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Enhancing the Historic Public Social Housing through a User-Centered Design-Driven Approach

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Abstract: The study presents a didactic experience for the deep refurbishment and the revitalization of the San Siro neighborhood in Milan (Italy). The public housing is a significative example of the 20th-century architecture (also named "Italian Modernism of Architecture"), designed by the Italian architects—Franco Albini, Renato Camus, Giancarlo Palanti, and Laslo Kovacs (1938–1941). Nowadays, it is a multicultural area, characterized by the presence of a fragile population, with strong socio-spatial inequalities, intercultural and intergenerational conflicts. Here, an architectural design project is realized, experimenting with innovative and up-to-date design solutions. This experience develops a sensitive awareness of the multidimensional complexity of the environmentally responsible design, which requires a critical balance among different disciplines and skills. The reusing of existing buildings has sustainable importance for preventing new land-uses and for saving the potential energy consumption related to the construction process. Only a widespread knowledge of the local socio-economic conditions through participatory actions permits the selection of appropriate retrofit solutions, considering also the high cultural, social, and economic values. Functional and social mix, space flexibility, green design, renewable energies, circular economy criteria, and continuative maintenance are the correct strategies for boosting the social revitalization and for improving fairness, safety, architectural quality, human comfort, energy efficiency, and sustainability in this public housing neighborhood.

Keywords: public social housing; 20th-century architecture; architectural design practice; design-driven research approach; user-centered design; integrated design process; regenerative design

1. Introduction

Public housing neighborhoods are important parts of a city. They represent a series of contradictions, related to the high human and social value as well as to their abandon, low-cost alienation, architectonic and social degradation, sub-letting, rack-renting, failed regeneration, or gentrification attempt [1,2]. In Italy, the problem is huge. There are approximately 1 million of public housing neighborhoods (954.161) [3] that represent 4% of Italian homes, in a country with a higher European (hereafter, EU) share of private houses (75–80%) [3]. Seventy percent of this patrimony is still owned and managed by specific public associations (i.e., the Istituto Autonomo Case Popolari–IACP) or public authorities (i.e., provinces, municipalities) [3]. The first public housing neighborhoods were built between the two world wars in the northern part of Italy to satisfy the needs of the farming population from the surrounding countryside or abroad [4,5]. The working class (also called "*the workers*") migrated to be employed in the "*new factories*" of the biggest cities (e.g., Milan, Turin). Similarly, some cheap affordable housings were built after the second world war, to conceive the needs of the immigrants from southern Italy, attracted by the massive industrial expansion of the north. In general, these districts were located in a peripheral part of the city. They expressed the architectonic, typological, and technologic style of this period, as the most famous experiences of Vienna and Amsterdam (e.g., Karl Marx Hofe in Vienna, Spaarndammerbuurt and Amsterdam Sud in Amsterdam) [6,7]. These peripheral but "*proudly workers*" areas contributed to the innovation of the Italian cities [8]. In the past (1963–1998), their construction and care were guaranteed by a dedicated national fund provided by the GesCAL association (Gestione Case per i Lavoratori). This fund was abolished after its closure in 1998 [8]. This creates "*slums*" with decay, lack of maintenance, destitution, and thieves. In the last decades, these districts suffered a strong physical and social transformation, with a widespread impoverishment due to the lack of funding and maintenance [9]. The neighborhood of public housings acquired a negative meaning, as homes for those who cannot afford a mortgage [10]. Actually, they are frequently subject to criminal activity, social disorders, internal conflicts, drug-taking, racketeering, dealing, vandalism, and military intervention for the illegally occupied home [2,9]. Social problems refer also to poor management, racial segregation and exclusion, and stigmatization [2].

Nevertheless, these districts have underestimated resources and potentials that could represent a key element for an overall redevelopment [9], thanks to their high social, economic, and architectonic values as well as to the connection with the public transport. Consequently, they represent a "*social periphery*" inhabited by the "*new poverty*" composed of the original population, now elderly, and by foreign and young migrants often with precarious and occasional jobs [2]. Their functional and morphological renovation, using both public and private investments, can produce positive effects for the socio-economical regeneration of the cities [11] and for the integration of new citizens [2]. Their replacement may address the needs of rental housing and local welfare. It can also boost the application of contemporary living models, sustainable management strategies, and maintenance procedures, which can balance the up-to-date requirements of energy efficiency, human comfort, and operating cost-reduction [12], ensuring also energy and economic benefits [13]. Their deep renovation represents an important challenge towards the transition from public neighborhoods to sustainable cities, particularly in the areas with poor building quality and social conflicts [14]. These innovative housing models can also have a positive impact on the "*energy poverty*", defined as the inability to purchasing the minimum energy goods [15]. The problem is huge and urgent. Around 10.4% of the EU population cannot pay rent and housing services costs (water, gas, electricity) that absorb around 40% of the incomes [16]. Only in Italy, the problem of "*absolute poverty*" refers to almost 5 million families [17,18].

Many EU countries are implementing actions for redeveloping the public housing districts, paying attention also to energy efficiency and environmental sustainability to overcome the issues of land consumption savings. In Italy, some planning actions have been realized departing from 1980 for satisfying the needs of public housing revamping [19]. Examples are the "*Piano di Riqualificazione Urbanistica*" (PRU, Programs of Urban Renewal), the "*Progetti Pilota Urbani*" (PPU, Urban Pilot Projects), "*Programmi di Recupero Urbano e Sviluppo Sostenibile del Territorio*" (PRUSST, Urban Regeneration Programs and Sustainable Development Planning), and the "*Contratti di Quartiere*" (Quarter Contracts). The last one started in 2001 for activating new design solutions to improve the energy and environmental quality of public homes [19–23]. These interventions were based on the involvement of the inhabitants for defining new design strategies and for programing a long-time sustainability [22]. Despite the high expectations, this experience was just an opportunity to carry out standard maintenance actions [23]. Similarly, the French "*Contrat de Ville*" applied several integrated policies for urban planning, energy retrofit, economic development, and social support for damaged public neighborhoods [22].

More recently, the "*European Energy Package 2030*" suggested testing "*pilot*" initiatives in public housings to reach the high EU targets on energy efficiency, energy costs, and environmental sustainability [24]. As well, innovative policies and retrofit designs were experimented concretely in these districts, to achieve high aesthetic, typological, energy, and environmental quality, without consuming further soil. The social crisis caused falling business profitability and high unemployment rates, notably affecting ethnic minorities [21]. The reduction of fund availability promoted the public response based on several technical-political remedial acts for boosting the social integration in French problematic housings [20]. The first experience was the French program "*Requalification à Haute Performance Energétique de l'Habitat collectif*" (REHA), a large scale national program [25,26] that defined design criteria and guidelines for retrofitting collective homes with high energy and environmental performance. After that, the PLUS+ program investigated the design strategies for public housing renovation [26]. The French architects—Druot, Lacaton, and Vassal—realized numerous pilot studies (e.g., Tour Bois le Prêtre, Paris, 2011; public housing Grand Parc, Bordeaux, 2016; La Chesnaie, Saint-Nazaire, 2014–2016), to demonstrate the possible balance between aesthetics, energy retrofit, and human comfort (i.e., volumetric additions and extensions, roofs or façades additions, loggias, balconies, intermediate spaces, bioclimatic greenhouses) [1]. These works proved the benefits related to the rationalization of indoor spaces for increasing the number of dwellings through a complete transformation of building façades and urban spaces.

The scientific literature on social housings refers mainly to the topics of energy efficiency, climate change, and economic development. The first aspect is related to the energy retrofit of building façades, guarantying affordable cost-optimal approaches [11,13,14,18]. Furthermore, the link between energy systems for space heating and users' behavior (i.e., users' comfort levels, set point temperature, functioning hours) is considered an important topic for improving energy efficiency and environmental sustainability in these contexts [27]. This issue is addressed by several studies that propose different methods for energy estimations [28,29], or for strategically driving the users' behaviors towards energy consciousness [27,30]. Besides, the application of renewable energy sources (hereinafter, RES) in social housings, considering both solar energy and biomass, is suggested to reduce the environmental impact and to offer economic benefits for tenants and housing providers. In this case, the studies refer mainly to case studies, as demonstrated by a detailed review [31]. The application barriers concern their technological complexity (i.e., ad hoc design, contracting of specialist services) as well as their design, installation, and maintenance costs [31–34]. Besides, significant design experiences showed the importance of the integrated approach between construction, energy efficiency, and environmental sustainability for the deep renovation of historical social housings (i.e., PLUS+ program in Paris, Bordeaux, and Saint-Nazaire; BedZed in London; Norrlansgatan Hammarby Sjostad in Stockholm; Manessestrasse in Zurich) [35–37]. These experiences improved also the quality housing standard, creating an urban identity between the inhabitants, avoiding ghettoization, and facing social disadvantage [35]. Despite the great efforts in developing effective technological solutions and case studies, the most critical factors for the deep renovation of existing social housings concern the non-technical barriers related to social (i.e., social planning, user behavior and comfort, cultural and social habits, generational aspects), logistic (i.e., dialogue understanding between partners, the impact of the construction on building use, availability of technological solutions), legislative (i.e., local building regulation; European, national, and local legislation), and financial (i.e., investment costs, pay-off time) constraints [35]. Behavior and local cultural factors, in particular, can reduce the efficiency of the renovation initiatives, impacting on energy use, conservation state, management, and maintenance operations [31,35]. These barriers need to be overtaken by an integrated approach based on tailored design strategies that consider innovative and affordable solutions, faster construction processes, legislative controls, and skill levels of the residents for improving their quality of life [1,35,36]. These aspects are important to overcome the social, logistic, legislative, and financial constraints, especially related to the management of complex technologies (i.e., RES, innovative, heating systems, complex façades, prefabricated structures). To overcome the gap between social and technical issues in the renovation practice of historic social housings, the present research adopts a user-centered "*design-driven approach*" based on a socio-technical perspective. The technical aspects, related to energy efficiency, human comfort, environmental sustainability, conservation principles, biophilic design, layout flexibility, and functional mix, start from an interactive-participative method that fosters the architectonic quality of the neighborhood according to the contemporary lifestyles of the residents. To this purpose, a specific didactic methodology is developed and experimented.

2. Aims

This work is conducted in the framework of the "*Off Campus. Il Cantiere per le Periferie*", a research initiative developed by the School of Architecture of the Politecnico di Milano, with the aim of strengthening the presence of the university inside the city, to be « (...) *more responsible, open, aware of social challenges, and closer to the community*» [38]. This initiative, coordinated by Mapping San Siro [39,40], originates from the cooperation between universities, inhabitants, and local networks, to develop innovative teaching and research approaches for fostering new skills, expertise, and values in future generations. Its approach aims at sensitizing researchers and students for favoring the social revitalization of "*fragile*" urban areas [41]. In this context, several Architectural Design Studios focused on the redevelopment of the San Siro neighborhood, the biggest public social housing area of Milan (Italy) (Section 4). The present work aims at identifying an innovative and up-to-date methodological didactic approach for defining the most appropriate solutions for the refurbishment of a historic public housing designed by the Italian architects—Franco Albini, Renato Camus, Giancarlo Palanti, and Laslo Kovacs (1938–1941). These buildings are significative examples of the 20th-century architecture (also named "Italian Modernism of Architecture"). Their refurbishment is based on a user-centered "*design-driven approach*" that answers to the urgent housing needs created by the recent social transformations of this district. This design proposal is developed as an "*integrated design process*" (hereinafter, IDP) with students, high-experienced and resident-architects, technicians from the industry sector, and inhabitants. This approach allows the students to realize the complex and multidimensional problems that demarcate the territory of the "*real-world*" professional activity in a critical way as well as to compare different design approaches.

3. Materials and Methods

The present work is structured in five phases, as illustrated below (Figure 1):

- Historical research and survey of the neighborhood (phase A)
- On-site visit (phase B)
- Hands-on training (phase C)
- Architectural design practice (phase D)
- On-site exposition (phase E).

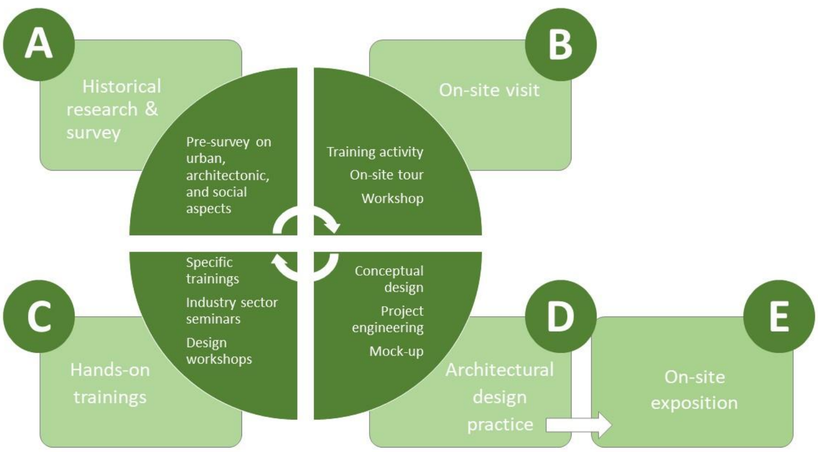


Figure 1. Working phases: (**A**) historical research and survey; (**B**) on-site visit; (**C**) hands-on training; (**D**) architectural design practice; (**E**) on-site exposition.

In the following, a description of the working phases is reported, dividing it into methods (Sections 3.1–3.4) and the results of the work (Sections 4.1–4.4).

3.1. Historical Research and Survey on the Neighborhood (Phase A)

The "Off Campus San Siro" repository collects numerous historical designs and documents of the Archivio di Stato di Milano (Historical Archive of Milan) on the San Siro neighborhood, thanks to the didactic project "*Envisioning San Siro*" promoted by the Politecnico di Milano for a complete reconnaissance of the neighborhood [41]. Thanks to this experience, the public social housing of the San Siro neighborhood is deeper studied, comparing historical [42–44] and recent publications [4,5,8,39–41,45–47]. A detailed analysis is developed as a pre-survey for guiding the students in the architectural design project (phase C, Sections 3.3 and 4.3). This activity concerns data on (i) historical, social, and economic developments of the districts; (ii) morpho-typological features; (iii) material and geometrical characters; (iv) national and local rules and constraints. This preliminary study outlines the urban and architectonic features as well as the social characteristics of the area. The results of this phase are reported in Section 4.1.

3.2. On-Site Visit (Phase B)

The historical research and the survey of the area (phase A, Sections 3.1 and 4.1) are supported by an on-site visit that contributes to the active and experiential learning through the interaction with the physical and social environment (Figure 2). The on-site visit is structured as a one-day excursion. It aims at increasing observational skills, contextual knowledge, and cognitive processes of the students. This activity is divided into training activity, on-site tour, and workshop. First, the training activity is focused on the most important urban, architectonic, artistic, and social aspects of the area. Its architectonic history is shown through historical pictures, plans, and designs. Besides, the theoretical and practical experiences of the architects involved in the original project are described. The training activity is preparatory for the on-site tour that directly explores the status of the public social housing of the San Siro neighborhood. The first interaction with the real-life context permits the students to understand the habits, cultures, activities, and needs of the inhabitants, defining the project as a user-center design proposal from the early stage. This kinesthetic experience allows us to appreciate the area in a "*non-structured*" way, increasing their empathetical imagination for the architectural design project (phase D, Sections 3.4 and 4.4). The students have visited this area several times to understand better its architectonical and social character. Finally, an on-site workshop is organized with the support of Mapping San Siro [39,40], focusing on the description of the research programs and the practical activities done with the inhabitants of the neighborhood for improving their quality of life. The results of this phase are synthesized in a matrix of weaknesses and opportunities of the area (Section 4.2).

(**a**) (**b**)

Figure 2. The on-site survey: (**a**) on-site tour in the San Siro neighborhood of public housing, and (**b**) workshop realized in the "Off Campus San Siro".

3.3. Hands-On Training (Phase C)

The hands-on training explores the architectural skills involved in the design practice, from ideation and conception through planning, project proposal, and technical engineering. They mirror the complex interplay between "*design making*" and "*design construction*" issues to prepare the students for their future professional activity. The pieces of training are arranged as a mix of oral presentations, interactive discussions, design workshops, and team-based design exercises to combine theoretical and applied knowledge. To provide meaningful and purposeful links with different disciplines, the courses of "*Technology of Architecture*" and "*Building Physics*" are combined together to match social innovation, energy efficiency, and environmental sustainability. The "*Course of Technology of Architecture*" introduces a range of construction systems and materials, including timber, steel, and concrete. It includes the basics of building services and construction detailing, as well as discusses the topics of accessibility, architectural barriers, expansion of the housing volumes, and regulatory adjustments of buildings. Several EU public housing experiments are presented to show innovative housing types and possible transformations tailored for new lifestyles. These technology solutions are considered the basis for developing new housing types and specific technological details. The pieces of training, workshops, and discussions in the "*Course of Building Physics*" address urban and building levels. The pieces of training are organized as teacher-centered instruction on sustainability and energy efficiency. This activity provides practical principles, skills, tools, approaches, and techniques for improving a knowledge-basis on environmental audit, bioclimatic, biophilia, green architecture, green design, energy audit, energy concept, building envelope, heating, ventilation, and air-conditioning (hereinafter, HVAC) systems, RES systems, passive and active retrofit solutions, architectural lighting design, nearly zero-energy buildings (hereinafter, nZEB), and building energy simulation (hereinafter, BES) models. Furthermore, one-day microlearning training is realized to develop energy and sustainable concepts in short-term learning activities. This experiment is structured in a team-based design exercise and work's presentation. A design exercise is proposed as a creative workshop to produce the design concepts, based also on the ideas born during the on-site survey (phase B, Sections 3.2 and 4.2). To give more freedom to the learners, images, videos, texts, sketches, texts, and audios can be used. Work's presentations are arranged as a competition to boost the engagement of students. First, each group presents his work, then the teacher and other groups vote the design project, considering energy and environmental correctness, technical quality, communication, and infographic. The team with the higher score wins the competition. Besides these teacher-centered pieces of training, specific architectural skills are offered by several external experts of the industry sector (i.e., structural engineering, system building, heavy-timber construction, steel construction) to bring together design and construction phases. Otherwise, several design workshops with high-experienced architects and resident-architects permit to improve the architectural design project (phase D, Sections 3.4 and 4.4), supporting the development of the creativity with constant corrections and suggestions.

3.4. Architectural Design Project (Phase D)

In parallel to hands-on training (phase C, Section 3.3), an architectural design project is developed in design teams with the support of the professors and the high-experienced architects. Working collaboratively favors the enhancement of educational skills, both in technical and social practices. Besides, it is fundamental for the professional activity of architects that involves different competences and working fields (i.e., architecture, engineering, sociology, psychology, video creation, graphic design, etc.). For this reason, eight design teams (each one composed of 3–4 people) are established considering personal skills, knowledge, and aptitudes. To define these teams, each student presents in a structured way his/her curriculum, shoving previous design experiences, software abilities (i.e., building information modeling–BIM, BES, video making, etc.), technical skills (e.g., model construction, building physics, cost analysis, and so on), and expectations. After the team's definition, the goals to reach the architectural design project are described, focusing on the retrofit of two linear buildings of the housing neighborhood (Section 4.2). The traditional definition of environmental sustainability is suggested as a fundamental basis for upgrading the building stock, combining the socio-ecological process, architectonic quality, energy efficiency, human comfort, and contemporary lifestyles. In this way, the contemporary housing design can be rethought within the interaction of private and public spaces, also considering flexibility, adaptation to new use, functional mixing, and high energy efficiency standards. The goals to reach the design project are defined as follows: (i) to address the mandatory structural and regulatory adjustments [48,49], particularly for overcoming the problems of the minimum dimension of dwellings and architectural barriers (e.g., installation of lifts); (ii) to rethink the original buildings and their internal layouts, according to needs, regulations, and constraints; (iii) to upgrade the homes to the contemporary lifestyles and space flexibility (e.g., the introduction of new functions, collective services, and open spaces); (iv) to fulfill the legislative requirements on energy efficiency and environmental sustainability using passive and active technologies; (v) to solve the problems of building decay and HVAC systems obsolescence; (vi) to reduce the environmental impact of the construction process; (vii) to discuss issues regarding environmental impact and sustainability relevant to construction; (viii) to encourage the coexistence of foreign people. In addition, the local "*Building Code*" [49] encourages the increase of the total volume in the range of 5–15%, realizing maintenance, restoration, or energy retrofit actions. The increasing of 15% must be related particularly to the following elements [49] (art. 140, comma 4): reduction of the overall energy consumption; improvement of the thermal performance of the building envelope; renovation of the HVAC systems; use of RES technologies. In addition, the introduction of new targets of inhabitants (e.g., away-from-home students or ancient people) is suggested for avoiding ghettoization and social degradation.

Three main steps of works are proposed: conceptual design, project engineering, and mock-up creation. The first step concerns the architectural projects (e.g., floor plant, roofing plan, elevation, and section, 1:100 and 1:50), considering environmental resources, building constraints, and project goals. The project engineering focuses on the technological-construction specifications related to building structures, construction materials (also considering market products), façade additions (e.g., hanging, hooked to the load-bearing walls, or resting on the ground volumes), and abacuses of building elements (i.e., windows, walls, ceilings, and joinery). Here, an individual submission explores the tectonics of the conceptual design, culminating in detailed drawings of the building façade with 1:20 and 1:10 models. Finally, the architectural design project is illustrated using digital or physical mock-ups of the building and the façade. The results of this phase and the lessons learned are reported in Section 4.4.

3.5. On-Site Exposition (Phase E)

Finally, the realization of an on-site exposition permits to share the architectural design projects within professors, architects, students, and inhabitants, as well as to improve the long-term retention of notions and technical skills for the students. The results of this phase are reported in Section 4.5.

4. Results and Discussion

The result of each working phase is reported below in a detailed way.

4.1. Historical Research and Survey on the Neighborhood (Phase A)

The results of the historical research are synthesized in this section as a starting point for the architectural design project (phase D, Section 4.4). Originally, the San Siro area was a small farming village located in the northwestern suburbs of Milan, on the banks of the Olona River. The name is derived from the historic Church of San Siro della Vepra [39]. This area was annexed to Milan in 1873 [42]. The public housing neighborhood was built between 1932 and 1947, after an important design competition launched in 1932 by the Istituto Fascista Autonomo Case Popolari (Fascist Autonomous Institute of Popular Houses–IFACP). This competition was an opportunity for young rationalist architects to explore the public housing design, widely studied and experimented in alpine countries (e.g., Germany, Austria). It represents also an important example of Italian Rationalism, an architectonic style characterized by a detailed design of living spaces and building components [42]. Originally, the neighborhood was located in the north-west part of Milan, next to the countryside. This area was absorbed by the rest of the city, changing completely the urban contexts. Nowadays, San Siro is a suburb that lies relatively close to the city center, well connected by the underground (line 5, Segesta, Italy). It is one of the most multi-ethnic and problematic neighborhoods of Milan, composed of 6000 dwellings for 11,000 inhabitants (Figure 3). It is a multicultural area, characterized by the presence of a fragile population, with strong socio-spatial inequalities, intercultural and intergenerational conflicts. Around 50% of the population are immigrants, with 85 nationalities (the average data for Milan is 20%) [39].

Figure 3. A top view of the San Siro neighborhood in Milan.

The buildings are physically damaged, mainly for the lack of economic investments, despite the extraordinary maintenance program realized by the "*Contratti di Quartiere*" (2003) that was devoted only to urgent security measures. In the last years, the sold-out of several dwellings addresses the financial difficulties [41]. Approximately 350 dwellings have an area lower than the dimensional threshold of 28.00 m^2 defined by regional rules [48], art. 9. Otherwise, about 700 homes need maintenance and regulatory adjustments. All these dwellings cannot be assigned for the uncomfortable and the unmaintained conditions. The project area is named "*San Siro Milite Ignoto*". It is located in the western part of the neighborhood. It addresses the rationalistic principles of the architects Albini, Camus, Palanti, and Kovacs (1938–1941) [42]. The town plan is designed according to geometric rules (hence the "Quadrilatero"), in opposition to traditional urban plans based on diagonal roads and irregular lots. The buildings and the neighborhood are not listed. The complex insists on an area of 240,000 m^2 for 480 homes. The lot is divided into four parts by two parallel streets (via Tracia and via Preneste). It consists of ten linear buildings oriented according to the heliothermic axis to optimize the exposure to the sun. Each building is a modular architecture composed of one, two, or three modules. This module is also on the basis of other public housings designed by Albini in Milan (e.g., Fabio Filzi neighborhood, 1935–1938, 447 flats; Ettore Ponti neighborhood, 1939–1941, 439 flats), as shown below (Figure 4).

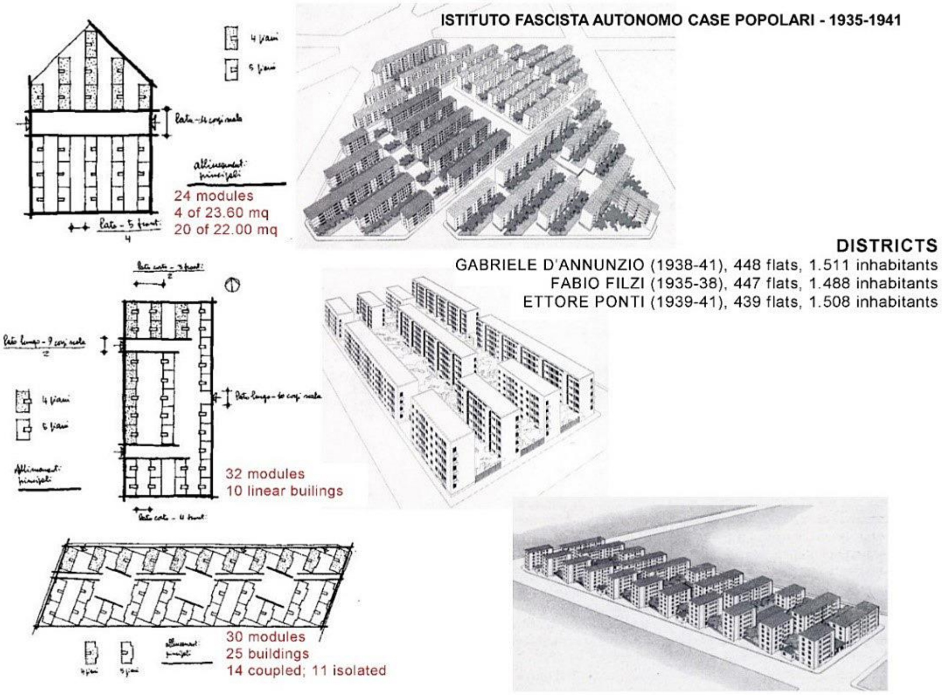


Figure 4. The "building module" is used in several examples of public housing in Milan (Sources: [44,45,48]).

The attention of the architectural design project (phase D, Sections 3.4 and 4.4) is focused on a housing development composed of two linear buildings, with a north-south orientation and five floors. Besides, here, the buildings follow the heliothermic axis for ensuring hygienic and thermal efficiency. Each building consists of three modules, corresponding to 120 flats with different sizes (one-room apartments, two-room apartments, and three-room apartments). The size of each dwelling is in the range 25–55 m^2, and 40 flats have a too low size to be rented [48]. The construction techniques are composed mainly of vertical load-bearing partitions in solid brick masonry, horizontal slabs in brick-cement, perimeter curbs in reinforced concrete, and flat roofs (Figure 5).

Figure 5. The state-of-the-art of the housing development designed by Albini, Camus, Palanti, and Kovacs (1938–1941).

Maintenance operation and requalification are managed by the Residential Housing Company of Lombardy Region (Aler), a regional entity created in 1996. Its management approach does not prioritize the building enhancement [45], creating hardship and marginality [45,48].

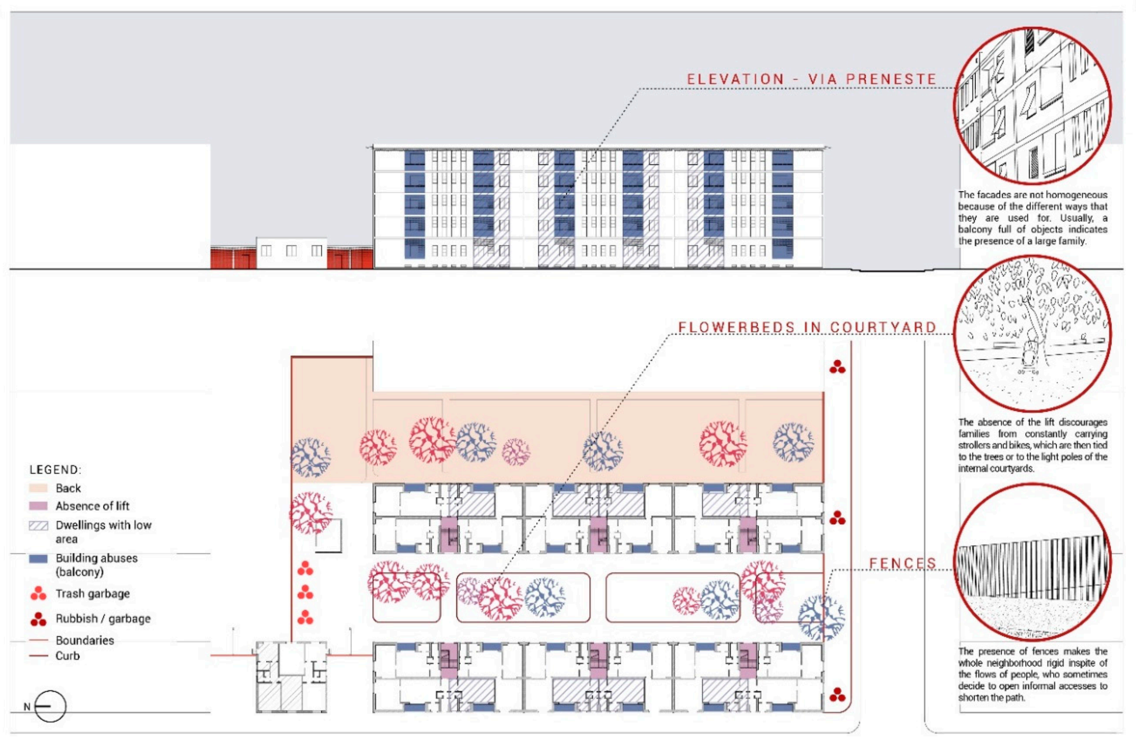
4.2. On-Site Survey (Phase B)

The results of the on-site survey (Section 3.2) are synthesized by each project team as fact-based analysis of the weaknesses and the opportunities of the area. This activity starts with the taxonomy of the collected data to understand how these features could be integrated toward a harmonized architectonic transformation (Section 4.3). Geographic data, local regulations, building codes, and climate are collected to have a first overview of the place. Several aspects are investigated directly in situ by on-site visits and interviews with the inhabitants. They concern transport systems, city connections, green areas, public places, common spaces, orientation, building shape, building typology, dimensions, construction techniques, structure, materials, aesthetic design, bioclimatic quality, distribution systems, conservation state, and social transformation. This knowledge is systematized in a matrix of weaknesses and opportunities (Table 1).

Table 1. Matrix of weakness and opportunities at urban and building levels.

<table>
<tr><th colspan="2">Weakness</th><th colspan="2">Opportunities</th></tr>
<tr><th>Urban</th><th>Building</th><th>Urban</th><th>Building</th></tr>
<tr><td colspan="2">Decay and damage</td><td colspan="2">Green areas</td></tr>
<tr><td colspan="2">Architectural barriers</td><td colspan="2">Social mix</td></tr>
<tr><td colspan="2">State of abandonment</td><td>Underground</td><td>Rational design</td></tr>
<tr><td colspan="2">Hardships</td><td>Pedestrian areas</td><td>Flexibility</td></tr>
<tr><td colspan="2">Poor maintenance and management</td><td>Multiculturalism</td><td>Bioclimatic design</td></tr>
<tr><td colspan="2">Social and racial exclusions</td><td>Multi-activities</td><td>Overhangs</td></tr>
<tr><td colspan="2">Internal conflicts</td><td></td><td></td></tr>
<tr><td>Vandalism</td><td>Building abuses</td><td></td><td></td></tr>
<tr><td>Rubbish</td><td>Self-construction</td><td></td><td></td></tr>
<tr><td>Insecurity</td><td>Insecurity</td><td></td><td></td></tr>
<tr><td>No public spaces</td><td>Human discomfort</td><td></td><td></td></tr>
<tr><td>No shops</td><td>Energy efficiency</td><td></td><td></td></tr>
<tr><td>Boundaries</td><td>Poor hygiene</td><td></td><td></td></tr>
<tr><td></td><td>Unlivable spaces</td><td></td><td></td></tr>
</table>

Shared weaknesses at the urban level are related to the absence of public squares and to the presence of decay, insecurity, vandalism, rubbish, state of abandonment, perception of unsafe areas, excess of stormwater, difficult relationship within the inhabitants, architectural barriers, fences, and only a few shops concentrated in the main square (Piazza Segesta). At the building level, they are related to physical and structural degradation, building abuses and remissions, land boundaries, architectural barriers, subsided housings, as well as to hygiene and energy inadequacy, low energy performance of the building envelope, low light levels (both daylight and artificial lighting), obsolescent HVAC systems, human discomfort, absence of maintenance operation, damaged green areas, and self-construction practices. Opportunities at the urban level are connected to the presence of underground, public and private green and pedestrian areas, multiculturalism, and multifaceted activities. Particularly, the vegetation is used to reduce the sun, wind, and pollution effects. At the building level, they refer to the presence of rational design, adjustable and flexible dwellings, natural cross-ventilation, bioclimatic concept, orientation through the heliothermic axis, gardens and green areas, overhangs, and balconies. The matrix of weakness and opportunities is illustrated in free form sketching. An example of the results is reported below (Figure 6).



(**a**)

(**b**)

Figure 6. Example of the fact-based analysis on the (**a**) weakness and the (**b**) opportunities of the area (Sources: F. Airoldi, A. Rili, V. Scaraffia).

A "*public presentation*" of this work is realized to share the design concept with the people involved in the design process. This collaborative learning favors the cross-fertilization of ideas, underpinning and stimulating the creativity by the work of others, suggestions, corrections, and discussions. This experience is used as embodied knowledge to develop the architectural design idea (phase C, Sections 3.4 and 4.4).

4.3. Hands-On Training (Phase C)

The results of the hands-on training (Section 4.3) are expressed directly in the architectural design projects (Section 4.4), trying to solve the weakness and to enhance the opportunities at urban and building levels (Section 4.2). The results of the microlearning training (Section 3.3) are presented as brainstorming for defining the architectural design practice on energy and environmental sustainability (phase D, Section 4.4).

4.4. Architectural Design Projects

Eight architectural design projects are presented, considering the main goals suggested for upgrading the social housing stock and combining social needs, architectonic quality, environmental sustainability, energy efficiency, and human comfort (Section 3.4). The design projects of the student are inventive. The first topic investigated is the reorganization of the housing development according to the complexity of the spaces, fostering the coexistence of inhabitants. The dominant aspect is the inclusion of new dwellings and services to accommodate new users, mainly university students. The promotion of the "*social mix*" between foreign people, students, and elders brings vibrancy to a predominantly older neighborhood and increases the number of rentable housings. The rental profits can be re-invested for ensuring continuative maintenance and management activity. Another common point in all the architectural projects concerns the exchange between public and private spaces. To this purpose, new public outdoor spaces satisfy the users' needs (i.e., garbage room, parking for strollers and bicycles, area for stairwells, playground). Recognizable paths are created to reach these public areas, using different colors, innovative materials, and green technologies. Their selection emphasizes recognizability and reversibility according to the criteria of architectural restoration. Furthermore, the functional mix is suggested. Flexible spaces for collective activities (e.g., gaming, meetings, study, parties, etc.) or supplementary living services (e.g., library, meeting room, study room, laundry, etc.) are inserted in public areas to be easily converted in other functions. For example, the architectural project "*Build Up San Siro*" (Figure 7) closes the first private court with a new distribution system that favors the daylighting. A new public space is given to the neighborhood through the occupation of almost 2/3 of the second court. It hosts a meeting room, a restaurant, and a playroom to attract new people. The project "*Starting from San Siro*" adds few volumes upon the roofs for hosting collective activities that favor the exchange between the inhabitants. Besides, the presence of a language school encourages integration with foreign people (Figure 10).

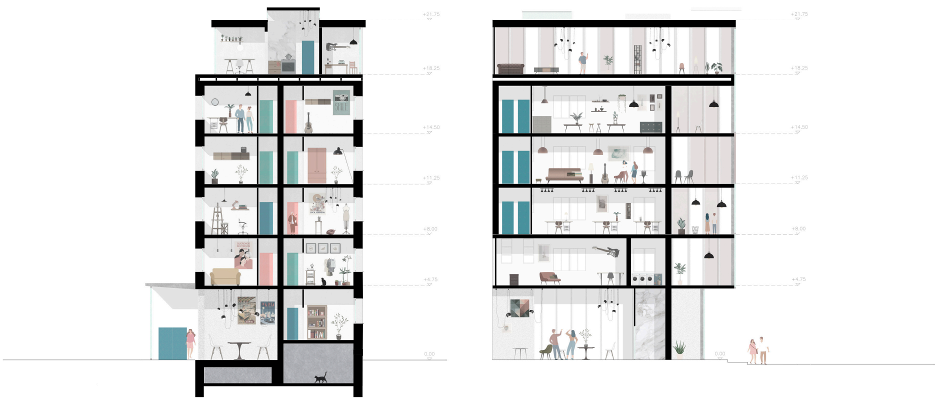
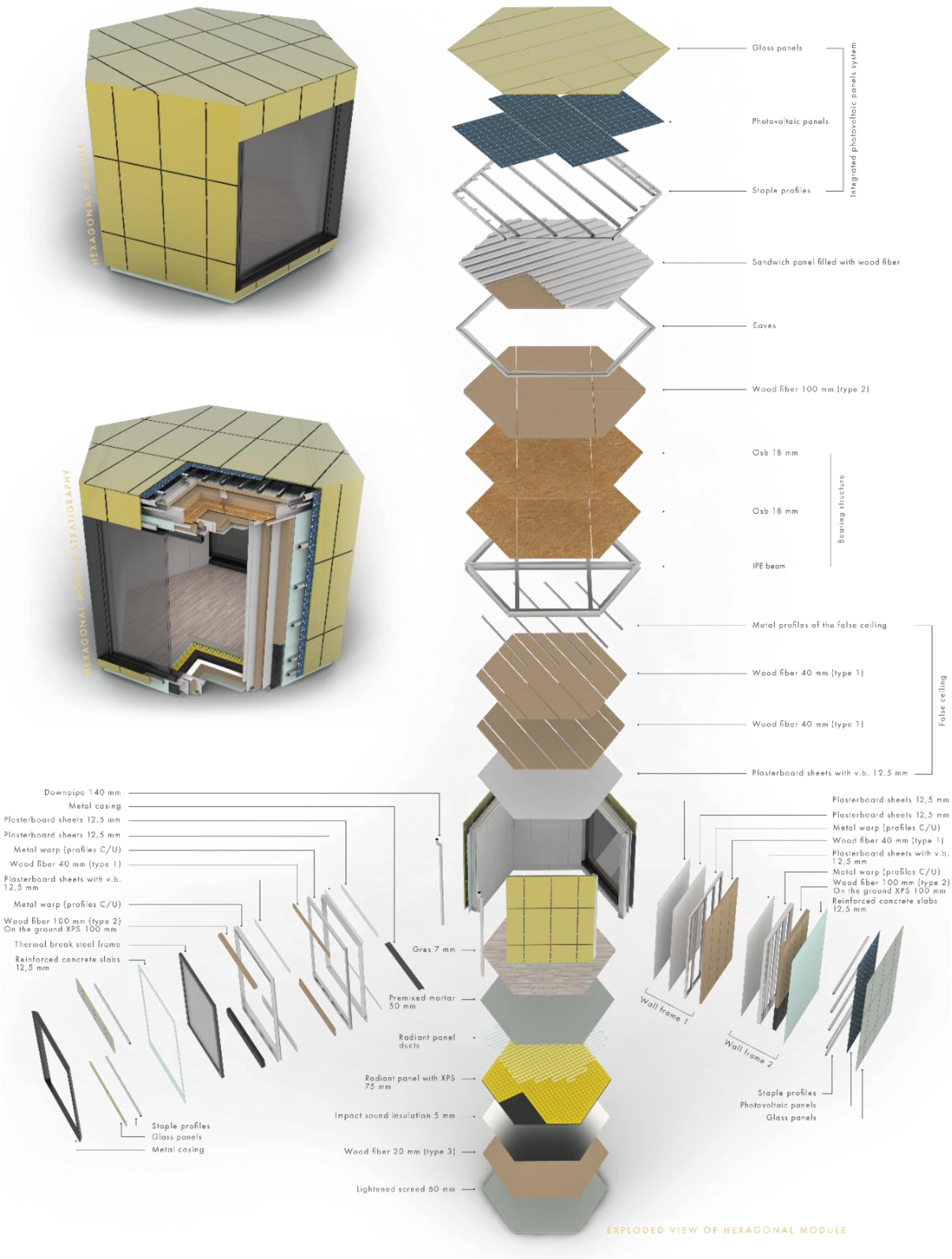


Figure 7. Cross-section of the architectural project "*Build Up San Siro*" (M. Annunzi, G. Azzini, L. Francesca, F. Rispoli).

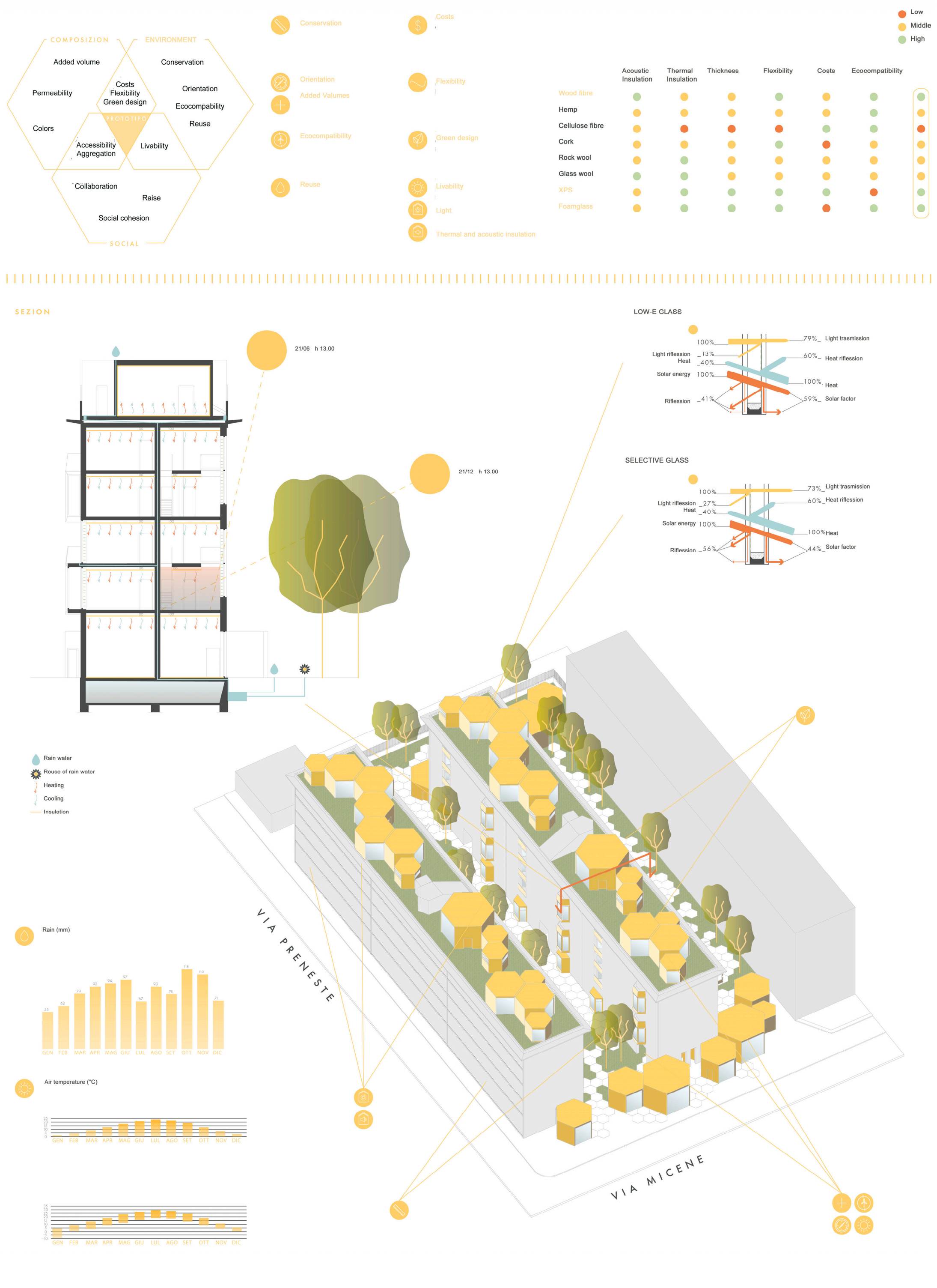
A second topic evaluated refers to the increasing in the total volume of the buildings [49]. This theme is addressed in opposite ways. For example, the architectural project "*Build Up San Siro*" preserves the historic characters of the buildings with extreme attention to the original design and without altering the geometrical features of the fronts (e.g., frames, window sizes, walls/windows ratio, and so on) (Figure 7). The volumetric additions are in continuity with the existing façades: a new roofing floor accommodates public services and distribution systems for the students. The additions are permeable spaces with transparent surfaces, to enhance their recognizability from the massiveness of the original building. Here, the existing fronts are completely restored, inserting an external thermal insulation composite system (hereinafter, ETICS) that respects original colors, frames, corner beads, breasts, ribbons, and chamfers. Besides, the architectural project "*Bee possible*" works with autonomous hexagonal elements, variously aggregated and sized (Figure 8). These elements are organized in clusters on the ground floor and the roof, to host temporary homes and study-rooms for the students as well as services, new entrances, and meeting rooms for the inhabitants. To guarantee a minimum visual impact on the main street, they are positioned on the internal courts and the lateral streets. This situation increases the social and aesthetical quality of the neighborhood. The hexagon, even used as a middle geometry, is replicated on the internal façades as an overhang or excavated volume to contain bow windows or lodges (Figure 9a). The approach of the architectural project "*Starting from San Siro*" (Figure 10) focuses on capturing heat and sunlight through the presence of slightly tilting volumes on the east fronts of the buildings. The volumes create also a new vertical scan on the façades. They host living areas, as dining and kitchen rooms, according to the bioclimatic criteria. The ground floor of the internal building is permeable to the light for improving the usability of the second courtyard. This crossing creates a large covered space, which is also an opportunity to place some services equipped with washing machines and dryers. No new volumes are added to the main street.

Figure 8. Prospect of the architectural project "*Bee possible*" (M. Belloni, F. Borroni, D. Bonetti, F. Savio).



(**a**)

Figure 9. *Cont.*



(**b**)

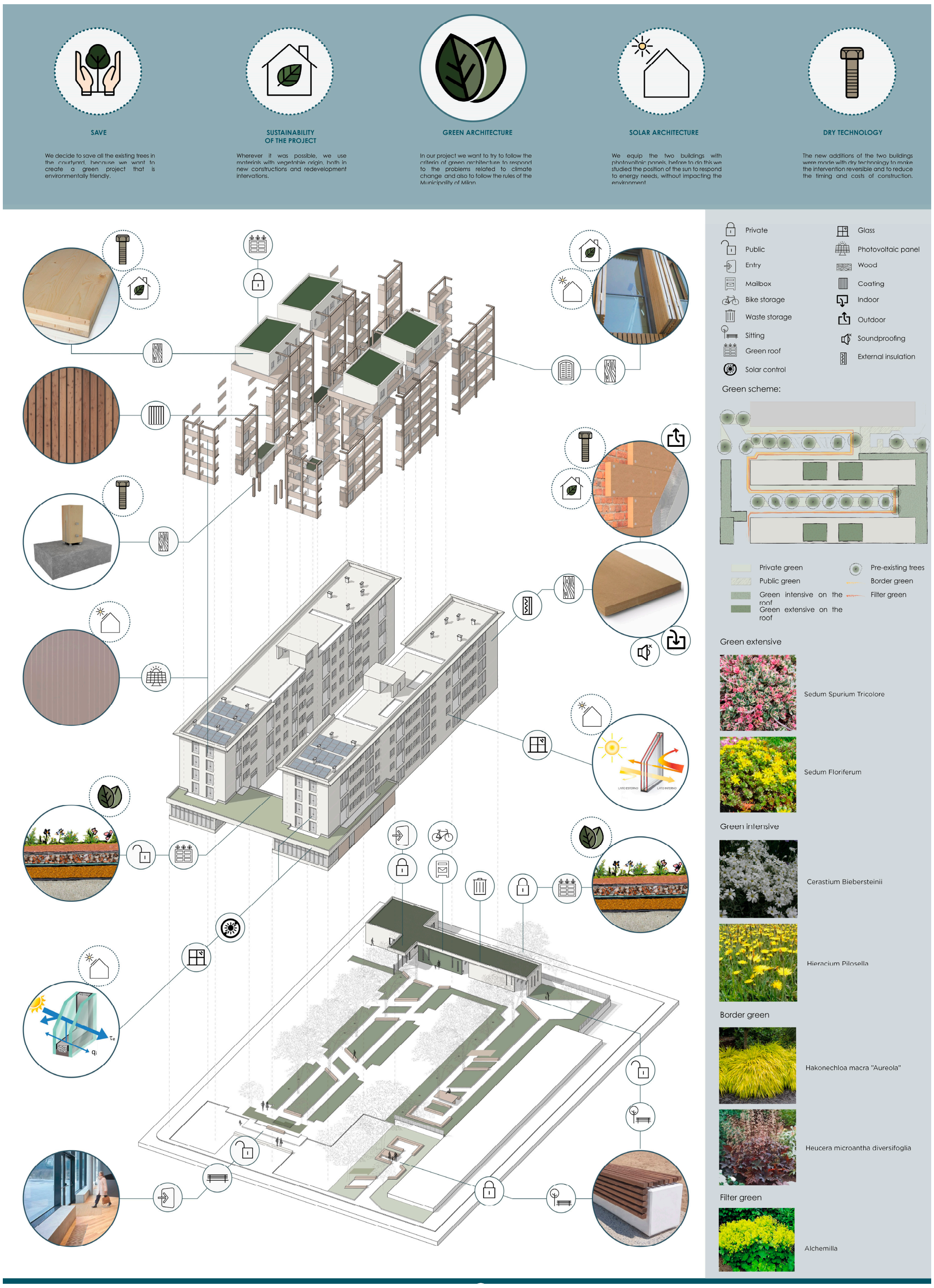
Figure 9. (**a**) The autonomous hexagonal elements and (**b**) energy and environmental concept of the architectural project "*Bee possible*" (Sources: M. Belloni, F. Borroni, D. Bonetti, F. Savio).

Figure 10. Floor plan of the architectural project "*Starting from San Siro*" (F. Airoldi, A. Rili, V. Scaraffia)

A third issue is the "*housing cut*". In several cases, some rooms are merged vertically to create duplexes, studio apartments, and two-rooms and three-rooms apartments (Figure 10). Their flexibility is guaranteed by a structural frame system made by lamellar wood or recycled iron.

Another topic investigated concerns the green design. All the architectural projects reserve special attention to biophilic and bioclimatic concepts [50]. This organic approach starts from the characteristics of the site, combining human health, environmental sustainability, ecology, local microclimate, natural resources, green spaces, circular economy, and neighboring production of building materials.

An important biophilic topic is related to the design of living landscapes and green spaces [50]. In all cases, the existing trees are maintained and recognized as a natural value for the district and a shadow system for outdoor spaces (e.g., Figure 9b, Figure 11b, and Figure 12). In many cases, new plants are inserted into the internal courts, using a broad range of greenery, hedges, and bushes for increasing biodiversity, improving air quality, suppressing dust particles, and reducing the urban heat island effect in the metropolitan area. Besides, the green courtyards are divided in the grassy courtyard, vegetable garden (to encourage the self-production of foods), exotic plants (to emphasize the multiculturalism), aromatic garden (to create sensory paths), playground, and green parking for strollers and bicycles (to satisfy the needs of the young families) (e.g., Figure 11b). For example, in the project "*Greenin' Micene-Preneste*", the grassy courtyards are partially opened to the citizens for reconnecting public and private spaces. Here, the living walls are used as fences and bollards (e.g., Figure 11b). It inserts also a green climbing façade on the internal courts: a light framework (composed of frames, trellises, and steel cables) is attached to the existing walls, for ensuring a minimal and reversible intervention that guarantees the preservation of the existing façades. Here, scented deciduous leaves trees (e.g., Jasminum, roses, ivy plants) enhance the local environment, creating an eye-catching design that involves the sense of smell, and increase the prestige of the buildings (Figure 11a). Environmental sustainability is optimized with thermal buffers, dust suppression, air purification, noise reduction, and high absorption properties. Furthermore, this green façade reduces the decay of the building surfaces (i.e., ultraviolet damage, fading, depolymerization), offsetting the maintenance costs. In the architectural project "*Bee possible*", a vertical gardening technique produces foods for the inhabitants with urban farming in the internal courts. In several architectural projects, green roofs covered with a stratum of vegetation permits greenhouse effects mitigation, heat island effect reduction, system load reduction, footprint replacing, energy savings, air pollution, and stormwater deflection (e.g., Figures 9b and 11b). In all the architectural projects, the bioclimatic concept at the building level refers to the internal layout that optimizes the natural energy sources (i.e., sunlight, wind) [50] (e.g., Figure 9b). Thus, in all cases, well-oriented internal functions are studied (Figure 7, Figure 9b, and Figure 10).



(a)

Figure 11. *Cont.*

(**b**)

Figure 11. Green design in the architectural project "*Greenin' Micene-Preneste*": (**a**) bioclimatic concept level, and (**b**) internal courtyards (M. Moglia, F. Valtorta, B. Scarlato).

A connected aspect is water management to solve the excess of stormwater in the older urban area. To this purpose, all the architectural projects increase the coverage of vegetation for reducing the stormwater management, with negative effects on water infrastructures and storm systems. Rainwaters and household greywaters are collected in tanks from roofs and gutters (e.g., Figures 9 and 12). They support the water supply to reduce the bills for garden maintenance. On the contrary, phyto-purification techniques of wastewater are excluded for the high costs of installation, management, and maintenance, resulting as not sustainable in this social context.

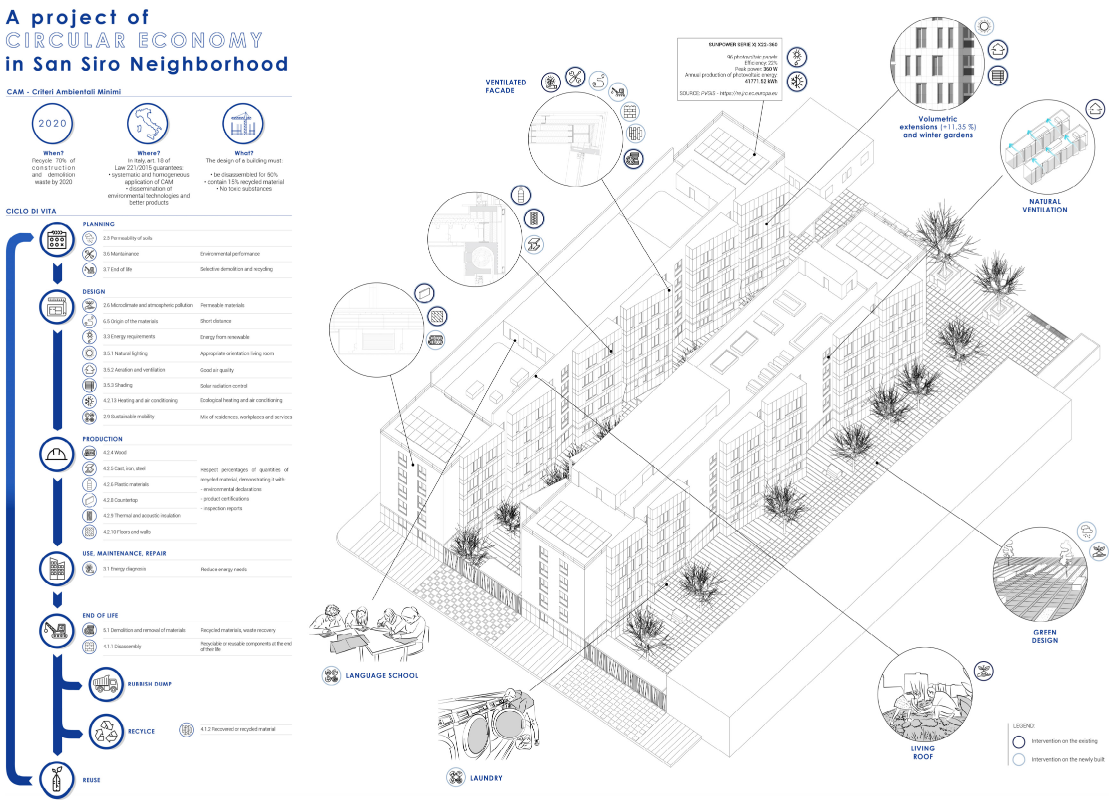


Figure 12. Energy and environmental concept in the architectural project "*Starting from San Siro*" based on the circular economy (F. Airoldi, A. Rili, V. Scaraffia).

Another topic concerns the improvement of the energy performance of the building. ETICS is selected as the main solution for the façade on the main street, to provide a thermal wrapping surface that preserves the original architectonic design as well as to guarantee thermal insulation, waterproofing, and damage reduction with a protective wall coating. In the façades on the courtyard, also the ventilated curtain walls are used. In all cases, natural-based solutions (i.e., wood fiber, cellulose fiber, hemp) or mineral materials (i.e., rockwool and glass fiber) are preferred to ensure a positive life cycle assessment (hereinafter, LCA). The construction materials are selected through a multicriteria approach that considers environmental impacts, thermal performances, acoustic performances, reversibility, maintenance procedures, and economic costs. For example, the energy and environmental concept of the architectural project "*Starting from San Siro*" is based on circular economy principles, starting from a deep technical and social analysis of the area (Section 4.2, Figure 6). Here, the growing population, the increasing demand for scarce resources, and the spread of poverty can lead to environmental degradation more than other areas. Thus, the construction process focuses on reusing, repairing, refurbishing, and recycling the existing resources, materials, and products to satisfy the social and economic needs of the inhabitants. Using this approach, the selected insulating materials are recycled rubber, wood, bamboo, and so on (Figure 12).

Besides, windows are a source of light, heat gains, and losses. Proper glasses, shading systems, and plants are considered to this purpose (Figure 11a).

Nowadays, each building has a local heating system located in a central equipment room, positioned on the down floor near the entrance of each building. The local heating is composed of an old boiler and a poorly insulated duck system inside the wall. Internally, the buildings have radiators without any heat regulation or control. In the architectural projects, HVAC systems are mainly connected to the district heating of the "Milano Ovest" area [51]. A heat pump with radiant heating, both basement floor and ceiling heating systems, is selected (e.g., Figure 13). In addition, few architectural projects also consider the mechanical ventilation for the hygrothermal regulation.

Finally, photovoltaic and solar thermal panels are dimensioned to cover 50% of the multi-story building energy demand. Here, integrated-building photovoltaic (hereinafter, BIPV) is preferred to building-applied photovoltaic (hereinafter, BAPV) to have an innovative aesthetics. BIPV is integrated mainly on the roof or on the south façade, considering legislation constrains, building orientation, and shadows of this densely built environment. Hidden colored PV modules are selected in each case.

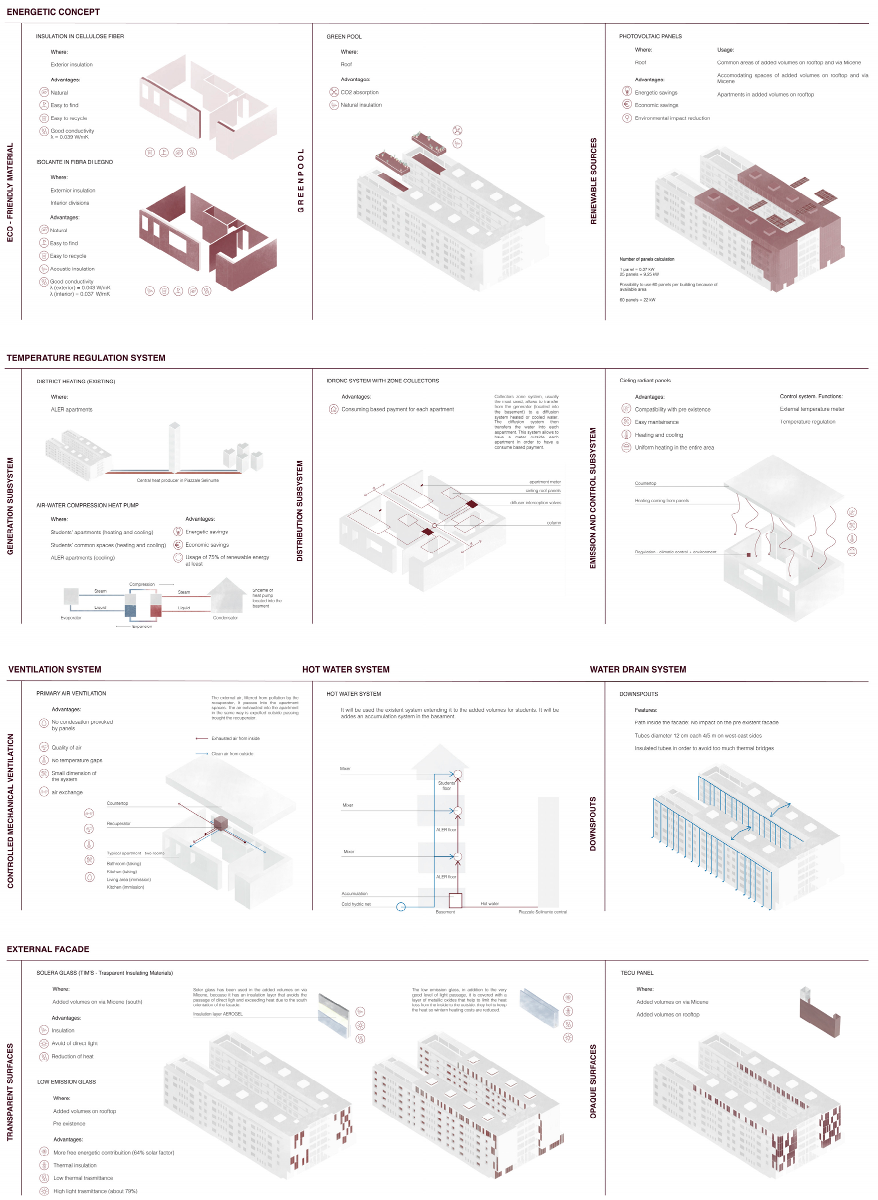


Figure 13. HVAC (heating, ventilation, and air-conditioning) scheme in the architectural project "*Build Up San Siro*" (M. Annunzi, G. Azzini, L. Francesca, F. Rispoli).

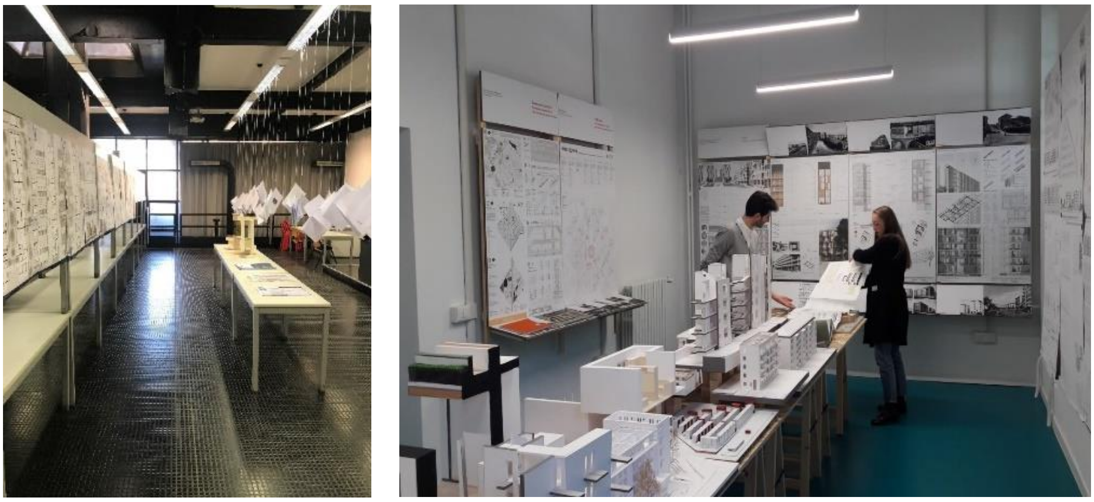
In light of the above-mentioned issues, the architectural projects develop some insights and lesson learned, as reported below:

- The environmentally responsible design is imperative in architectural education
- A teaching scheme based on different architectural disciplines and competences is at the basis of a sustainable design project
- The reusing of existing buildings has sustainable importance for preventing new land-use and for saving potential energy consumptions linked to their demolition and re-construction

- The refurbishment of the social housing estate provides more available dwellings instead of demolishing or privatization
- This 20th-century architecture has high cultural, social, and economic values, despite the absence of heritage constraints
- The absence of heritage constraints permits a deep refurbishment, balancing sustainability, energy efficiency, and aesthetics
- The critical understanding of the inherent qualities of the buildings is at the basis of their refurbishment
- The preservation of the original buildings prevents and overcomes the physical, technological, normative, and functional decay and obsolescence
- The volumetric additions also improve the use of dwellings, without further land-use
- The intervention on historic buildings allows the adaptation of the housings to the current regulations and lifestyles
- Space flexibility is an important topic both for outdoor spaces and internal layouts
- The study of the environmental and energy potentials of the area is at the basis of a detailed biophilic and bioclimatic design
- Green design is a strategy for boosting the social revitalization of the area
- The application of energy efficiency and sustainable principles requires an ad hoc design that considers also LCA and circular economy criteria
- Effectiveness of management, availability of economic resources, and management costs are at the basis of the selection of construction techniques, materials, and retrofit solutions in a public housing neighborhood
- Maintenance and management activity must be planned in the architectural design project
- Continuative maintenance and management can be guaranteed by the reinvestment of rental profits
- A widespread knowledge of the local socio-economic conditions (i.e., tenants needs, habits, and culture) must be considered for the success of the architectural design project
- The functional mix boosts the social revitalization of the neighborhood and the building
- The "*social mix*" between foreign people, students, and elders brings vibrancy to a predominantly older neighborhood and increases the number of rentable housings
- Demography and skill level of social housing residents are important for designing and managing complex technologies (i.e., RES, complex façades)
- Participatory actions are important mechanisms for empowering marginalized neighborhoods
- Preserving affordable housing in lower-poverty neighborhoods is difficult [46,52]. The environmentally responsible design is an important option for the deep energy retrofit of public housing neighborhoods.

4.5. On-Site Exposition (Phase E)

The on-site exposition of the architectural design projects is realized in the Politecnico di Milano and in the "Off Campus San Siro". Particularly, the last one is developed for boosting the social revitalization of the area, fostering the creation of urban communities with good neighboring relations that can support other project ideas (Figure 14).



(**a**) (**b**)

Figure 14. The presentation of the architectural design projects realized in (**a**) the Politecnico di Milano and (**b**) the on-site exposition "Off Campus San Siro".

5. Conclusions

The study presents a didactic experience for enhancing the San Siro public social housing neighborhood in Milan (Italy). This socio-technical approach starts from a deep knowledge of the area and the building, comparing historical and recent publications on morpho-typological, technological, environmental, economic, and social aspects (Sections 3.1 and 4.1). The historical research is supported by several on-site visits (guided and not guided) and on-site workshops with experienced researchers that work concretely with the inhabitants by low-cost architectural and social programs (Sections 3.2 and 4.2) as well as by survey and interviews with the inhabitants. This situation permits to develop a user-centered "*design-driven approach*" from the early stage of the architectural project. Besides, the hands-on training develop the architectural skills involved in the design practice, combining architectural and technological design, urban planning, energy efficiency, environmental sustainability, and social innovation (Sections 3.3 and 4.3). These activities are preparatory for defining the architectural design proposal (Section 4.4), following specific and clear design goals (Section 3.4). Finally, the on-site exposition shares the design ideas with the inhabitants, to boost the social revitalization of the area (Sections 3.5 and 4.5). This experience develops a sensitive awareness of the multidimensional complexity of the architectural design project that requires a critical balance among different disciplines and knowledge. Besides, it suggests several criteria and ideas to improve fairness, safety, architectural quality, human comfort, and sustainability in public housing (Section 4.4).

The pioneering approach of this didactic experience is related to several aspects. First, the experimentation on peripheral areas characterized by a social "*fragility*" improves the awareness of the students on the possibilities of building renovation, adopting high housing and architectural quality criteria, even in the public area often forgotten by contemporary politics. Second, a focus on the "*social architecture*" permits to balance technical and aesthetical criteria for promoting the well-being of the community rather than the "*spectacularization*" of the architecture and the urban environment in contemporary cities. Furthermore, the user-center approach on "*social architecture*" is an opportunity to experiment with a socio-technical approach for driving the design proposal, to define tailored technical solutions, as well as to reply to the user needs. As well, this user-center approach is a key element to improve people's lifestyles by stimulating positive behaviors. Besides, the experiment with modern architecture encourages a reflection on the deep renovation and the regenerative design of this emergent topic in the contemporary architectural debate.

Besides, the architectural design practice combines the disciplinary skills of technological and environmental design with buildings' physics and energy efficiency in a practical way. In both cases, the approach mirrors the complex interplay between "*design making*" and "*design construction*" issues to prepare the students for their future professional activity. This positive and synergic collaboration has yielded excellent results, recognized also by the students.

From the didactic point of view, the training activity is developed as a "*knowledge exchange*" between university, architects, industries, and community, to bring together design and construction phases. Knowledge exchange is a bi-directional process that involves transferring knowledge [53], also helping the development of concrete and multidimensional research questions [54]. Additionally, some suggestions for the scientific community can be delineated: (i) a first interaction with the real-life context permits to understand habits, cultures, activities, and needs of the inhabitants; (ii) the engagement with inhabitants and users is important from the early design to produce a user-center design-driven approach; (iii) training activities should contribute to the active and experiential learning through the interaction with the physical and social environment; (iv) the kinesthetic experience allows to appreciate the "*non-structured*" way, increasing the empathetical imagination for the architectural design project; (v) learners need freedom in their expression to integrate analog and digital tools (i.e., images, videos, texts, sketches, texts, and audios); (vi) design exercise helps to create the "*architecture ideas*" in a faster way; (vii) hand-drawn sketches should encourage to engage different cognitive faculties (more than cameras or a cellphones); (viii) working in teams favors the cross-fertilization of ideas and prepares for the professional activity, despite the difficulty in assessing individual contributions; (ix) conceptual design, project engineering, and mock-up are three faces of the same architectural project; (x) public presentation of the work (during the design studio or with an on-site exposition) helps to improve the architectural project and the long-term retention of notions and technical skills.

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Nomenclature

EU	European
IDP	Integrated design process
HVAC	Heating, ventilation, and air conditioning
RES	Renewable energy sources
nZEB	Nearly zero-energy buildings
BES	Building energy simulation
ETICS	External thermal insulation composite system
LCA	Life cycle assessment
BIPV	Integrated-building photovoltaic
BAPV	Building-applied photovoltaic

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