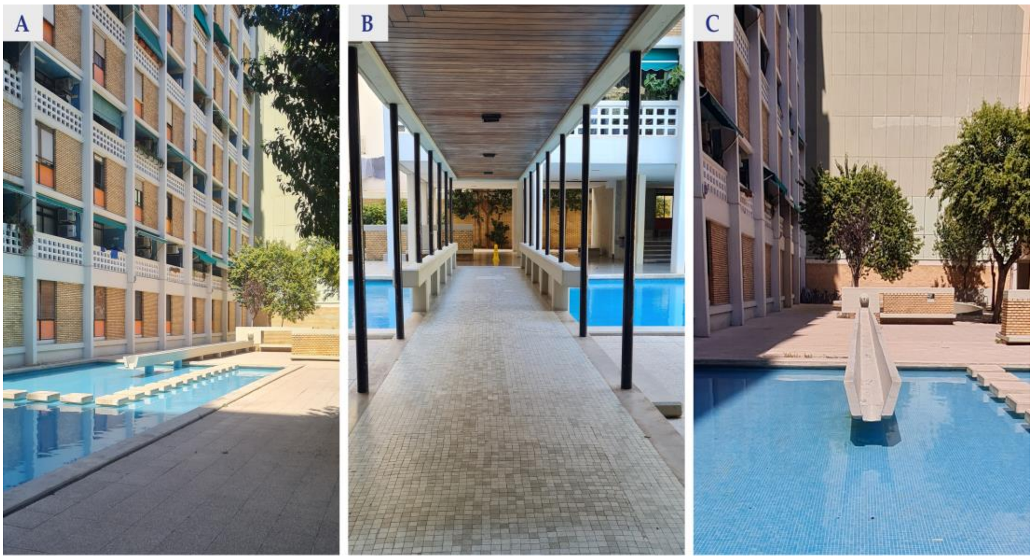

Figure 9. Images of the common courtyard: (**A**) Inner courtyard and building façade 2; (**B**) Detail of the covered walkway in the courtyard; (**C**) Detail of the indoor pool fountain made of reinforced concrete. © 2024, authors.

From a technical perspective, Artal Ríos demonstrates careful consideration for the functionality and future maintenance of the infrastructure.

The technological systems, centralized and accessible via ventilation shafts, ensure efficient and rational distribution of shared services. Additionally, the presence of an industrialized mechanical laundry located on the roof of one of the taller blocks reflects the intent to provide communal services that meet the modern demands of urban life [30].

The design of the residential complex also stands out for its careful attention to residential comfort in relation to the local climate. Although bioclimatic features were not yet systematically developed at the time, they were implemented with expertise. The layout of the three blocks around the large central space and trellised elements allow for natural ventilation and air circulation. The orientation of the apartments and the choice of materials contribute to maintaining thermal balance inside the buildings without the need for air conditioning systems. In particular, the light-coloured, high-thermal-inertia flooring, combined with the large internal pool, helps to keep temperatures cool during the summer.

From a spatial distribution perspective, Artal Ríos arranges the interior spaces to optimize natural lighting and air flow. The placement of windows on both levels of the duplex apartments ensures cross-ventilation, contributing to residential comfort throughout all seasons [42].

The Santa María Micaela complex represents an exemplary case of architectural excellence in the context of social housing during the 1950s and 1960s. Santiago Artal Ríos's ability to combine technological innovation, modernist aesthetics, and residential functionality results in a project of great value, still admired today for its bold formal composition and the quality of the technical solutions employed. His work remains a point of reference in the history of Spanish Modernist architecture and in the ongoing pursuit of balance between architectural expression and residential well-being [43].

5. The Comfort Characteristics and the Energy Analysis

After having acquired all the historical–architectural information relating to the Santa Maria Micaela complex, a transposition into a BIM environment was carried out with the Edificius software by ACCA, which allowed us to understand, according to a reverse engineering principle, all the characteristics of the building system and the environmental system. The results of this digitalisation phase were placed as the basis of an energy simulation process (Figure 10).

A detailed energy analysis of a sample housing unit within the Santa Maria Micaela residential complex in Valencia was carried out, focusing not only on thermal data but also on ventilation flow patterns to identify potential performance improvements.

The study also incorporated an assessment of the occupants' perception of comfort, visualised through a psychrometric diagram created with Autodesk's Weather Tool software. The input data for this assessment included the geographical coordinates of the building.

A duplex flat, specifically unit 27, located between the third and fourth floors of the tallest building aligned with Carrer Santa Maria Micaela, was chosen for this in-depth study. During an on-site inspection, it was observed that the unit retained the original layout, finishes and fixtures as designed, as well as representing the behaviour of similar types present in the complex.

The consideration of air currents was further supported by examining the prevailing winds in Valencia throughout the year, differentiating them by intensity, direction and hourly frequency (Figure 11A). The longitudinal development of the residential units was determined by a climate-sensitive design, in particular about the exploitation of natural ventilation: three main pathways within the flat were identified (Figure 12).

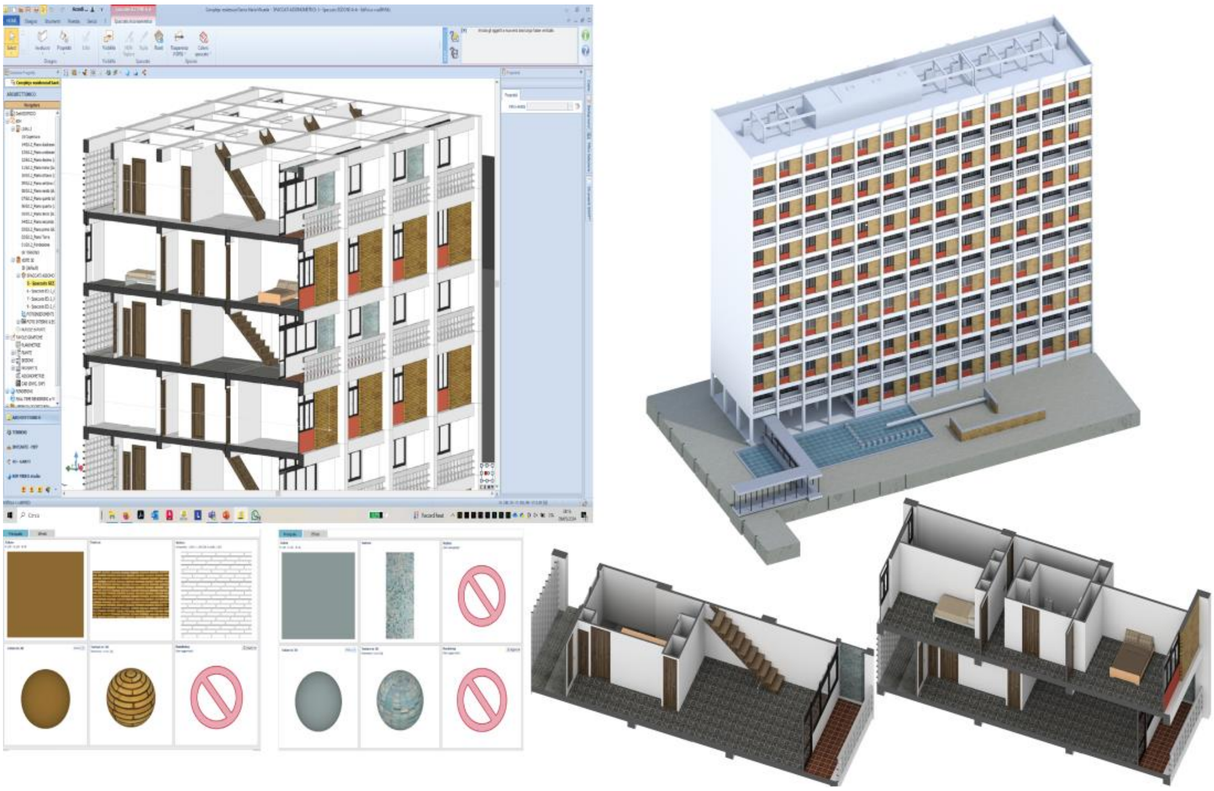

Figure 10. Representative figure of the BIM model produced with ACCA's Edificius program. © 2024, authors.

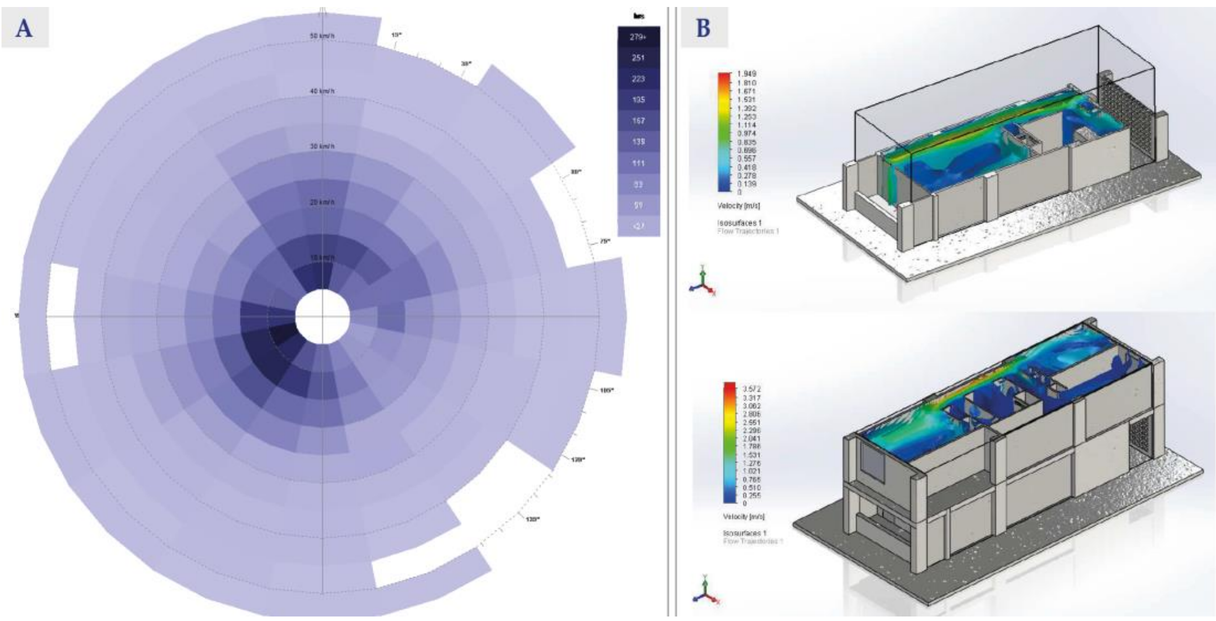

Figure 11. (**A**): Summer prevailing wind frequency in Valencia, Weather Tool; the colour scale shows that during the summer season the most frequent winds blow from the north or west, with very low intensity. (**B**): Ventilation flow analysis, Solid Works. © 2024, author's elaboration.

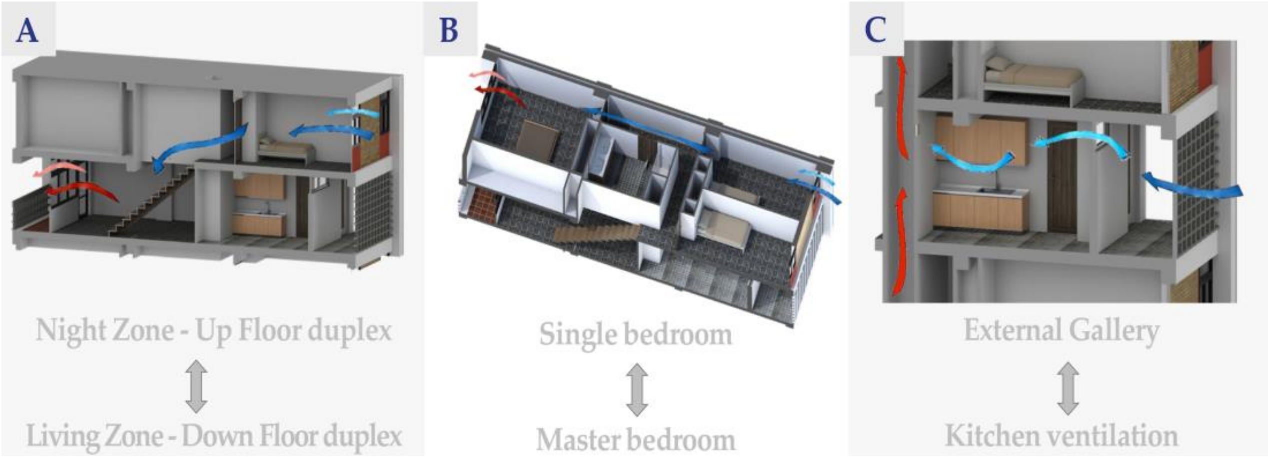

Figure 12. Main ventilation paths identified: (**A**) From the high floor to the low floor of the duplex; (**B**) Among the rooms in the night zone; (**C**) from the gallery to the kitchen air column. © 2024, authors.

Unit 27 is a duplex, accessed from a common gallery with a northern exposure, composed on the first level (third floor) of a living area divided as follows: a kitchen near the entrance with the windows facing the gallery protected by a *cobogò* grid and a living room with a loggia overlooking the courtyard to the south; on the second level (fourth floor) the staircase leads to a hallway leading to two single bedrooms facing north, and a double bedroom to the south.

The living area is naturally crossed by a flow of air in a north–south direction, keeping the entrance door open. This air movement also extends upstairs to one of the two single bedrooms located adjacent to the staircase landing (Figure 12A). The sleeping area is also affected by another current, which from the master bedroom reaches the other single bedroom, ensuring continuous ventilation thanks to the open windows and doors, improving the thermo-hygrometric conditions inside the flat (Figure 12B).

The design of the window fixtures also plays a crucial role in how residents perceive air flow. The choice of opening mode for the windows in the bedroom area, but also for the large composite glass window in the living area, makes it possible to modulate the flow of air passing through, either by opening the classic double-hung casement or by opening the *vasistas* above, thus directing air circulation to a higher level, eliminating the sensation of discomfort that a flow at human height might generate.

This analysis was further supported by simulations using SolidWorks software. A 3D model of the apartment provided output data on air flow dynamics, considering parameters such as building orientation, average wind speed in Valencia and atmospheric pressure.

A chromatic scale was used to highlight areas where ventilation had the greatest impact, with peak air speeds of 3.5 m/s (12.6 km/h) observed on the upper floor, specifically between the master bedroom and the adjacent bedroom (Figure 11B). These speeds remained within the range of a gentle breeze, ensuring comfort. Air flow management not only aids in preventing mould growth but also helps avoid the spread of odours from the kitchen to adjacent rooms. The air flow enters the kitchen through two *vasistas*, coming from the external gallery, after having already been filtered by the *cobogò* grid. Once inside, through an air vent, it is channelled into a large duct that runs vertically through the building to the terrace. This system makes it possible, without the use of any mechanical aids, to expel smoke and odours without affecting other rooms. The hot air, due to its lower density, tends to rise by convection, exploiting the chimney effect of the tower cavity, thus facilitating natural ventilation inside the building (Figure 12C) [44].

6. Approach to Energy Requalification

Regarding the energy analysis, a simulation of the current thermal condition of the selected housing unit was carried out using the Italian BIM software TerMus by ACCA. This was compared to the Spanish energy rating calculated for the entire building using CE3X, a tool developed by Efinovatic.

In Spain, the energy performance of buildings is regulated by the *Código Técnico de la Edificación* (Technical Building Code), which implements European directives dating back to 1993 [45]. According to *Real Decreto* 235/2013 [46], it is mandatory for both residential and non-residential buildings to be issued an energy certificate by a qualified technician, assigning an energy rating from G (least efficient) to A (most efficient) [47].

Similarly, Italy follows Legge 90/2013 [48], which introduced the *Attestato di Prestazione Energetica* (APE). This system assigns buildings a rating from G (least efficient) to A, with subclasses A1 to A4, where A4 is the highest level of efficiency.

Although both countries use the same alphabetic rating scale, their methodologies differ significantly. In Spain, the focus is on CO_2 emissions, expressed as kg of CO_2 per square meter annually. In Italy, the main metric is non-renewable global primary energy consumption per square meter per year (Epgl,nren), measured in kWh/m^2 annually. (Figures 13 and 14).

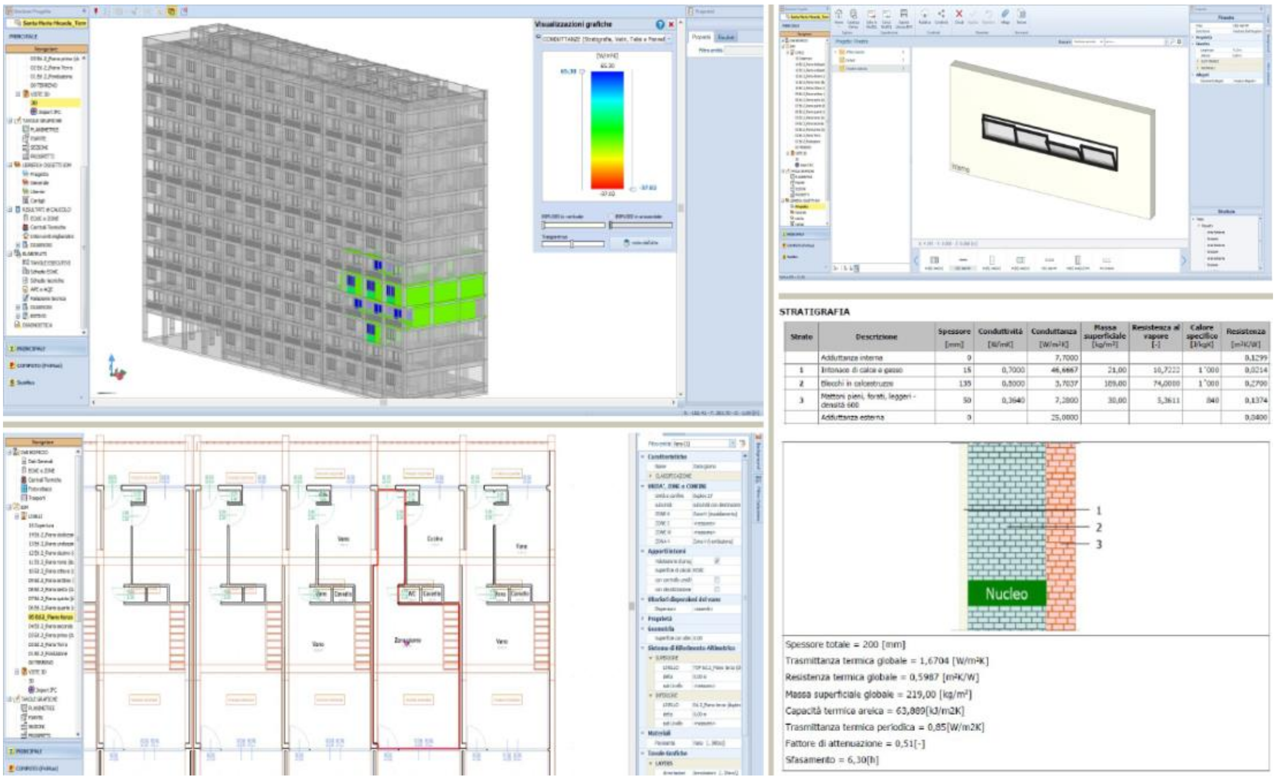

Figure 13. Representative figure of energy models produced with TerMus ACCA. © 2024, authors.

The energy performance of the building was assessed using TerMus software, which required simulating a location, as it only supports evaluations based on Italian regulations. As a result, the building was virtually placed in Messina, which shares the same C climate zone with Valencia according to the Köppen–Geiger classification.

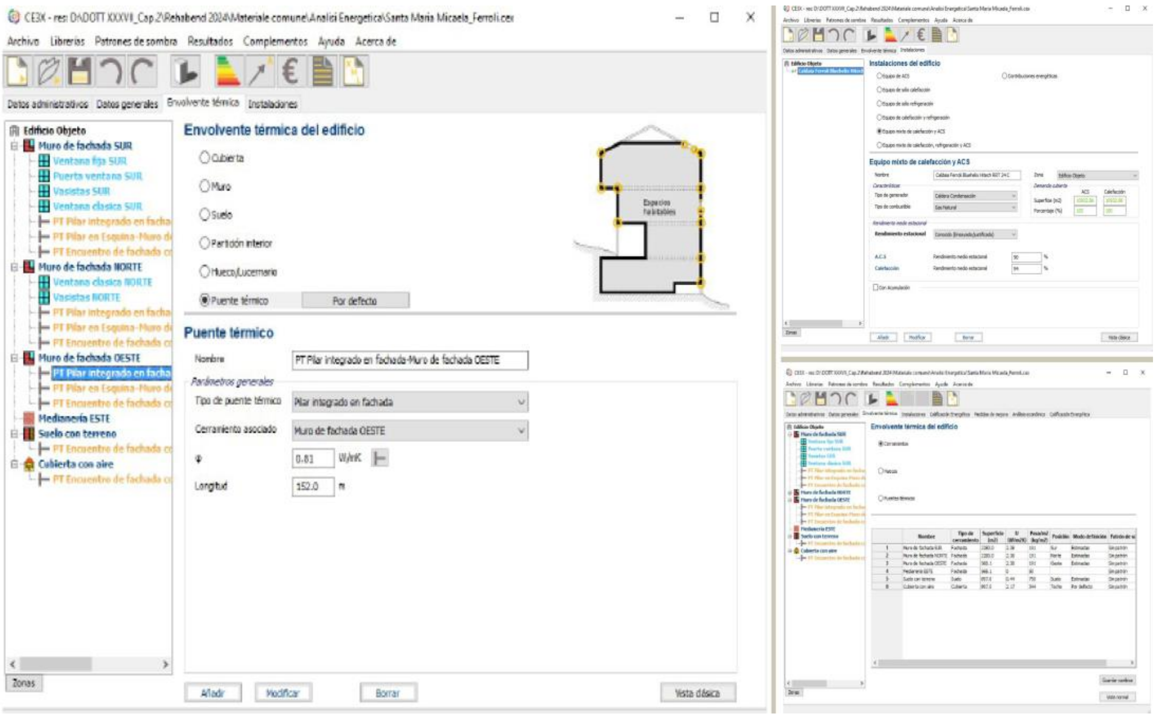

Figure 14. Representative figure of analysis process with CE3X by Efinovatic. © 2024, authors.

The initial evaluation through the Italian Energy Performance Certificate (APE) rated the apartment as energy class E, with a non-renewable global primary energy consumption of 64.6411 kWh/m^2 per year. However, when analysed using the software compliant with the Spanish *Código Técnico de la Edificación* (CTE), the building achieved a class D energy rating, with CO_2 emissions amounting to 17 kg/m^2 per year (Figure 15).

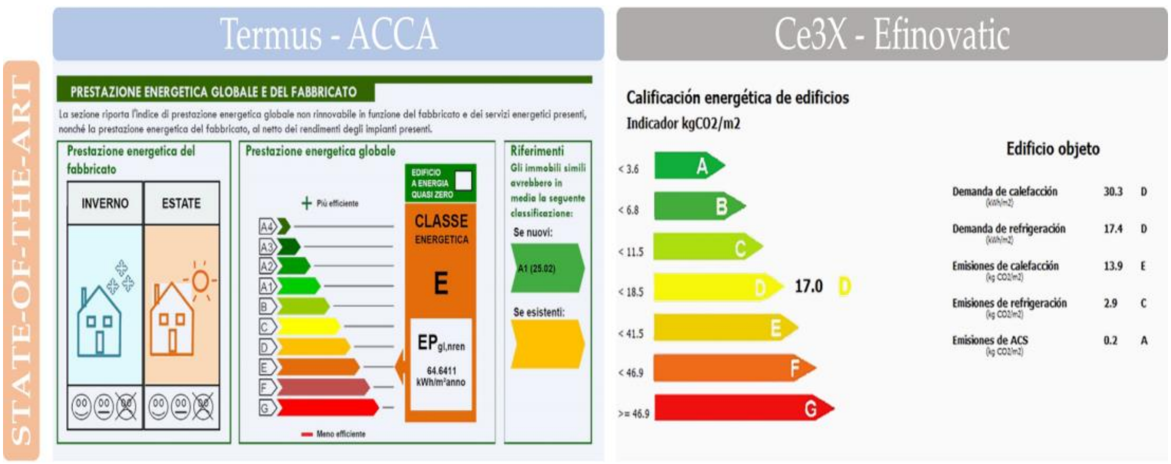

Figure 15. State-of-the-art energy classification. On the (**left**), using TerMus software, ACCA. (**Right**), using the Spanish model, CE3X. © 2024, author's elaboration.

In order to assess how thermo-hygrometric conditions change over time and space, one can make use of the psychrometric diagram. Its adapted version for the Weather Tool application is called the Milne–Givoni diagram, an evolution of the primary Bioclimatic Chart of Hungarian architect Victor Olgyay, drawn up in 1963.

At the centre of this approach is the human being: by knowing their clothing coefficient and metabolic activity (which vary according to clothing and activity in the environment), the psychrometric diagram makes it possible to identify a comfort zone, in which the individual does not perceive thermal discomfort, i.e., is in ideal thermo-hygrometric conditions.

The graph shows on the abscissas axis the dry-bulb air temperature expressed in degrees centigrade, while the ordinates report the humidity or pressure parameters and other parameters such as enthalpy or specific volume: in particular, Figure 16 shows the absolute humidity AH expressed in g/m^3 (the ratio between the mass of water vapour contained in the air expressed in grams and the volume of the air containing it expressed in cubic metres). The comfort zone, relative to the sum of the periods analysed is established based on these parameters.

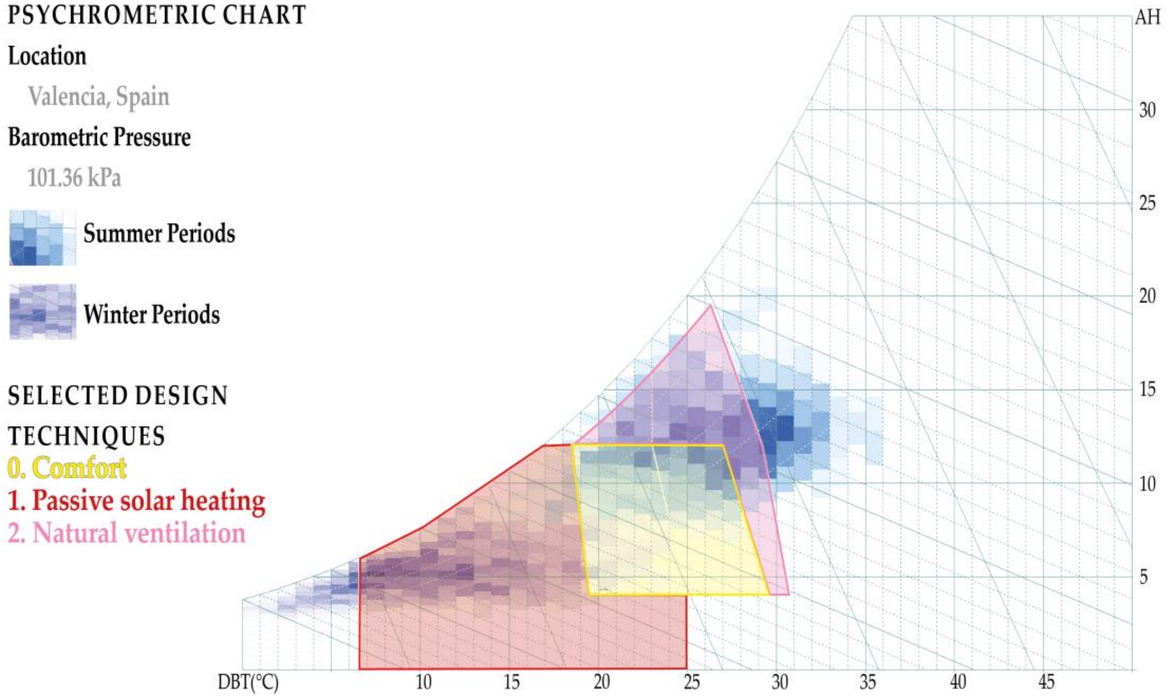

Figure 16. Psychrometric chart of the site of the building analysed, Weather Tool. © 2024, authors.

Setting the analysis for the city of Valencia, we can see that the shaded areas in the diagram indicate the thermo-hygrometric conditions typical of the location: the darker the colour, the more frequently this condition occurred in the typical year. Only a small part of these conditions fall within the yellow polygon, which represents the overall comfort zone, relative to the sum of the two periods analysed (summer season and winter season) (Figure 16).

With the aid of the software used, it is possible to prepare intervention strategies to extend the comfort conditions. As regards the extension of the comfort conditions in the winter period, by setting a high degree of sedentariness, increasing the clothing index and increasing the envelope performance by suggesting the strategy of Passive Solar Heating, it is possible to encompass most of the discomfort moments to the left of the comfort polygon; with a 'glazing ratio' of 40% comfort conditions can be achieved without the need for active systems. Acting on the natural ventilation, on the other hand, would expand the comfort zone at high temperatures, while not ensuring the fulfilment of thermo-hygrometric comfort conditions throughout the summer.

7. Discussion

The connections between climate and residential comfort in the Santa María Micaela complex in Valencia exemplify a significant instance of bioclimatic architecture, wherein local climatic characteristics are integrated into architectural design to enhance the well-being of residents. Valencia, located along the Mediterranean coast, enjoys a climate typically characterized by mild, dry winters and hot summers, moderated by the influence of maritime winds. This climatic context has guided many of the design choices made by Santiago Artal Ríos, particularly regarding natural ventilation and passive thermal regulation.

The organization of the residential complex is based on three separate building volumes arranged around a spacious central courtyard. This configuration facilitates effective natural ventilation throughout the residential blocks, further enhanced by the presence of lattice elements on the façades, which promote air flow.

This passive ventilation system not only prevents overheating of the interiors during the summer months but also reduces the need for mechanical cooling systems, providing a comfortable and well-ventilated environment. As noted by Victor Olgyay [49] in his pioneering study on bioclimatic design, the configuration of buildings to maximize natural ventilation is a key component in ensuring thermal comfort in hot climates.

The light-coloured flooring, made from materials with high thermal inertia, contributes further to the regulation of internal temperatures, ensuring coolness during the hottest hours of the day. Additionally, the presence of a large water mirror in the central courtyard serves an evaporative cooling function, lowering the surrounding air temperature and helping to create a favourable microclimate, as emphasized by Baruch Givoni [50] in his studies on bioclimatic architecture.

One of the distinguishing elements of the project is represented by the elevated galleries, which serve as ventilation corridors, allowing air flows to traverse the various building levels and reach the apartments. This system, which draws on traditional techniques of Mediterranean architecture, ensures cross-ventilation within the living units, particularly in the duplex configurations, where openings on both levels facilitate vertical air flow. As highlighted by Norbert Lechner [51], cross-ventilation is one of the most effective methods for passive cooling in temperate and hot climates.

Within the residences, the functional arrangement of spaces reflects a careful consideration of bioclimatic needs. The lower floor of the duplex units, designated as the living area, is oriented to maximize natural light, with the living room facing southeast, thereby benefiting most from solar radiation during daylight hours. In contrast, the bedrooms, located on the upper floor, are partly oriented toward the northwest to reduce direct sun exposure, thereby ensuring a cooler environment during summer nights. This distinction between living and sleeping areas optimizes the passive energy efficiency of the building.

An additional innovative element is represented by the inclusion of a vertical ventilation duct, which ensures air exchange in the more humid areas, such as the kitchen and bathroom. This feature addresses hygiene and comfort needs, improving indoor air quality, an aspect also highlighted by recent studies on the effectiveness of natural ventilation in urban residential contexts [52]. Moreover, the varying sizes and opening mechanisms of the windows allow for adaptability in air circulation according to seasonal or individual needs, thereby enhancing thermal well-being throughout the year.

The Santa María Micaela residential complex stands out as an advanced example of rationalist bioclimatic architecture, which combines technological innovations with climatic sensitivity to enhance residential comfort. Artal Ríos's design choices not only respond to the climatic challenges of the Mediterranean context but also demonstrate a profound understanding of sustainability and residential well-being principles, anticipating trends that would later become central to contemporary architectural design.

From the data reported so far, what emerges is that the residential complex has its own intrinsic bioclimatic design. However, in order to optimise the winter and summer comfort conditions, low-invasive interventions could be hypothesised, which do not alter the aesthetics of the original design: the installation of a high-efficiency condensation boiler, combined with photovoltaic panels on the terrace to increase the use of renewable energy, and the replacement of single-glazed metal windows with low-emissivity triple glazing, preserving the original appearance and dimensions.

No system solution is suggested for summer air-conditioning, in coherence with the bioclimatic design of Artal Ríos, which focuses on ventilation between the two fronts, even though during the summer season the natural exposure to currents fails to satisfy comfort needs in the hottest periods. To improve ventilation, it is proposed to add a second external window frame to the entrance door, such as a shutter with adjustable fins, to provide an additional filter towards the common gallery, while still allowing air to pass through when the door is open. This intervention, accompanied by the possibility of also opening the fanlight of the internal doors—currently fixed—if necessary, would offer an additional advantage for ventilation and at the same time provide greater privacy in individual rooms.

The proposed actions would lead to a considerable improvement in the energy classification—even though neither a mechanical ventilation aid nor the installation of a summer air-conditioning system has been considered—leading the analysed building unit to reach energy class A2 according to the Italian Energy Performance Certificate (APE), with overall consumption of non-renewable primary energy of 22.7193 kWh/m^2 per year, and an energy classification of class C, with CO_2 emissions of 9.3 kg/m^2 per year, through the simplified analysis of the CE3X software, based on the Spanish regulations (Figure 17).

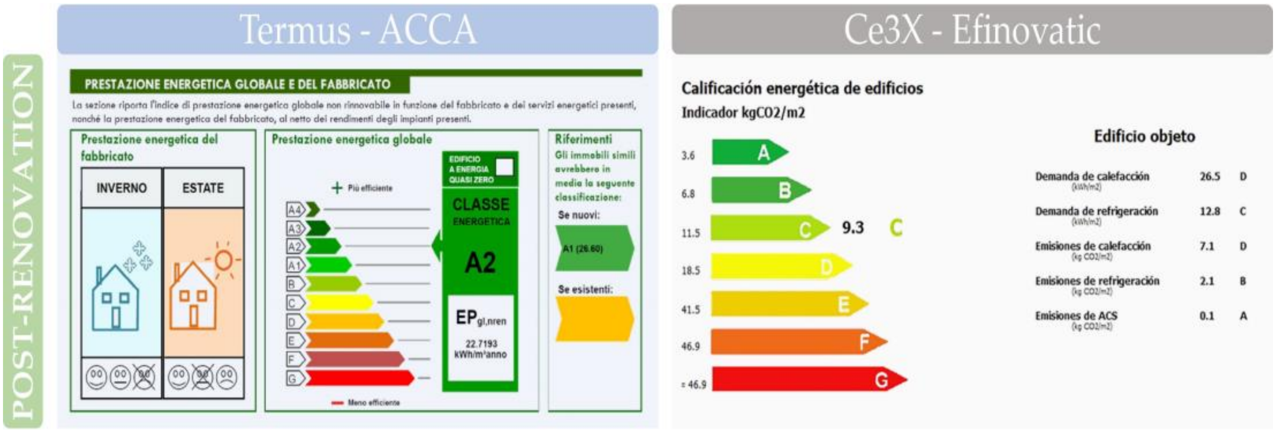

Figure 17. Post-renovation energy classification. On the (**left**), using TerMus software, ACCA. On the (**right**), using the Spanish model, CE3X. © 2024, author's elaboration.

8. Conclusions

The interdisciplinary and multi-scalar methodological approach allowed us to explore the technical-constructive characteristics of the building and to verify the bioclimatic potential impressed in the design phase by Santiago Artal Ríos. The energy simulation performed with different analytical paths (TerMus, CE3X, Weather Tool, SolidWorks) confirmed this finding and allowed us to propose scenarios aimed at optimising the summer and winter behaviour for a representative building unit, which can be extended to the entire architectural complex. Incorporating all the real characteristics into digital data proved to be an effective prerequisite for deepening the knowledge of thermal-hygrometric well-being from which any performance requalification measures could be initiated.

The potential of the web GIS, which was introduced here as an interface of all acquired information (formal, material, constructional and climatic), that can be further and constantly implemented, could become a necessary tool for the institutional management of energy efficiency problems in social buildings.

The conceived multimedia proposal, being replicable, will allow the research group not only to extend the analyses conducted to test and refine its own prospects, but also to elaborate a protocol (or guidelines) for the conservation, performance modernisation and valorisation of this architectural heritage that is still little known, but of great cultural importance.

Author Contributions: Conceptualization, G.A., G.B., G.C., O.F., F.M., G.F.R. and L.M.P.I.; methodology, G.B., O.F., F.M. and L.M.P.I.; software, G.A. and G.F.R.; validation, G.B., O.F., F.M. and L.M.P.I.; formal analysis, G.C. and G.F.R.; investigation, G.A., G.B., G.C., O.F., F.M., G.F.R. and L.M.P.I.; resources, G.A., G.B., G.C., O.F., F.M., G.F.R. and L.M.P.I.; data curation, G.A. and G.F.R.; writing—original draft preparation, G.A., G.B., G.C., O.F., F.M., G.F.R. and L.M.P.I.; writing—review and editing, G.A., G.B., G.C., O.F., F.M., G.F.R. and L.M.P.I.; visualization, G.A., G.B., G.C., O.F., F.M., G.F.R. and L.M.P.I.; supervision, O.F. and F.M.; project administration, G.A., G.B., G.C., O.F., F.M., G.F.R. and L.M.P.I. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Data Availability Statement: The data used in this study are not publicly available. Interested researchers may contact the corresponding author for more information on the data used in this research.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Galbiati, G.; Graf, F.; Marino, G.; Fürbringer, J.M. A modelling framework for modern heritage buildings energy simulation. *J. Build. Eng.* **2023**, *80*, 107973. [CrossRef]
2. Von Rettberg, B.; Rodriguez-Maribona, I. European Building and Urban Stock Data Collection. EFFESUS Project Deliverable D1.1. 2013. Available online: https://cordis.europa.eu/project/id/314678/reporting (accessed on 15 October 2024).
3. Patrimoine Architectural du XXe Siècle en Europe. Valeurs, Doctrines et Politiques Publiques de Reconnaissance. *In Situ Revue Des Patrimoines* **2022**, *47*, 6–9. Available online: https://journals.openedition.org/insitu/34184 (accessed on 10 September 2024).
4. Gucyeter, B. Calibration of a building energy performance simulation model via monitoring data. In Proceedings of the Building Performance Analysis Conference and SimBuild, Chicago, IL, USA, 26–28 September 2018; pp. 542–549.
5. Crawley, D.B.; Hand, J.W.; Kummert, M.; Griffith, B.T. Contrasting the capabilities of building energy performance simulation programs. *Build. Environ.* **2008**, *43*, 661–673. [CrossRef]
6. Lidelöw, S.; Örn, T.; Luciani, A.; Rizzo, A. Energy-efficiency measures for heritage buildings: A literature review. *Sustain. Cities Soc.* **2019**, *45*, 231–242. [CrossRef]
7. Buda, A.; de Place Hansen, E.J.; Rieser, A.; Giancola, E.; Pracchi, V.N.; Mauri, S.; Herrera-Avellanosa, D. Conservation-compatible retrofit solutions in historic buildings: An integrated approach. *Sustainability* **2021**, *13*, 2927. [CrossRef]
8. Rieser, A.; Pfluger, R.; Troi, A.; Herrera-Avellanosa, D.; Thomsen, K.E.; Rose, J.; Chung, D. Integration of energy-efficient ventilation systems in historic buildings—Review and proposal of a systematic intervention approach. *Sustainability* **2021**, *13*, 2325. [CrossRef]
9. Ide, L.; Gutland, M.; Bucking, S.; Santana Quintero, M. Balancing trade-offs between deep energy retrofits and heritage conservation: A methodology and case study. *Int. J. Archit. Herit.* **2022**, *16*, 97–116. [CrossRef]
10. Franco, G.; Mauri, S. Reconciling Heritage Buildings' Preservation with Energy Transition Goals: Insights from an Italian Case Study. *Sustainability* **2024**, *16*, 712. [CrossRef]
11. Ruggeri, A.G.; Calzolari, M.; Scarpa, M.; Gabrielli, L.; Davoli, P. Planning energy retrofit on historic building stocks: A score-driven decision support system. *Energy* **2020**, *224*, 110066. [CrossRef]
12. Atmaca, N.; Atmaca, A.; Özçetin, A.İ. The impacts of restoration and reconstruction of a heritage building on life cycle energy consumption and related carbon dioxide emissions. *Energy Build.* **2021**, *253*, 111507. [CrossRef]
13. Piselli, C.; Romanelli, J.; Di Grazia, M.; Gavagni, A.; Moretti, E.; Nicolini, A.; Pisello, A.L. An integrated HBIM simulation approach for energy retrofit of historical buildings implemented in a case study of a medieval fortress in Italy. *Energies* **2020**, *13*, 2601. [CrossRef]
14. IEA-SHC Task 59—Deep Renovation of Historic Buildings Towards Lowest Possible Energy Demand and CO_2 Emission (NZEB). Available online: http://task59.iea-shc.org/ (accessed on 20 October 2024).
15. ATLAS Research Project. Interreg Alpine Space Programme 2014–2020. ID: ASP644. Available online: https://www.alpine-space.eu/project/atlas/ (accessed on 20 October 2024).
16. Exner, D.; Haas, F.; Herrera-Avellanosa, D.; Hüttler, W.; Troi, A. HiBERatlas. Available online: http://www.hiberatlas.com/ (accessed on 20 October 2024).
17. Neri, M.L.; Catini, R.; Cervellini, F.; Ippoliti, E.; Ordasi, Z.; Sandri, A.M.; Tachi, G.L. *L'altra Modernità Nella Cultura Architettonica del XX Secolo*; Gangemi Editore: Roma, Italy, 2015.
18. Rodríguez, J.M.; Rodríguez, M.; José, M. *Historia del Arte Contemporáneo en España e Iberoamérica*; Editorial Edinumen: Madrid, Spain, 1998.
19. Bohigas, O.; Canella, P. *Architettura Spagnola Della Seconda Repubblica*; Dedalo: Matera, Italy, 1978.
20. Frontero, D. *Barcellona: Architettura Contemporanea*; Edizioni Associate: Milan, Italy, 2003.
21. Venteo, D. *Barcelona: A Historical Guide to the Contemporary City*; Ajuntament de Barcelona: Barcelona, Spain, 2014.

22. García, J. Racionalismo y Funcionalismo en la Arquitectura Social Española. In *Arquitectura Social Española*, 2nd ed.; Ministerio de Fomento: Madrid, Spain, 2013.
23. Casadevall, G.D. Guerra civile e architettura spagnola moderna: La fine di un sogno. *Diacronie* **2011**, *7*, 3. [CrossRef]
24. Mestre, J.; Tristan, I. *Extramuros. Geometría y Mestizaje*; Contrastes Culturales: Valencia, Spain, 2009.
25. Díaz, P. José Luis Sert y la Arquitectura Moderna en el Exilio. In *José Luis Sert y la Arquitectura Moderna*, 2nd ed.; Alianza Editorial: Madrid, Spain, 2003.
26. Fernández, L. Arquitectura y Poder en la España de Franco. In *Arquitectura y Poder*, 2nd ed.; Ediciones Cátedra: Madrid, Spain, 2010.
27. Alonso, R. Arquitectura Moderna y Franquismo en España. In *Arquitectura Moderna y Franquismo*, 2nd ed.; Ediciones Cátedra: Madrid, Spain, 2007.
28. Méndez, I. Ley de Viviendas de Renta Limitada: Una Historia de la Vivienda Social en la España de Franco. In *Ley de Viviendas de Renta Limitada*, 2nd ed.; Instituto Juan de Herrera: Madrid, Spain, 2011.
29. Torres Cueco, J. Valencia: La arquitectura en los años cincuenta. Una revista y cuatro proyectos. In *Los Años 50: La Arquitectura Española y su Compromiso con la Historia*; Congreso Internacional: Pamplona, Spain, 2000.
30. Patuel Chust, P. *Arquitectura y Urbanismo Valenciano en el Franquismo (1939–1975)*; Publicacions de la Universitat de València: Valencia, Spain, 2021.
31. Sanchis, R. La Arquitectura Racionalista en Valencia: Proyectos de Vivienda Social. In *Arquitectura Racionalista en Valencia*, 2nd ed.; Colegio de Arquitectos de Valencia: Valencia, Spain, 2011.
32. Camí, J. El Impacto del Movimiento Moderno en la Vivienda Social de Valencia. In *Movimiento Moderno en la Vivienda Social*, 2nd ed.; Universitat Politècnica de València: Valencia, Spain, 2013.
33. Pérez, M. Espacios Públicos y Vivienda Social en Valencia: El Legado del Movimiento Moderno. In *Vivienda Social en Valencia*, 2nd ed.; Universidad de Valencia: Valencia, Spain, 2014.
34. Ortega, F. Vivienda social y urbanismo en Valencia: Una perspectiva histórica. In *Urbanismo y Vivienda Social en España*, 2nd ed.; Ediciones Trea: Gijón, Spain, 2015.
35. Bernardo, G. Critical and typological analysis of the habitat in Spain after developmentalism. *Int. J. Archit. Technol. Sustain.* **2022**, *7*, 18–29.
36. Torres Cueco, J. Imágenes de lo Moderno. In *Historia de la Ciudad. Recorrido Histórico Por la Arquitectura Y El Urbanismo de la Ciudad de Valencia*; Colegio Oficial de Arquitectos de la Comunidad Valenciana: Valencia, Spain, 2000.
37. AA.VV. Architecture of the Modern Movement, 1925–1965. In *Registro DOCOMOMO Ibérico*; Fundación Mies van der Rohe: Actar, Spain, 2012.
38. García Sanz, J.; Artal Ríos, S. Dos Grupos de Viviendas en Valencia. *ConArquitectura: Arquit. Con Arcilla Cocida* **2001**, *2*, 89.
39. Sánchez, R. La evolución de la arquitectura social en España y su impacto en Valencia. In *Arquitectura Social en España*, 2nd ed.; Colegio de Arquitectos de Valencia: Valencia, Spain, 2012.
40. Testoni, C. *6 Architetture per Spiegare Cos'è il Cobogò Brasiliano*; Domus Editoriale: Domus, Spain, 2022; ISSN 0012-5377.
41. Aguilar, M. Arquitectura racionalista en España: Una mirada contemporánea. In *Arquitectura Racionalista en España*, 2nd ed.; Editorial Gustavo Gili: Barcelona, Spain, 2015.
42. Pozo Municio, J.M. *Los Brillantes 50. 35 Proyectos*; T6 Ediciones: Madrid, Spain, 2004.
43. Peñin, A. *Valencia 1874–1959, Ciudad, Arquitectura y Arquitectos*; Escuela Técnica Superior de Arquitectura, Universidad Politécnica de Valencia: Valencia, Spain, 1978.
44. Araujo, R. La arquitectura y el aire: Ventilación natural. *Tectonica* **2011**, *35*, 4–19.
45. Direttiva 93/76/CEE del Consiglio, del 13 Settembre 1993. Available online: https://eur-lex.europa.eu/legal-content/IT/ALL/?uri=CELEX:31993L0076 (accessed on 18 September 2024).
46. Gobierno de España, Boletín Oficial del Estado. Real Decreto 235/2013. B.O.E. núm. 89, de 13 de Abril de 2013. Available online: https://www.boe.es/eli/es/rd/2013/04/05/235/con (accessed on 18 September 2024).
47. IDAE. Calificación Energética de Edificios. Available online: https://www.idae.es/tecnologias/eficiencia-energetica/edificacion/calificacion-energetica-de-edificios (accessed on 8 October 2024).
48. Gazzetta Ufficiale della Repubblica Italiana. LEGGE 3 Agosto 2013, n. 90. Available online: https://www.gazzettaufficiale.it/eli/id/2013/08/03/13G00133/sg (accessed on 17 October 2024).
49. Olgyay, V. *Design with Climate: Bioclimatic Approach to Architectural Regionalism*; Princeton University Press: Princeton, NJ, USA, 1963.
50. Givoni, G. Passive Low Energy Cooling of Buildings. In *Architecture Series*; John Wiley & Sons: Hoboken, NJ, USA, 1994.
51. Lechner, N. Heating, Cooling, Lighting: Sustainable Design Methods for Architects. In *4, Illustrate*; John Wiley & Sons: Hoboken, NJ, USA, 2014.
52. De Dear, R.; Kim, J.; Candido, C.; Deuble, M. Adaptive thermal comfort in Australian school classrooms. *Build. Res. Inf.* **2015**, *43*, 383–398. [CrossRef]