

Article

Reconciling Heritage Buildings' Preservation with Energy Transition Goals: Insights from an Italian Case Study

Giovanna Franco * and Sara Mauri

Department of Architecture and Design, University of Genoa, 16123 Genoa, Italy; s5734610@studenti.unige.it

* Correspondence: giovanna.franco@unige.it

Abstract: The construction industry in Europe significantly contributes to energy consumption and carbon dioxide emissions, and this has prompted the European Union to issue directives for renovating and decarbonizing the existing building stock to meet 2050's energy and environmental targets. However, achieving nearly zero-energy building (nZEB) standards in historic buildings is a complex challenge, as heritage values cannot be compromised for the sake of energy improvements. Our research advocates for a “whole building approach”, integrating various disciplines to achieve low-energy retrofitting while preserving historical material authenticity. The proposed methodology, inspired by the EN16883:2017 standard, involves a comprehensive building survey and assessment, the definition of conservation-compatible design solutions, and a performance analysis of these selected measures in relation to nZEB standards. This method was then applied to an ongoing project on a small, listed building in Genoa, demonstrating the feasibility of achieving conservation and high energy savings and, in these specific circumstances, the possibility of approaching nZEB parameters. This best practice example highlights the importance of adopting a cross-disciplinary, structured method to balance different values and needs in retrofitting projects, and it shows how creative and innovative solutions can break down the typical barriers encountered when implementing retrofitting solutions for built heritage.

Keywords: heritage buildings; low-energy retrofit; conservation; whole-building approach; sustainable development

**Citation:** Franco, G.; Mauri, S.

Reconciling Heritage Buildings'

Preservation with Energy Transition

Goals: Insights from an Italian Case

Study. *Sustainability* **2024**, *16*, 712.<https://doi.org/10.3390/su16020712>

Academic Editors: Luigi Fusco Girard,

Francesca Nocca and Martina Bosone

Received: 31 October 2023

Revised: 23 December 2023

Accepted: 9 January 2024

Published: 13 January 2024

**Copyright:** © 2024 by the authors.

Licensee MDPI, Basel, Switzerland.

This article is an open access article

distributed under the terms and

conditions of the Creative Commons

Attribution (CC BY) license ([https://creativecommons.org/licenses/by/](https://creativecommons.org/licenses/by/4.0/)[https://creativecommons.org/licenses/by/](https://creativecommons.org/licenses/by/4.0/)

4.0/).

1. Introduction

Nearly eight years have passed since the Paris Agreement was signed at the 21st Conference of the Parties (COP21), outlining the strategy to tackle dramatic global warming trends and thus achieve decarbonization through a robust worldwide effort [1]. The signatory countries pledged to cap the rise in global average temperature well below the threshold of 2 °C above pre-industrial levels, aspiring to limit this increase to 1.5 °C to avoid disastrous environmental, economic, and social consequences. They also agreed to peak emissions as soon as possible and achieve carbon neutrality in the second half of the century, commitments that were restated during COP26 in Glasgow in 2021 [2].

The construction industry in Europe is one of the most energy- and carbon-intensive sectors, responsible for approximately 40% of energy consumption and 36% of carbon dioxide emissions, as reported by the United Nations Environment Programme [3]. In response, the European Union has issued ad hoc “Energy Performance of Buildings Directives” (EPBD)—the most recent versions of which are the EPBD 2018/844/EU [4] and the version approved by the European Parliament on 24 March 2023 [5]—to promote the renovation and decarbonization of the existing building stock in order to reach the energy and environmental targets set by 2050. These directives have been transposed by each European Union (EU) member state, including Italy. The Italian national legislation aligned with EPBD requirements starting with Legislation 195/2005 [6], amended by Law 90/2013 [7], and then adding the Ministerial Decree 26 June 2015 (MD) [8], followed by

Legislation 48/2020 [9]. The MD is particularly significant since it outlines the procedures for calculating the energy performance of buildings and establishes the minimum energy performance requirements for buildings and their units [10]. In addition, it defines the criteria for nearly zero-energy buildings (nZEBs), which were to be applied to new constructions and major renovations starting from 1 January 2019 for public buildings and from 1 January 2021 for all other buildings. According to the EPBD recast 2010/31/EU [11], an nZEB building is “a building that has a very high energy performance [. . .]. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby”. However, the Italian Ministry for Ecological Transition has reported that the percentage of nZEBs represents a mere 0.03% of the existing buildings on a regional basis. Notably, fewer than 10% of these nZEBs consist of upgraded existing buildings, primarily small one- or two-family buildings and schools [12]. This statistic highlights the significant work still required to achieve net-zero targets in Italy’s existing building stock. In addition, the fact that about 30% of these buildings were constructed before 1945, thus qualifying as historical [13,14], introduces a further layer of complexity. As a matter of fact, retrofitting historic buildings to the nZEB requirements is particularly difficult due to their heritage value. This challenge is even more pronounced for listed buildings. The current European and Italian legislation exempts monumental buildings from satisfying the minimum energy efficiency requirements through derogation [6,11], but this often leads to sidestepping the issue.

This paper aims to precisely demonstrate how it is possible to strike a balance between heritage value preservation and energy efficiency improvement in the retrofitting of historic listed buildings. The study focuses on the theoretical–methodological level with the application of a real case study concerning a listed monumental building in Genoa. A complex interdisciplinary methodological approach and an integrated design allowed this building to nearly achieve parameters close to the nZEB standards as specified in the MD [8]. In particular, the MD sets out thermal transmittance (U) limits for architectural elements in different climatic zones across Italy, and Genoa falls within climatic zone D. For existing private buildings in this zone undergoing major renovations, the decree establishes U -values of $0.29 \text{ W/m}^2\text{K}$ for external walls and ground floors, $0.26 \text{ W/m}^2\text{K}$ for roof structures, and $1.80 \text{ W/m}^2\text{K}$ for windows. What emerges from this case study is a systematic approach that makes it possible to achieve conservation, on the one hand, and high energy savings standards on the other, without losing historical and material value.

This research aligns with the principles of architectural conservation and opens up the scientific hybridization of disciplines traditionally far removed from this field. The originality of this work, therefore, lies in its potential to integrate varied approaches for enhancing built heritage, resolving past conflicts, and setting a precedent for future projects. It is ultimately intended to become an exemplary case of good practice, addressing a gap that still exists in the reference country. To this end, a further purpose of the paper is the dissemination of the results of this intervention among the actors to whom this awareness-raising process can be addressed.

2. Historic Buildings and Energy Efficiency

In the realm of historic building renovations, the primary boundary within which energy performance improvements must operate is the field of conservation and restoration.

The discipline of architectural restoration today faces new challenges, poised between the reasons for conservation and the need or aspirations for enhancement and new uses. The relationship between these two polarities is always delicate and sometimes quite conflicting.

Just as in the past, we continue to claim that we want to preserve, maintain, conserve, or restore fragments of earlier eras and societies for various, sometimes conflicting, reasons and purposes:

- To know, discover, understand, and reveal the history within the material body of ancient artifacts;

- To safeguard and care for existing artifacts, counteracting the effects of damage they have suffered throughout history;
- To repair ancient or recent damage that has been caused by the unpredictable forces of nature or, more often, by a lack of care;
- To remember and, thus, highlight within the material fabric what we consider important for our present and, more importantly, for future generations;
- To reuse or continue using a monument, maintaining historical continuity, or implementing significant changes so that it remains an active part of our present and future lives, as well as the urban and landscape scenes [15].

This discipline is underpinned by internationally recognized criteria such as authenticity, compatibility, reversibility, and minimum intervention [16]. However, the meanings and interpretations of these principles can vary significantly across different cultural contexts, reflecting diverse values and approaches. In Italy, a country with a rich and long-standing tradition of architectural conservation, these principles are deeply rooted. The Italian conservation methodology views historic buildings as cultural documents, offering insights into their histories through the materials they are constructed from [17]. These materials not only preserve the traces of past events but also provide a window into the construction knowledge and craftsmanship of their era. This approach moves beyond the mere preservation of the buildings' visual appearance, advocating instead for the preservation of their material authenticity. This perspective stresses the importance of each element in its individuality, including those that have long been overlooked (like plasters or mortars) or deemed secondary (like windows and shutters), recognizing them as irreplaceable witnesses of the past with civilizational value [18]. The Italian conservation philosophy aligns with the guiding principle of modifying or changing only as much as necessary while doing as little as possible [19]. This rigorous approach to the conservation of historic buildings imposes greater constraints on design and operational choices, especially when it comes to improving their energy performance.

Today, new challenges have also emerged from new reasons to affirm and pursue the protection of our built environment. Among these, we can highlight the following: intelligent technological solutions for more ecological construction that respects the environment and our planet's limited resources; the need to conserve resources (economic, energy, territorial, human, social, and environmental) due to the energy crisis, and the fragile ecological state of the Earth [20].

Despite the complexity this introduces into the decision-making process, it should not deter efforts to address these challenges. Historic buildings, whether listed or unlisted, represent a substantial portion of the building stock in many countries [13,14], making their role in meeting the goals of sustainable development and an ecological transition, as set in European strategies, crucial [21–24]. Therefore, the potential impact of improvements in energy management and efficiency in these buildings on the reduction of global energy consumption and greenhouse gas emissions is significant and cannot be overlooked. Supporting this viewpoint, the "Heritage Counts" research conducted by Historic England [25] has demonstrated that historic buildings, when sympathetically refurbished and retrofitted, are projected to emit less carbon by 2050 than newly constructed buildings [26]. Given that dealing with this topic in the delicate and sensitive context of built heritage is not an easy task, understanding how to effectively integrate the concepts of energy and sustainability into the dialogue on built cultural heritage becomes essential.

In this regard, the number of publications addressing ways to improve the energy efficiency of buildings with heritage value has been sharply and steadily increasing during the last decades. Comprehensive literature reviews on this topic, such as those conducted by Martínez-Molina et al. [27] and Lidelöw et al. [28], have revealed a notable surge in peer-reviewed articles from 2014 onwards. This rise in research activities is largely attributable to three important EU-funded research programs: energy efficiency for EU historic districts' sustainability (EFFESUS) [29], efficient energy for EU cultural heritage (3ENCULT) [30],

and Climate for Culture [31]. These initiatives have played a crucial role in shaping research directions in this field, fostering heightened academic interest.

Parallel to the growing scholarly attention, the approach to improving energy efficiency in historic buildings has evolved as well. Most attempts at intervention have mainly been based on the assumption that historic buildings' potential for energy improvement is dictated by their level of formal protection [32]. However, a significant shift in this approach has been introduced by Herrera-Avellanosa et al. [33], who proposed a new method based on finding a "negotiation space" within which heritage conservation and the implementation of actions fostering greater sustainability and energy efficiency must be carefully "weighed" in the search for tailor-made and compatible solutions [34–37].

Despite a well-defined theoretical framework for interventions in historic buildings, in professional practice, we are still far from achieving a shared retrofit methodology among key stakeholders [38]. To bridge this gap, it is essential to have case studies illustrating how the theoretical principles can be applied successfully in real-world scenarios [39]. The importance of collecting and disseminating the lessons learned from projects has been recognized at the international level through research initiatives like the International Energy Agency's Task 59 "Renovating Historic Buildings Towards Zero Energy" [40], which led to the development of the HiBERAtlas platform, a database that presents examples of best practices [41,42].

Whether one speaks of conservation, modification, or restoration with adaptive reuse [43–45], in each case, it all depends on the extent to which the physical body of ancient structures is affected. Restoration, in its many forms, has always shown particular attention, indeed a real debt, to the material stratified over the course of history. Memories, symbolic value, traces of lives, skills, and all the intangible aspects associated with this material (whether already known or yet to be discovered) will only survive our actions if they do not alter its physical and formal consistency more than is strictly necessary to ensure its stability and durability [46,47].

The fundamental distinction lies in considering a building (or heritage as a whole) as the true reason for an intervention, the real protagonist of the protection/conservation/restoration/renovation process, as opposed to treating it merely as an opportunity for self-assertion.

3. Materials and Methods

In every restoration, conservation, and reuse project, new technologies often support architectural investigations. Historical investigations, based on a solid critical apparatus, are very often rigorous and rich. Collections of diagnostic data on the physical state of artifacts, in terms of materials and construction techniques, or on their state of decay/preservation, are meticulously, faithfully, and punctually visualized and summarized in "thematic maps" with significant communicative and perceptive impact. The use of "virtual simulations" for interventions with built materials, structures, and spaces of ancient architecture is widespread and refined. Complex structural studies and non-destructive testing and monitoring are also frequently exploited, generally with the advice of experts from different disciplines.

The concept of the "design project" always emerges when addressing the topics and issues of conservation/restoration of our built heritage, bringing to light profoundly different meanings and nuances. On the other hand, we recognize that the "project" represents a crucial crossroads for research, and especially professional practice, both in this field and in other areas of human activity.

Our research method was grounded in the assumption that buildings operate as a whole structure, highly responsive to alterations within them. Therefore, planning retrofitting measures in isolation, rather than as part of a joined-up process, risks leading to unintended negative consequences affecting not only the building fabric but also the occupant's health and well-being [38,48,49]. In light of this, we advocate for a "whole building approach", understood as a holistic and integrated methodology maximizing the

strengths of various disciplines and skills involved, such as diagnostics, conservation, and plant engineering, to achieve low-energy retrofitting [50–52]. This approach calls for the definition of a process to guide the planning of well-thought-out solutions prior to their implementation, aiming to find a sustainable equilibrium between building use, energy performance, and conservation. A significant breakthrough in this direction was made by the European Committee for Standardisation, which detailed a systematic working procedure in the EN16883:2017 “Conservation of Cultural Heritage—Guidelines for Improving the Energy Performance of Historic Buildings” [53]. One of the primary contributions of the European standard is to underline the importance of selecting interventions based on a comprehensive building survey, which includes assessing its use, structural and energy behavior, state of repair, context influences, and indoor environmental conditions. Although this “knowledge phase” is often relegated to the theoretical realm and overlooked in practice [54], it is crucial to provide the information necessary to make informed decisions that guarantee the quality and effectiveness of a retrofitting project by achieving the much-sought-after balance between different aspects [53].

The aim of our paper is, therefore, to illustrate the pivotal role of an extensive knowledge and analysis process in guiding the development of a conservation-compatible retrofitting strategy. Using a listed historic building as a case study, we also demonstrate how, under specific circumstances, it is possible to achieve outcomes that closely align with the nZEB parameters, even if they are not mandatory.

Firstly, an integrated methodology, inspired by the structure and ideas of the European standard, was defined.

As shown in Figure 1, the methodological framework can be divided into the following main phases, explored in depth in Sections 3.1–3.3:

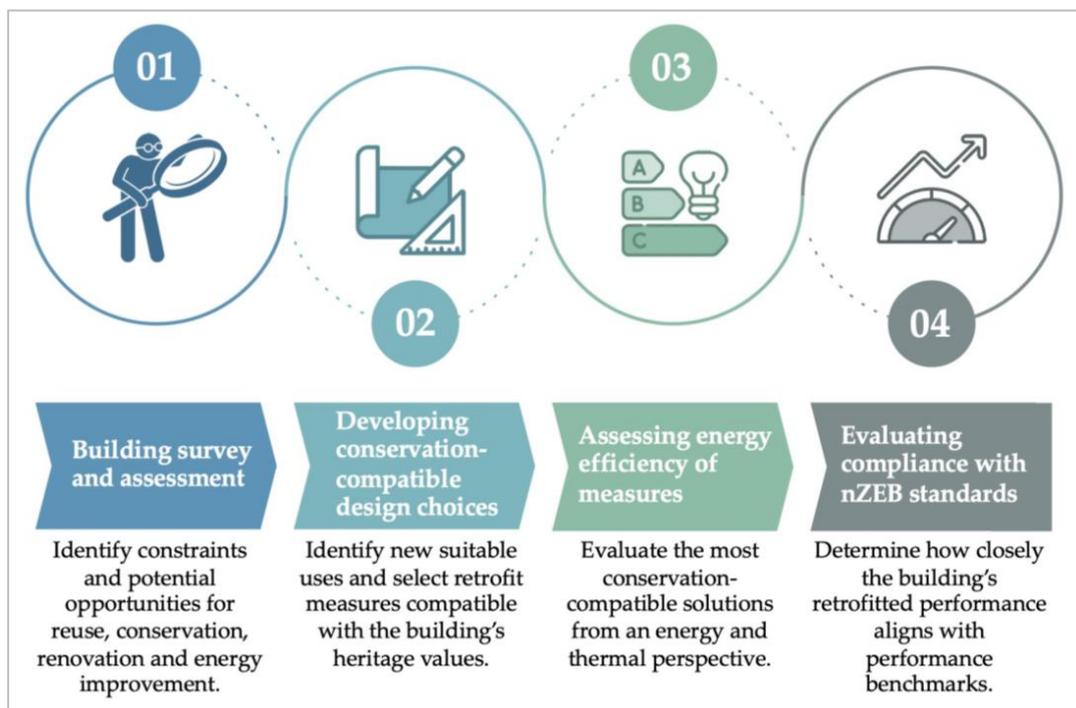


Figure 1. General methodological framework.

1. **Building survey and assessment:** This initial phase involves a detailed survey and assessment of the historic building, employing specialized methods to identify constraints and potential opportunities for reuse, conservation, renovation, and energy improvement. This comprehensive understanding forms the foundation for all subsequent retrofitting decisions.

2. Developing conservation-compatible design choices: Based on the insights gained from the initial assessment, this phase focuses on formulating a holistic design strategy. It involves identifying new, suitable uses for the building and selecting retrofitting measures that are compatible with its heritage values, all in coordination with the Italian heritage authorities (Superintendency).
3. Assessing the energy efficiency of measures: This phase is dedicated to evaluating the most conservation-compatible solutions for the building envelope and engineering systems (identified and selected in phase 2) from an energy and thermal point of view.
4. Evaluating compliance with the nZEB standards: The final phase assesses how closely the building's retrofitted performance aligns with the nZEB standards.

The proposed method was then applied to a small, listed building with a history that was largely unexplored prior to the start of its restoration and reuse project in 2016 (Figure 2). This lack of data presented a unique opportunity to conduct an extensive preliminary assessment, which proved to be invaluable in informing the selection of appropriate and well-balanced retrofit solutions.

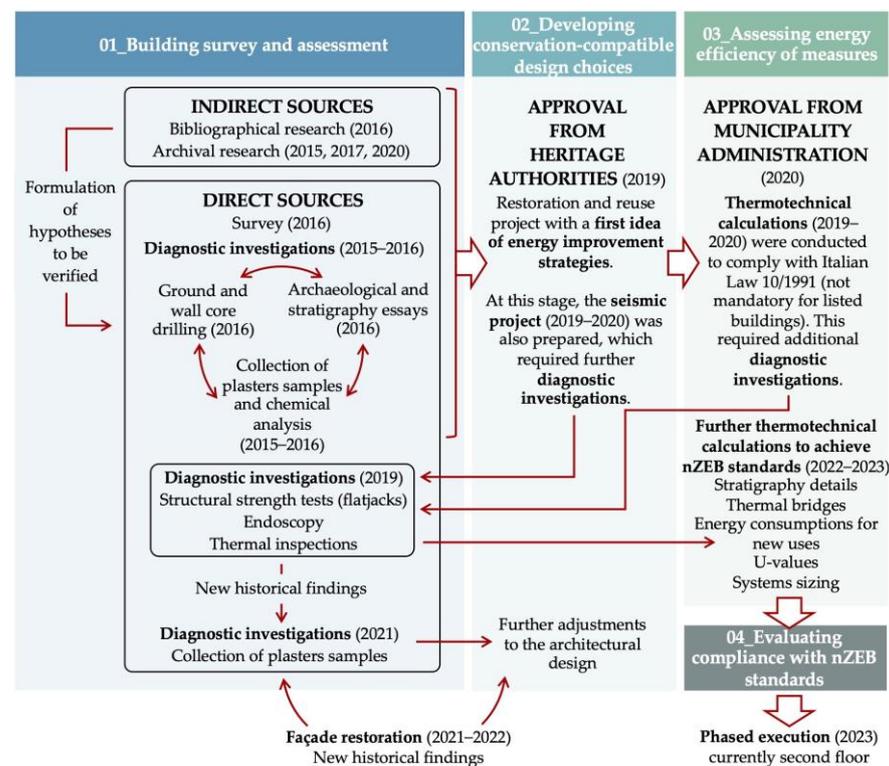


Figure 2. Methodological framework applied to the case study.

As shown in Figure 2, the linear methodology outlined in Figure 1 evolved into an iterative process when applied to a real-world project. This diagram clarifies how theoretical principles can be adapted to a real case study with all the complexities inherent to professional practice, including the interaction between various authorities and stakeholders, leading to feedback and continuous adjustments that play a crucial role in achieving the desired outcomes.

In undertaking this work, we navigated several challenges:

- Striking a balance between preserving historical and material features, ensuring user comfort, and protecting the environment while also proving that, in some cases, it is possible to meet nZEB standards;
- Approaching renovation works according to architectural conservation principles (see Section 2);

- Bringing together different specialists in an integrated design process under the umbrella of common objectives by applying strategies, tools, and methods from different disciplinary fields.

3.1. Phase 1: Building Survey and Assessment

Well-rounded and multidisciplinary knowledge of a historic building's construction history, characteristics, conditions, and structural and energy behavior is essential when making changes to it. This means that any whole-building renovation project should start with a detailed survey and assessment of the building in its context [53]. Proper preliminary knowledge and an appropriate level of information allow us to look at the building from many different angles and perspectives, identifying weak elements or areas that need to be addressed, that require special attention, or that might limit some intervention options and providing an initial idea of where to work on and how. Therefore, this phase lowers the risk of unintended consequences during the later stages of the process [52].

The data collection methods used in the case study and its main outcomes are critically summarized in Table 1.

Table 1. Integrated and multidisciplinary methodology to acquire preliminary knowledge of the monumental building.

Aim of the Work	Methods and Tools	Main Outcomes
Survey	Topography and longimetry	Geometries and dimensional anomalies to be investigated by comparing indirect (archival) and direct sources and the state of conservation
	Photogrammetry on facades	
Historic analysis	Archival research	History of the building, its alterations over time, and the construction phases
	Bibliographical research	
	Archaeological tests	
Constructive analysis	Stratigraphy tests	Confirmation of the hypotheses that have emerged from indirect sources on the composition and dating of materials and constructive techniques, as well as structural problems related to seismic risk
	Chemical analysis of plaster samples	
	Geological analysis and ground and wall core drilling	
	Endoscopy	
	Structural strength tests	
Energy certification	Quasi-steady-state model	Energy class according to Italian law
Data management	GIS (maps and plans)	Recording of multiple scattered data and documents in a single digital database, better visualization and interpretation of data, and more efficient planning and decision-making
	GIS (pictures and facades)	
	3D modeling	

The investigation process started with extensive archives and bibliographical research to better understand the history of the building, its alterations over time, and its constructive phases, thus enabling us to write a completely new story of part of the city located in a central urban site, as well as of the building itself. The other step conducted at the very beginning of this work was a building survey to detect and evaluate its features and conditions, the results of which were compared with those of the archives to highlight geometric and dimensional anomalies to be further investigated (as shown in Section 5.1).

To corroborate hypotheses about the construction phases that emerged through indirect sources, archaeological tests were carried out on the foundations; meanwhile, to study the building from a material, constructive, and structural perspective, stratigraphy testing, structural tests, chemical and geological analysis, and thermal inspections were conducted. As far as chemical analysis was concerned, the plaster samples were taken at strategic points determined through the other diagnostic and documentary activities: at the base of the construction, in the structures of the brick vaults, in the pillars on the ground floor, in the tower, and in the parapet of the roof terrace. The results (the composition of the plasters and typologies of the aggregates) were then compared not only with the aforementioned investigations but also with scientific databases. Last, but no less significant, was the energy certification, which refers to the period before the building became disused, which occurred about ten years ago. This certification, conducted through a quasi-steady-state model, identified the building's class and the overall energy performance in compliance with Ministerial Decree 26 June 2015 [8], Liguria Regional Law 22/2007 [55], Legislation 102/2014 [56], and the EPBD Directives [4,11]. It is important to note that, given the building's state of disuse, assessing its current energy performance, and conducting environmental monitoring would not have been feasible or meaningful.

All this rich and complex graphical and textual information was recorded in a GIS database. Additionally, a 3D model was created. Both these tools allow better visualization and interpretation of data, making the subsequent decision-making process smoother.

All the knowledge gathered established a clear, coherent, and systematic picture of the building that could be translated into recommendations about suitable design choices (phase 2).

3.2. Phase 2: Developing Conservation-Compatible Design Choices

After preliminary knowledge was acquired, phase 2 focused on devising a design strategy that brought together all the previously collected information and data, employing a consistent, holistic, and integrated “whole building approach” to all aspects of the project. This included looking at preserving historical material surfaces, enhancing structural behavior, planning for reuse, and implementing energy improvements within the limits allowed by conservation needs. Our guiding principle was to do “as much as necessary, as little as possible” [19], carefully considering any modifications and new additions to ensure that they were respectful, non-invasive, and low-impact [16].

The criteria directing the identification of compatible design strategies align with what has been outlined in the preceding sections. First of all, it is essential to identify and select what should be considered as intangible heritage value to be preserved, even in a design process that envisages different uses from the original ones (and sometimes uses that are already modified), and thus involves new requirements and standards [57–59].

However, these heritage values, which may be expressed in the building's morphology, its material consistency, the history it represents—often stratified and not easily decipherable—its internal spatiality, and its relationship with its context at various scales (from the immediate surrounding garden to its connections with the urban settlement structure and its potential role in the city's skyline) were not always immediately perceptible. They were determined via both direct and indirect investigations, as described in Table 1, whose results must nonetheless be subject to critical interpretation.

The more a project, which necessarily involves critical interpretations and modifications of spaces (even if only for minimal technical and sanitary adjustments), can capture and reflect the “spirit” of a place, the more it can be culturally shared and accepted. As a matter of fact, there is no single way to approach a conservation and reuse project; behind every decision, it is necessary to think about the purposes even before the technical methods of implementation.

In the case study described in this paper, concerning a listed historic building, priority was given to enhancing the spatial layout, which was characterized, both on the ground and first floor, by a large, vaulted space in direct contact with the garden. This was

achieved through a portico system on the ground floor and a series of large, arched openings on the first floor, significantly defining the entire volumetric structure. Priority was also given to preserving the few surviving historical material traces that had withstood wartime bombings and heavy modifications in the 20th century, discovered during the diagnostic investigations.

However, the architectural and conservative restoration design of the facades was not the predominant project activity, although it was prominent. From the early stages of the project, engineering expertise was integrated to improve the building's seismic behavior and energy performance, with the ambitious goal of achieving the nZEB parameters defined for newly built buildings even though they are not compulsory by law in listed buildings [6,11]. This exemption was viewed not as an "excuse" for inaction but as an incentive to explore an alternative way of intervening in both the building envelope and engineering services, guided by the search for balance and optimization between the instances of conservation and those of energy improvement.

Concerning services, the project also addressed the sensitive issue of integrating photovoltaic panels into historic buildings, which are essential to meet nZEB requirements. This issue has been much discussed by the scientific community because such panels are often considered overly invasive in the protection and preservation of heritage values and, consequently, not very compatible [60,61]. Therefore, in this project, the problem was not solved in a simplistic way by inserting and superimposing panels on old parts but, rather, by resorting to new ideas by designing new ad hoc "devices".

To find shared solutions with the Italian heritage authorities' limitations, the constraints and thresholds of modifiability identified in phase 1 were proposed and discussed.

3.3. Phases 3 and 4: Assessing the Energy Efficiency of Measures and Their Compliance with the nZEB Standards

Based on the different parameters to be respected, linked to the various uses and types of intervention (conservation, reuse, energy, and structural improvement actions), the building was divided into four thermal zones. For each thermal zone, a series of conservation-compatible solutions identified during phase 2 were energetically and thermally verified to see whether they actually complied with the minimum legal requirements. This served to demonstrate that, although reaching these parameters is not mandatory in listed buildings (like that of our case study), in some particular cases, it is still possible to achieve remarkable performance (close to the nZEB standards), challenging the logic of derogation. For illustrative purposes, this study focused only on some portions of thermal zone 1.

Firstly, the performance of the structural and architectural elements was analyzed and verified according to the parameters given in Annex 1, Appendix A of the Ministerial Decree 26 June 2015 [8], which is applicable to existing buildings undergoing major renovations. The implementation of data and legal verifications was carried out with ACCA's TerMus software version 42.00 (as described in the following sections) [62]. This phase also included the calculation and verification of thermal bridges with dedicated software, a process that is currently ongoing.

In addition, the project involved calculating the winter and summer heat loads of the rooms belonging to the four thermal zones considered for the dimensioning of the thermal system (heating and cooling).

A more advanced stage of the project will address the contribution to achieving the nZEB standards through the integration of photovoltaic panels and the calculation of the global energy performance post-intervention.

4. The Case Study: A Listed Building in Genoa

The case study selected to demonstrate good practice was Villetta Serra, a small historic building situated in the heart of Genoa, at the beginning of the Acquasola Esplanade, an area that has undergone many transformations over the years. Villetta Serra, with its distinctive

architectural features, has been recognized as a listed building by the Superintendency of Archaeology, Fine Arts and Landscape (the local office of the Ministry of Cultural Heritage) (Figure 3a,b).

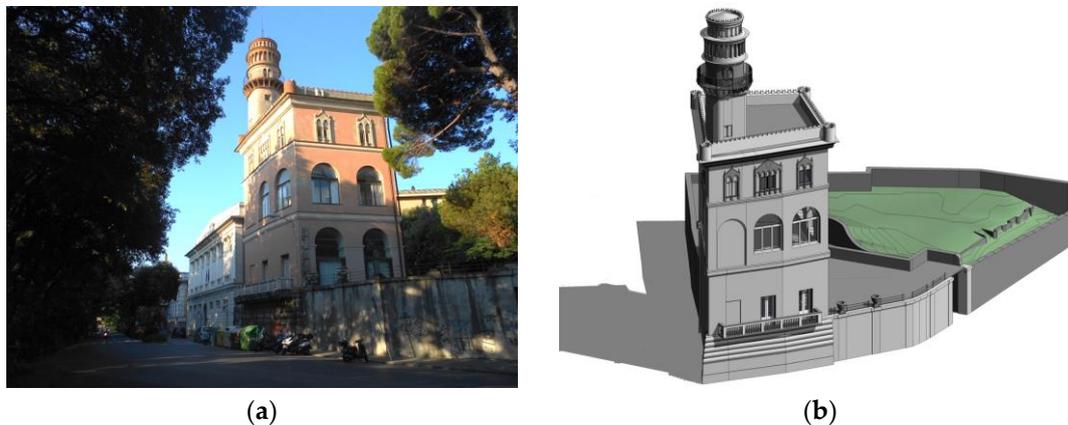


Figure 3. (a) Pictures of the building at the time of its transfer from public to private ownership. (b) 3D model of the building and its garden from the west side (elaboration by Marta Casanova).

Despite its prominent location and visibility in the city's skyline, the building's history remained largely unexplored until the restoration and reuse project described here. The new private owner, who purchased the building from the Municipality of Genoa in 2014, embarked on a long process of knowledge, preservation, reuse, and structural and energy efficiency improvement with the goal of getting as close as possible to the nZEB requirements. This ongoing process began in 2016.

The primary goal of the intervention was to give new life to the building after years of neglect, particularly since the Municipality of Genoa had moved the Actor's Museum (established there in 1978 after significant modifications to the interior and exterior, without affecting the load-bearing structure) to another location. The project aimed to restore dignity and value to this significant fragment of the city, uncover its hidden history, and open some parts of it to the public in ways compatible with its new private uses. From the outset, the second objective was to demonstrate that it is possible to combine conservation/restoration with energy efficiency. In addition to spaces for residential use, the building will house the headquarters of a professional project and an experimental laboratory for processes and technologies aimed at energy saving and the seismic improvement of historic buildings.

The building, located on raised ground above the current level of the access road, has a trapezoidal design with three floors above street level and an additional basement floor. Beyond the flat roof of the main structure rises a tower containing only a spiral staircase, which is the most distinctive element of the building and allows a 360-degree view of the surrounding landscape. The interior configuration of each floor includes a single quadrangular room covered by a pavilion barrel vault with lunettes at the four corners, large, arched openings on the first two floors, and square windows embellished with marble columns on the top floor. The formal typology of the building is decidedly unusual and curious, as it does not conform to residential criteria or a single-family villa. Its current appearance, before the renovation works (Figure 3a), is not its historical one, although the load-bearing structures and the composition of the facades and openings are.

Although Villetta Serra is now embedded in the city center, it is located in an area that originally, in medieval Genoa, corresponded to the site of the expansion of the city's first defensive walls, dating back to the first half of the 12th century. At that time, the building did not exist, but this fact is useful in corroborating some hypotheses that emerged during the direct and indirect investigation phases. The extensive analyses conducted at the behest of the new owner have brought to light previously unknown fragments of an urban pattern rich in history and stratifications (see the following section).

The building's usage in the 20th century was as unique as its design. When the building passed from the ownership of the Marchese Serra to the Municipality of Genoa, it underwent significant renovation works (which erased its decorative apparatus, already heavily damaged during wartime bombings) to transform it into a small municipal museum (the Actor's Museum). But what was its previous use? And who had it built? These questions find answers in the following section, thanks to the investigations carried out.

The building, even until the early decades of the 20th century, had a very large garden, which was later reduced to make way for a key urban planning project for urban renewal as part of a 1930s urban planning project.

In any case, its original function was that of a belvedere, later transformed into a coffee house upon its purchase by the Marchese Serra, with a large botanical garden, following a custom of the Genoese nobility who owned a system of small villas within the urban walls for leisure and delight without having to leave the city.

5. Results

5.1. Phase 1: Building Survey and Assessment

The building survey and assessment phase paved the way for an insightful understanding of Villetta Serra, which is essential for making informed decisions, thus guiding the project for reuse, conservation, and structural and energy improvement.

Delving into the building's historical, material, and constructive evolution through the various data collection methods (see Section 3.1) led to surprising discoveries that were previously unknown. While tradition suggested that the building was established in 1825, the findings paint a different picture. Digging deeper into the past, one of the most interesting discoveries was the incorporation into the building of a pre-existing portion of the city walls (built in 1270), which later expanded in the 1500s with the construction of the Durazzo Bastion (Figure 4), and the probable construction on the site of a watchtower next to the Olivella Gate, one of the city gates.



Figure 4. Overlay via GIS software of the Durazzo Bastion, part of the fortified wall, with the building's site along the bastion's access wall.

The first major documented transformation of the building occurred between 1821 and 1823, when Marchese Serra purchased the property for his own leisure, engaging the municipal architect Carlo Barabino and the scenographer and decorator Michele Canzio to modify the exterior appearance (but not the load-bearing walls, composed mainly of stones and partly bricks) in accordance with a neo-Gothic style (Figure 5a). Traces of this phase were still partially visible in 2014. In that three-year period, the renovation works of an older structure belonging to the convent of Santa Marta (erected on their land as a belvedere in the late 17th or early 18th century) were also documented (Figures 5b and 6a).

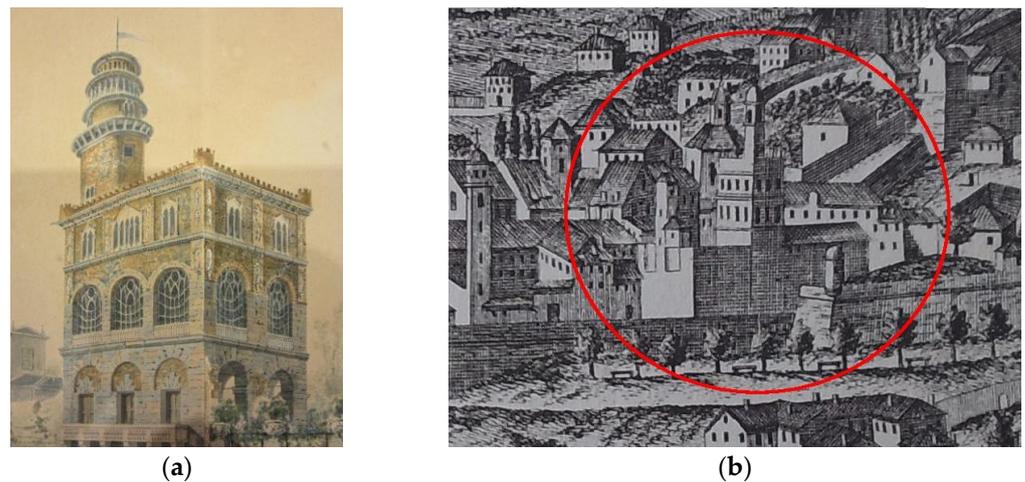


Figure 5. (a) Watercolor by Prefect De Gubernatis testifying to the decoration work carried out in 1821–1823 to give the building a neo-Gothic appearance (GAM Turin). (b) View of the building in a print by Giolfi; at this time (the 18th century), it was under ecclesiastical ownership.

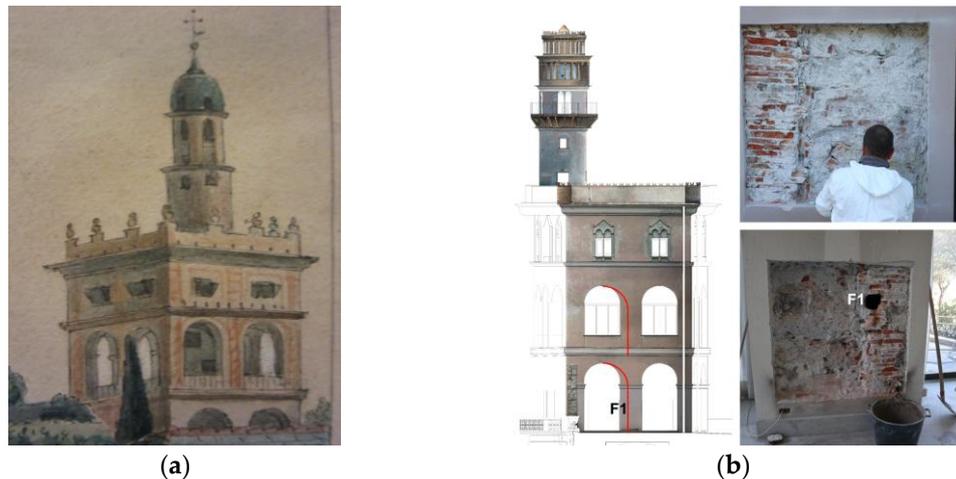


Figure 6. (a) View of the complex when it belonged to the Convent of Santa Marta and was used as a belvedere. (b) Indication in red of the 18th-century phase openings, regularized in the 19th century, usable for the passage of vertical ductwork.

In 1889, Marchese Serra's heirs sold all his property, including the huge garden, to the municipality. The bombings during World War II caused significant damage to the exterior plastering and the roof. Years of neglect and unauthorized occupancy led to a deteriorated state, prompting the municipality in 1973 to restore the property. The restoration, reflecting the era's practices, involved significant remodeling, including replastering with concrete mortar, inserting heavy steel reinforcement in at least one of the two vaulted areas, reconstructing the flat roof with a reinforced concrete structure, and substantially renovating the ground floor. Further interior renovations to accommodate a small museum were carried out in 1978, with the extensive use of reinforced concrete structures and the replacement of windows and doors.

All the collected data helped identify which parts were still original, which had been added or modified over time (Figure 6b), and which were fairly new. This allowed us to define, in agreement with the Italian heritage authorities, the "thresholds of modifiability" (i.e., those liable to removal). The most recent parts from the 20th century were deemed to have lesser historical and material value, making them suitable for more impactful interventions.

Moving from this reconstruction to the on-site investigation of the building, direct analyses were also crucial in illustrating the building's structural behavior, conservation

status, and thermal performance. A thorough examination revealed that the load-bearing walls were in good condition except for the top portion of the tower, where there were some lesions lying on the masonry laying plans. The building's flat roof showed signs of degradation attributed to rainwater infiltration through the pavement of the extrados. Moreover, the identification of the thicknesses and stratigraphy of the constructive elements responsible for heat dispersion (the ground floor, external walls, windows, and roof) made it possible to assess their pre-intervention thermal transmittance (U-value) (Table 2).

Table 2. Thermal transmittance of some building elements prior to the retrofitting intervention.

Building Element	Thickness [mm]	Thermal Transmittance U [W/m ² K]
North wall, second floor	980	0.786
South wall, second floor	940	0.815
West wall, second floor	750	0.984
East wall, second floor	740	0.995
Roof	-	1.12
Ground floor	-	1.26

In conclusion, the energy certification provided an estimation of the building's energy performance before any improvement, thereby rounding off the phase 1 assessment (Table 3).

Table 3. Global energy performance refers to how much energy is required to heat the entire building, while envelope energy performance refers to how much energy is required due to heat loss from the envelope, i.e., the walls, windows, doors, floors, and roofs.

Total surface S m ²	393
Volume V m ³	2150
Envelope surface S _{env}	1280
Surface/volume	0.59
Climatic zone	D
Current global energy performance, E _{gl}	380.25 kWh/m ² y
Current envelope energy performance, E _{env}	230.45 kWh/m ² y
Thermal energy need	33.75 kWh/m ³ y
Energy class	F

5.2. Phase 2: Developing Conservation-Compatible Design Choices

The decision about which design solutions to consider or exclude arose from the opportunities and constraints that emerged from the systematization and interpretation of the aspects investigated in phase 1, alongside a shared decision-making path with Italian heritage authorities.

First of all, the architectural conservation and reuse project envisaged a new organization of the interior spaces following, as a guiding principle, that of obtaining the maximum legibility of the undivided interior spaces as a salient feature worthy of preservation. The basement floor spaces remained unchanged, subject only to conservation interventions, and were intended for mixed uses, including a meeting room and a small auditorium suitable for public meetings. Even the ground floor was not altered in its space and will be used as a representative office. The first floor, still characterized by large, arched openings, will be used as a private apartment. The second floor, located beneath the roof terrace, will be used as a mixed accommodation/studio destination, again maintaining the current spatial layout and enhancing the 360-degree view of the outside.

In order to allow better use of the different floors of the building, an internal lift was installed from the ground floor (the entrance level to the terrace) to the top floor (Figure 7). The lift shaft was created within a small compartment hidden by a 19th-century wall to regularize the trapezoidal space, making it quadrangular (the same was done with the

vault, also regularized, with a partly wooden structure, following the perimeter of the room). The small lift is not visible inside the large room and, therefore, does not alter the spatial perception of the environment in any way; nor does it emerge from the terrace roof.

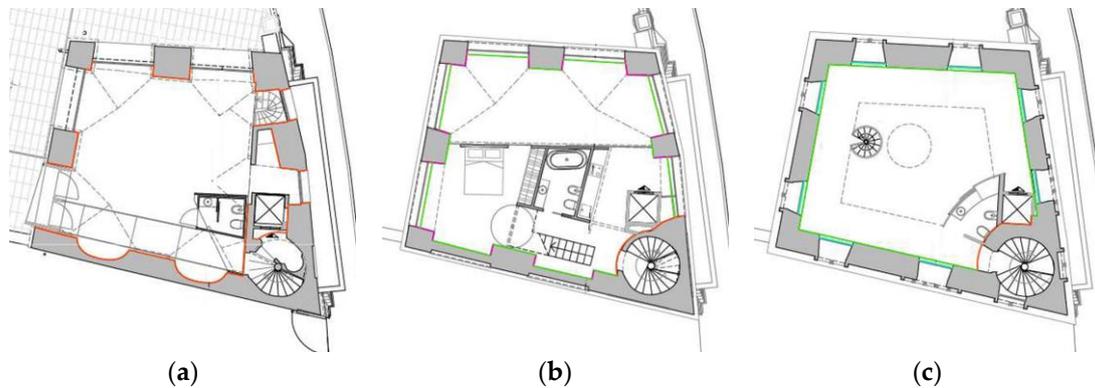


Figure 7. (a) Ground floor plan showing the location of the internal lift (the bottom right, near the staircase) and the position of the insulation layers (the colored lines along the walls). (b) First floor plan. (c) Second floor plan.

The set of interventions also envisaged the enlargement of the rooms located at the street level (the basement floor) with the replacement of the access staircase built in the last phase of the 20th century by demolishing traces of the historic garden, the construction of a new access staircase with another external lift, and the creation of new office spaces by excavating the embankment and staircase. In addition, the renovation of technical rooms built in the 20th century for the heating plant was included and re-used for the same aim.

The project involved the restoration of the facades, which was recently completed; they were painted according to the building's neo-Gothic appearance, restoring the 19th-century image to the city, of which some material traces had also been preserved (Figure 8a). The historic garden will also be restored, based on some material traces hidden by vegetation, and following the 19th-century drawings.

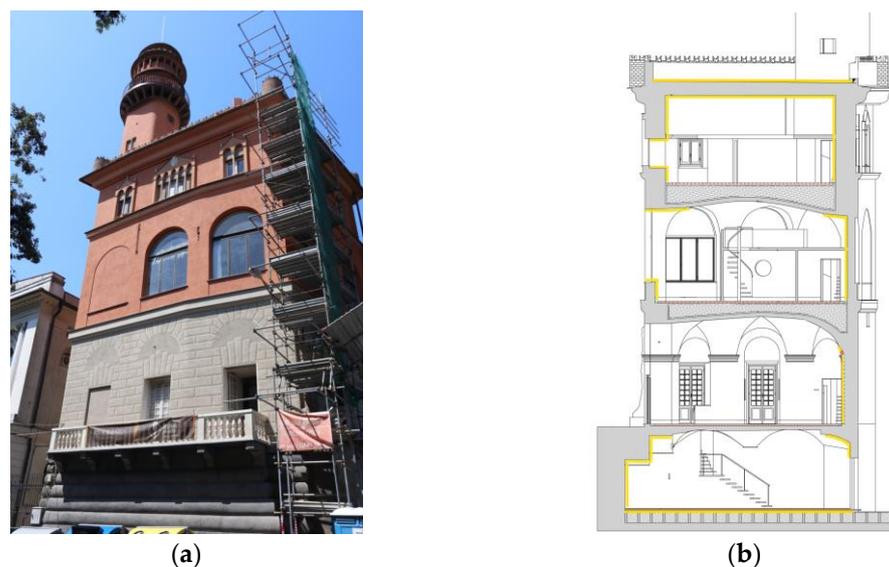


Figure 8. (a) The building after the restoration of the facades (Formento restauri). (b) A section of the building indicating the position of the insulation layers (in yellow).

Particular attention was paid to identifying strategies for enhancing the energy performance of the building envelope and systems. Even before the kick-off of the long

knowledge-gathering phase, the idea of insulating the opaque walls from the outside was discarded, although later analysis of documents and material traces (phase 1) revealed that the existing plaster was quite recent and cementitious (dating back to the second half of 20th century). The approach adopted, therefore, involved insulating the walls from the inside. The whole retrofitting strategy also included the full replacement of the existing windows and doors, which were already replaced almost entirely in 1978, the insulation of the ground floor slab (details of the insulation method will be defined at a later project stage), and the extrados and intrados of the roof slab, both of which were heavily modified during the last renovation (Figures 7 and 8b).

With regard to services, a new centralized thermal system was proposed to cater to both winter heating and summer cooling through radiant floor panels, as well as a hot water supply for sanitary and hygienic purposes. The generation system will consist of a geothermal heat pump with vertical probes, capable of producing the hot and chilled water needed to provide the planned energy services. The choice of installing a geothermal heat pump system was considered preferable to a more conventional air/water system, although this decision could be subject to revision during the final intervention phase, especially considering the archaeological vulnerability of the site (despite the positive results of the preliminary archaeological tests in phase 1). Compatible with architectural constraints, and if necessary, an appropriate mechanical ventilation system equipped with a heat recovery unit will also be installed.

The dimensions of the technical spaces for the thermal power plant, which already existed, are sufficient to accommodate the geothermal heat pump, inertial storage tanks, collectors and circulation pumps, electrical panels, and anything else necessary for the proper functioning of the system (heating and cooling).

Particularly interesting in the integrated design methodology is the choice of the piping layout (for air conditioning, the power supply, the water supply, mechanical ventilation, and smoke exhaust), made possible without invasive trenching in the masonry and vaulted structures through the presence of cavities created during the neo-Gothic renovation phase (in the external arches on the perimeter walls) and as a result of the installation of the lift (during which a gap was created between the shaft and the wall of the spiral staircase without any demolition).

To further satisfy the demand for renewable sources, the integration of photovoltaic panels was also taken into consideration (Figure 9). Specifically, a covering structure for the mobile phone networks installed within the parapet of the roof terrace was designed. This entailed a sort of “carter” cladding on the parts exposed to solar radiation and not shaded by the parapet. The cladding was proposed to be constructed using a metal framework, onto which photovoltaic panels will be mounted, covering a total area of 20 m². The result will never be visible on the outside or invasive to the livability and character of the roof terrace.

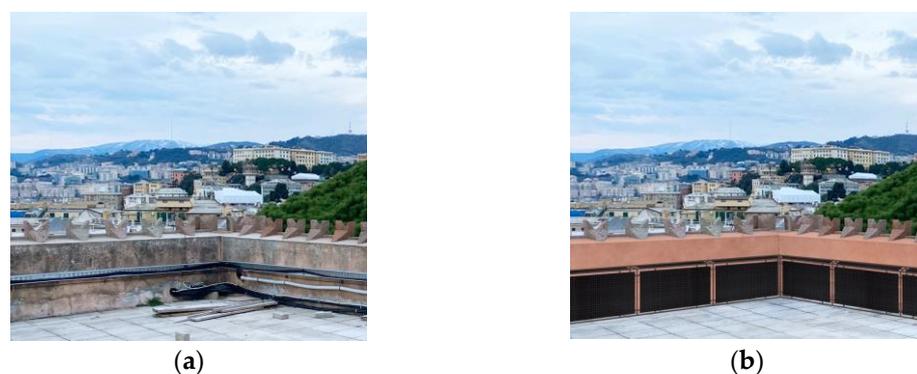


Figure 9. (a) The roof terrace before the renovation works (note the cables that cannot be removed). (b) Simulation of a cable-covering intervention with a metal framework into which photovoltaic panels are integrated (elaboration by Marta Casanova).

Finally, the project envisaged improvements to the structural behavior for seismic risk, which is already implemented in the tower and is not described in this article.

5.3. Phases 3 and 4: Assessing the Energy Efficiency of Measures and Their Compliance with the nZEB Standards

As we have seen, the renovation project is multifaceted and includes a wide range of aspects, from reuse and conservation to energy and structural improvement. For this reason, as indicated in Section 3.3, the building was divided into four thermal zones corresponding respectively to the following uses: (1) apartments/offices located on the first and second floors of the existing building, subject to interventions for the energy improvement of the building envelope and a new thermal system; (2) offices located on the basement and ground floors, subject to the same interventions as zone 1; (3) the west-side addition of offices located on the basement floor with a new thermal system; and (4) a new construction used as an office with a new thermal system. Below, we focus only on certain parts of thermal zone 1.

The new performance of opaque and transparent architectural elements, subjected to the energy retrofitting measures indicated in the previous phase, were calculated and compared with the minimum legal parameters stated in Ministerial Decree 26 June 2015 for existing nZEB buildings [8]. On the load-bearing walls (the second floor), it is planned to keep the inner cementitious plaster and use it as a base on which to apply the insulation layer from the inside. A variety of insulation materials were considered: calcium silicate hydrate panels, aerogel panels, wood fiber panels, and thermal plaster. Wood fiber insulation panels (80 mm thick) were chosen for all walls except the east wall of the bathroom and staircase, where very high-performance aerogel panels (30 mm and 40 mm thick, respectively) were preferred. This final choice was guided by point calculations that took into account the specific geometric (such as the coplanarity of stone ashlars), material (the existing stratigraphy), and hygrothermal (the presence of moisture) conditions of the walls. The results show thermal transmittance values ranging from 0.296 W/m²K to 0.322 W/m²K for walls insulated with wood fiber and between 0.278 W/m²K and 0.334 W/m²K for walls insulated with aerogel (see Table 2 for the pre-intervention values and Table 4 for the post-intervention ones).

Table 4. Comparison between the post-intervention U-values and the legislative limits established by Ministerial Decree 26 June 2015. The values in the green boxes meet the requirements.

Building Element	Thickness [mm]	Thermal Transmittance U [W/m ² K]	Thermal Transmittance U _{lim} [W/m ² K]
North wall, second floor	1073	0.296	0.29
South wall, second floor	1033	0.30	0.29
West wall, second floor	843	0.321	0.29
East wall, second floor	833	0.322	0.29
East wall (bathroom portion), second floor	780	0.334	0.29
Staircase wall	650	0.278	0.29
Roof	750	0.192	0.26
Windows	-	0.69/0.80	1.80

The new windows and doors will have to meet several requirements, encompassing energy saving, air and water tightness, ease of use, structural strength to withstand the weight of triple glazing, a limited cross-sectional area, and a design that harmonizes with the building's historical appearance (Figure 10). The new steel windows were designed to have optimal thermal properties, with U_w values expected to reach up to 0.69 W/m²K for fixed glazing, and up to 0.8 W/m²K for operable windows (calculations were conducted individually for each window, according to the project abacus).

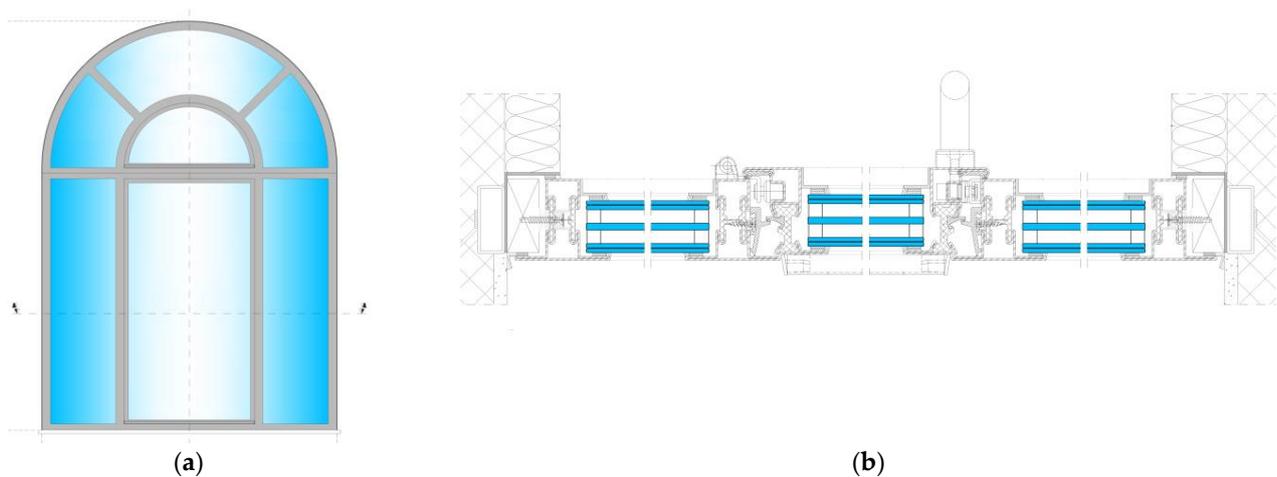


Figure 10. (a) Design of the window planned for the first floor. (b) Horizontal section of the window planned for the first floor.

The performance of the roof will also be improved by intervening on both the extrados and the intrados of the existing slab. Externally, the surface layers will be removed and replaced by a new stratigraphy containing a glass foam insulating panel (100 mm thick) and a new stoneware flooring. Here, the thickness will increase by only 5 cm compared to the current slab, without affecting safety. Internally, aerogel insulation panels will be added. The expected overall U-value is about $0.192 \text{ W/m}^2\text{K}$ (see Table 2 for the pre-intervention value).

In meeting the minimum standards set by the Ministerial Decree [8], only one of the six walls on the second floor achieved the required thermal transmittance values, while another two came very close to meeting these standards. However, the low U-values of the roof and windows, which were well below the legal threshold, helped balance this out (Table 4).

The calculation and assessment of thermal bridges are ongoing, with a focus on several key areas: the junctions between the walls and windows; corners at the north/west, north/east, and south/west (the perimeter walls have different thicknesses and do not form right angles); and the interface between the insulated roof and parapet.

Finally, the project involved the calculation of winter and summer heat loads for rooms in all thermal zones, performed in compliance with Italian Law 10/1991 [63], to properly size the new thermal system. The winter loads include heat losses through transmission and ventilation and take recovery into account. The summer heat loads consider the heat transfer through transmission and ventilation, as well as internal (in the case of offices: people, lighting, and equipment) and solar inputs through windows and doors. The results presented in Table 5 were considered optimal because they were based on calculations of energy consumption that stemmed from two key improvements: the addition of insulation layers to the opaque envelope and the replacement of existing windows and doors with new, high-performance models.

Table 5. Winter and summer renovation project heat loads.

Thermal Zone/Use	Spaces	P_{win} [W]	P_{sum} [W]
Thermal zone 1	First floor	4452	6569
	Second floor	3144	2226
Thermal power plant use: 25%	Total loads zone 1	7596	8795
Thermal zone n.2, power plant: 35%	Total loads zone 2	9237	13451
Thermal zone n.3, power plant: 12%	Total loads zone 3	2662	5172
Thermal zone n.4, power plant: 7%	Total loads zone 4	1503	1953
	Total loads, zones 1–4	21 kW	29.4 kW

The thermal system is a new construction and, therefore, will comply with all the requirements of the relevant legislation in force [7].

Since the project is still a work in progress, the next steps will involve calculating the contribution from the photovoltaic panels to achieving the nZEB standards and the global energy performance after the intervention, to be compared with the data shown in Table 3.

6. Discussion

The results achieved so far, corresponding to the completed phase of facade restoration and detailed architectural, structural, and thermal project, as well as the commencement of interventions for the second floor under the roof, highlight both positive outcomes and some challenges that may be applicable to similar cases.

The first and most significant result is, undoubtedly, the demonstration of the feasibility of achieving the nZEB standards even in listed buildings and even by modifying the initial strategies. As a matter of fact, these strategies initially involved partially replacing cement plaster coatings, but instead, they were preserved by overlaying insulating materials approved by the heritage authorities, deemed compatible with the conservation of the historic building. A second important outcome is the broader awareness among various stakeholders involved in the process of the gradual and steady convergence of two “worlds” that seemed entirely distant, if not conflicting, a few decades ago, thus making this example transferable to other contexts. A third significant result is the growing focus on developing new skills that are becoming increasingly necessary in research and design teams aiming at integrated approaches.

However, certain challenges have also emerged that are important to underline, especially in the context of potentially transferring such an approach to other scenarios. The primary and most substantial challenge lies in the difficulty of finding professionals capable of managing complex processes of this nature, involving high-level expertise in the fields of conservation and restoration. This consideration leads to the need for research aimed at increasing transdisciplinarity, rather than just multidisciplinary, thereby moving beyond the logic of sector-specific studies and working towards a greater sharing of objectives, skills, methodologies, and the use of sector-specific research findings. Furthermore, this experience underscores the importance of working collaboratively not only in terms of objectives and methodologies but also through interoperable platforms to verify, utilize, and potentially modify in real time the changes made by each technician to address the numerous problems that arise during the implementation phase.

A direct consequence of this challenge has been the management time of the entire process: initially, the timeline was slowed down to follow the archival research (which cannot have a defined and limited duration) and also due to difficulties that arose during the construction phase from unforeseen issues that emerged despite accurate and detailed diagnostics, which were exacerbated by the lack of a technical figure capable of coordinating the various competencies. From the outset of this process, the client intended to establish a professional work approach according to the standards, criteria, and methodologies of scientific research.

Some challenges also concerned economic aspects: clients are not always—indeed, they are almost never—willing to invest time and money in a lengthy diagnostic phase, although, in this case, the results obtained, even in terms of knowledge alone, will contribute to increasing the asset value of the property. On the other hand, diagnostics cannot be conducted randomly or indiscriminately but must also follow a project that evolves gradually, depending on the findings of indirect sources.

Further considerations can, then, be made from a purely economic perspective, demonstrating the technical and economic feasibility, considering the benefits that will be achieved and measured in terms of consumption. The percentage impact of the insertion of insulation, compared to the total amount of work, was estimated between 12% and 15%, also based on the materials used, while that of the triple-glazed windows was significantly higher (around 50%). On the other hand, achieving the nZEB objectives would allow

for a reduction in systems costs by reducing the number of machines required and their capacity. The inclusion of photovoltaic panels, as designed, involved an increase in costs of around 2–4%.

7. Conclusions

The Villetta Serra project, focusing on retrofitting a historic listed building to the nZEB standards, represents a significant step forward in reconciling the often-conflicting goals of preserving heritage buildings and meeting modern energy efficiency and comfort standards.

The methodological approach adopted in this project, while building upon existing methodologies, stands out for its practical application to the complex and challenging context of real monumental architecture. The outcomes discussed in this study are not mere theoretical projections. The project's completion of the detailed design phase for a significant portion of the building supported by extensive research and interdisciplinary collaboration ensures the reliability of our findings, although there is no monitoring phase envisaged due to the private nature of the project and the absence of dedicated funding. This aspect is crucial, as it moves the project beyond the robust theoretical principles illustrated in Section 2 to valuable and immediately applicable suggestions and advice for future projects aiming to achieve similar goals.

Therefore, the project sets a significant precedent, demonstrating a viable pathway to achieving high energy efficiency standards by employing a logic of “compensation” and “balancing” between different values and needs in the search for shared design solutions that would guarantee the fulfillment of the objectives pursued by each stakeholder involved in the process. It is worth mentioning that the success of this project is rooted in its specific context: due to its material and construction history, it presents parts that can be easily modified, thus facilitating the integration of new devices that, however, may not be feasible in other specific cases. When tackling such projects, it is crucial to adopt a case-by-case approach, recognizing that no universally applicable solutions exist. Not all listed historic buildings can achieve such high performance, especially if they involve giving up heritage value in favor of energy improvement at all costs. Nevertheless, it is always possible to explore various improvement scenarios, including unconventional or tailor-made measures specifically designed for built heritage. Thinking outside the box allows for the discovery of alternative solutions that address the problem, rather than avoiding it. That being said, the success of these types of projects is only possible with strong collaboration and communication between various stakeholders, including heritage authorities, conservation and energy efficiency experts, and owners. In this regard, heritage authorities need to be open and receptive to the importance of energy efficiency, setting aside preconceived notions about the feasibility of some retrofitting measures. On the other hand, professionals must be mindful of conservation values, ensuring that their actions are in line with the principles of preserving a building's oldest parts in order to find common ground for a dialogue with heritage authorities. None of this would be possible without the initiative and willingness of the client, who is the driving force behind the process. In the case of Villetta Serra, the client has shown remarkable sensitivity and eagerness to address these issues, aspiring to make a significant impact in the current landscape by going beyond mere legal requirements.

In conclusion, the project not only achieved its specific objectives but also contributes to the growing body of knowledge on the sustainable retrofitting of heritage buildings.

Author Contributions: Conceptualization, G.F. and S.M.; methodology, G.F. and S.M.; resources, G.F.; writing—original draft preparation, G.F. and S.M.; writing—review and editing, S.M.; visualization, S.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data are contained within the article.

Acknowledgments: The case study here presented, which is still ongoing, is the result of a huge multidisciplinary work by different experts. Private owner: SMART ENERGY&HERITAGE LAB. Topographic and longimetric survey: Enrico Tassistro, Marco Campi, and Terramap. Photogrammetric survey, 3D modeling, and GIS: Alessandro Baiardi, Simonetta Acacia, and Marta Casanova. Archival research: Roberto Santamaria. Archaeological tests: Chiara Davite. Stratigraphy tests: Sara Martini and Patrizia Bianchi. Chemical analysis: Sonia Mugnaini and Scienza per l'arte. Diagnosis: Elisa Barattero. Structural consultancy and project: Federico Martignone. Energy efficiency consultancy: Marco Cartesegna. Architectural design and restoration project: Nicola Sarti. Intervention on the facades: Formento restauri. Scientific consultancy on the overall knowledge process: Giovanna Franco, who was even responsible for the archival research regarding modifications done in the 1970s.

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

References

1. United Nations Framework Convention on Climate Change (UNFCCC), Paris Agreement. Available online: https://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf (accessed on 24 October 2023).
2. United Nations. Goal 13: Take Urgent Action to Combat Climate Change and Its Impacts. Available online: <https://www.un.org/sustainabledevelopment/climate-change/> (accessed on 24 October 2023).
3. United Nations Environment Programme, Putting the Environment at the Heart of People's Lives—Annual Report. 2018. Available online: <https://wedocs.unep.org/20.500.11822/27689> (accessed on 24 October 2023).
4. European Union. *Directive 2018/844 of the European Parliament and of the Council of 30 May 2018 Amending Directive 2010/31/EU on the Energy Performance of Buildings and Directive 2012/27/EU on Energy Efficiency*; EU: Brussels, Belgium, 2018.
5. European Parliament. Amendments Adopted by the European Parliament on 14 March 2023 on the Proposal for a Directive of the European Parliament and of the Council on the Energy Performance of Buildings (Recast). Available online: https://www.europarl.europa.eu/doceo/document/TA-9-2023-0068_EN.html#title2 (accessed on 30 October 2023).
6. Italian Republic. *Legislation 19 August 2005 no. 192 "Attuazione della Direttiva 2002/91/CE Relativa al Rendimento Energetico Nell'edilizia"*; Istituto Poligrafico e Zecca dello Stato: Rome, Italy, 2005.
7. Italian Republic. *Law 3 August 2013 no. 90 "Conversione, Con Modificazioni, Del Decreto-Legge 4 Giugno 2013, no. 63, Recante Disposizioni Urgenti per il Recepimento Della Direttiva 2010/31/UE del Parlamento Europeo e del Consiglio del 19 Maggio 2010, Sulla Prestazione Energetica Nell'edilizia per la Definizione Delle Procedure D'infrazione Avviate dalla Commissione Europea, Nonché Altre Disposizioni in Materia di Coesione Sociale"*; Istituto Poligrafico e Zecca dello Stato: Rome, Italy, 2013.
8. Italian Republic. *Decree of the Ministry of Economic Development 26 June 2015 "Applicazione Delle Metodologie di Calcolo Delle Prestazioni Energetiche e Definizione Delle Prescrizioni e Dei Requisiti Minimi Degli Edifici"*; Istituto Poligrafico e Zecca dello Stato: Rome, Italy, 2015.
9. Italian Republic. *Legislation 10 June 2020 no. 48 "Attuazione della Direttiva (UE) 2018/844 del Parlamento Europeo e del Consiglio, del 30 Maggio 2018, che Modifica la Direttiva 2010/31/UE Sulla Prestazione Energetica Nell'edilizia e la Direttiva 2012/27/UE Sull'efficienza Energetica"*; Istituto Poligrafico e Zecca dello Stato: Rome, Italy, 2020.
10. Corrado, V.; Ballarini, I.; Dirutigliano, D.; Murano, G. Verification of the New Ministerial Decree about Minimum Requirements for Energy Performance of Buildings. *Energy Procedia* **2016**, *101*, 200–207. [CrossRef]
11. European Union. *Directive 2010/31/EU of the European Parliament and of the Council on the Energy Performance of Buildings (Recast)*; EU: Brussels, Belgium, 2010.
12. Ministry of Ecological Transition, Strategy for Energy Retrofitting of National Building Stock. 2021. Available online: https://energy.ec.europa.eu/system/files/2021-12/2020_ltrs_italy_-_en.pdf (accessed on 24 October 2023).
13. European Commission. *Energy-Efficient Buildings PPP Multi-Annual Roadmap and Longer Term Strategy*; Publications Office of the European Union: Luxembourg, 2010.
14. Troi, A.; Bastian, Z. *Energy Efficiency Solutions for Historic Buildings*; Birkhäuser: Basel, Switzerland, 2015.
15. Musso, S.F. Conserving-Restoring for the Future What We Inherited from the Past. In *Historical Buildings and Energy*; Franco, G., Magrini, A., Eds.; Springer: Cham, Switzerland, 2017; pp. 23–44.
16. ICOMOS, Charter Principles for the Analysis, Conservation and Structural Restoration of Architectural Heritage. Available online: <https://www.icomos.org/en/about-the-centre/179-articles-en-francais/ressources/charters-and-%20stand-ards/165-icomos-charter-principles-for-the-analysis-conservation-and-structural-restoration-of-architectural-%20heritage> (accessed on 30 October 2023).
17. Feiffer, C. Le Tendenze del Restauro Italiano tra Conservazione, Recupero, Restauro e Ripristino. In *Il Restauro della Porta di Pietro I "Il Grande" a San Pietroburgo*; De Lettera: Milan, Italy, 2007.
18. Commissione D'indagine per la Tutela e la Valorizzazione del Patrimonio Storico, Archeologico, Artistico e del Paesaggio. *Per la Salvezza dei Beni Culturali in Italia: Atti e Documenti della Commissione d'Indagine per la Tutela e la Valorizzazione del Patrimonio Storico, Artistico e del Paesaggio*; Colombo: Roma, Italy, 1967.

19. Australia ICOMOS, The Burra Charter. The Australian ICOMOS Charter for Places of Cultural Significance. Available online: https://australia.icomos.org/wp-content/uploads/BURRA_CHARTER.pdf (accessed on 30 October 2023).
20. Dimitrova, E.; Lavenier, M.L.; McMahon, P.; Mürniece, B.; Musso, S.F.; Nagy, G.; Rauhut, C.; Rourke, G.D.; Sciacchitano, E.; Selfslagh, B. *European Quality Principles for EU-Funded Interventions with Potential Impact Upon Cultural Heritage*; ICOMOS: Charenton-le-Pont, France, 2019.
21. Lerario, A. The Role of Built Heritage for Sustainable Development Goals: From Statement to Action. *Heritage* **2022**, *5*, 2444–2463. [[CrossRef](#)]
22. Gaballo, M.; Mecca, B.; Abastante, F. Adaptive Reuse and Sustainability Protocols in Italy: Relationship with Circular Economy. *Sustainability* **2021**, *13*, 8077.
23. Dorpalen, B. *Valuing Carbon in pre-1919 Residential Buildings*; Historic England: London, UK, 2019.
24. Mickaityte, A.; Zavadskas, E.K.; Kaklauskas, A.; Tupenaite, L. The Concept Model of Sustainable Buildings Refurbishment. *Int. J. Strateg. Prop. Manag.* **2010**, *12*, 53–68. [[CrossRef](#)]
25. Historic England, Heritage Counts. Available online: <https://historicengland.org.uk/research/heritage-counts/> (accessed on 24 October 2023).
26. Historic England. *There's no Place Like Old Homes: Re-Use and Recycle to Reduce Carbon in Heritage Counts*; Historic Environment Forum: London, UK, 2019.
27. Martínez-Molina, A.; Tort-Ausina, I.; Cho, S.; Vivancos, J.L. Energy Efficiency and Thermal Comfort in Historic Buildings: A Review. *Renew. Sust. Energ. Rev.* **2016**, *61*, 70–85. [[CrossRef](#)]
28. 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](#)]
29. [CORDIS European Commission. Energy Efficiency for EU Historic Districts Sustainability. Available online: https://cordis.europa.eu/project/id/314678/it](https://cordis.europa.eu/project/id/314678/it) (accessed on 30 October 2023).
30. 3ENCULT. Available online: <http://www.3encult.eu/en/project/welcome/default.html> (accessed on 30 October 2023).
31. Climate for Culture. Available online: <https://www.climateforculture.eu> (accessed on 30 October 2023).
32. Uranga, E.J.; Etxepare, L.; Lizundia, I.; Sagarna, M. Energy Efficiency Intervention and Preservation in residential Built Heritage. Analysis, Proposal and results in the Gros District of San Sebastian. In Proceedings of the 3rd International Conference on Energy Efficiency in Historic Buildings, Visby, Sweden, 26–27 September 2018.
33. Herrera-Avellanosa, D.; Haas, F.; Leijonhufvud, G.; Bröstrom, T.; Buda, A.; Pracchi, V.; Webb, A.L.; Hüttler, W.; Troi, A. Deep Renovation of Historic Buildings: The IEA_SHC Task 59 Path Towards the Lowest Possible Energy Demand and CO₂ emissions. *Int. J. Build. Pathol. Adapt.* **2019**, *38*, 539–553. [[CrossRef](#)]
34. Buda, A.; De Place Hansen, E.J.; Rieser, A.; Giancola, E.; Pracchi, V.; Mauri, S.; Marincioni, V.; Gori, V.; Fouseki, K.; Polo Lopez, C.S.; et al. Conservation-Compatible Retrofit Solutions in Historic Buildings: An Integrated Approach. *Sustainability* **2021**, *13*, 2927. [[CrossRef](#)]
35. Webb, A.L. Energy Retrofits in Historic and traditional Buildings: A Review of Problems and Methods. *Renew. Sust. Energ. Rev.* **2017**, *77*, 748–759. [[CrossRef](#)]
36. Eriksson, P.; Milić, V.; Broström, T. Balancing Preservation and Energy Efficiency in Building Stocks. *Int. J. Build. Pathol. Adapt* **2019**, *38*, 356–373. [[CrossRef](#)]
37. Eriksson, P. Balancing Building Conservation with Energy Conservation—Towards Differentiated Energy Renovation Strategies in Historic Building Stocks. Ph.D. Thesis, University of Gothenburg, Gothenburg, Sweden, 20 May 2021.
38. De Selincourt, K.; Disastrous Preston Retrofit Scheme Remains Unresolved. Passive House Plus. 2018. Available online: <https://passivehouseplus.ie/news/health/disastrous-preston-retrofit-scheme-remains-unresolved> (accessed on 25 October 2023).
39. Femenias, P. Demonstration Projects for Sustainable Buildings: Towards a Strategy for Sustainable Development in the Building Sector Based on Swedish and Dutch Experience. Ph.D. Thesis, Chalmers University of Technology, Goteborg, Sweden, 2004.
40. IEA SHC Task 59 Renovating Historic Buildings towards Zero Energy. Available online: <https://task59.iea-shc.org> (accessed on 25 October 2023).
41. Historic Building Energy Retrofit Atlas. Available online: <https://www.hiberatlas.com/it/benvenuti-1.html> (accessed on 25 October 2023).
42. Troi, A.; Exner, D.; Haas, F. Teaching experience with the Historic Building Energy Retrofit Atlas—HiBERAtlas. *IOP Conf. Ser. Earth Environ. Sci.* **2021**, *863*, 012032. [[CrossRef](#)]
43. Fiorani, D.; Kealy, L.; Musso, S.F. (Eds.) *Conservation-Adaptation. Keeping Alive the Spirit of the Place. Adaptive Reuse of Heritage with Symbolic Value*; EAAE: Hasselt, Belgium, 2017.
44. Lanz, F.; Pendlebury, J. Adaptive Reuse: A Critical Review. *J. Archit.* **2022**, *27*, 441–462. [[CrossRef](#)]
45. Arfa, F.H.; Zijlstra, H.; Lubelli, B.; Quist, W. Adaptive Reuse of Heritage Buildings: From a Literature Review to a Model of Practice. *Hist. Environ. Policy Pract.* **2022**, *13*, 148–170. [[CrossRef](#)]
46. ICOMOS, The NARA Document on Authenticity (1994). Available online: <https://www.icomos.org/en/charters-and-texts/179-articles-en-francais/ressources/charters-and-standards/386-the-nara-document-on-authenticity-1994> (accessed on 30 October 2023).
47. ICOMOS. Nara +20: On Heritage Practices, Cultural Values, and the Concept of Authenticity. *Herit. Soc.* **2015**, *8*, 144–147. [[CrossRef](#)]

48. Centre for Sustainable Energy, Low-Carbon Retrofitting. Taking a Whole-House Approach. Available online: <https://www.cse.org.uk/resource/home-energy-fact-sheets/> (accessed on 25 October 2023).
49. Marincioni, V.; Altamirano-Medina, H.; Rickaby, P.; Griffiths, N.; Aktas, Y.D.; King, C. Towards an Integrated Moisture-Safe Retrofit Process for Traditional Buildings in Policy and Industry. *IOP Conf. Ser. Earth Environ. Sci.* **2021**, *863*, 012030. [CrossRef]
50. May, N.; Griffiths, N. *Planning Responsible Retrofit of Traditional Buildings*; Sustainable Traditional Buildings Alliance: London, UK, 2015.
51. Sustainable Traditional Building Alliance, What Is Whole House Retrofit? 2016. Available online: <https://stbauk.org/wp-content/uploads/2020/08/STBA-What-is-Whole-House-Retrofit-Nov2016.pdf> (accessed on 25 October 2023).
52. McCaig, I.; Pender, R.; Pickles, D. *Energy Efficiency and Historic Buildings: How to Improve Energy Efficiency*; Historic England: London, UK, 2018.
53. *EN 16883:2017; Conservation of Cultural Heritage—Guidelines for Improving the Energy Performance of Historic Buildings*. CEN: Brussels, Belgium, 2017.
54. Gori, V.; Marincioni, V.; Altamirano-Medina, H. Retrofitting Traditional Buildings: A Risk-Management Framework Integrating Energy and Moisture. *Build. Cities* **2021**, *2*, 411–424.
55. Liguria Region. *Liguria Regional Law 29 May 2007 no 22 “Norme in Materia di Energia”*; Regione Liguria: Genoa, Italy, 2007.
56. Italian Republic. *Legislation 4 July 2014 no 102 “Attuazione Della Direttiva 2012/27/UE Sull’efficienza Energetica, che Modifica le Direttive 2009/125/CE e 2010/30/UE e Abroga le Direttive 2004/8/CE e 2006/32/CE”*; Istituto Poligrafico e Zecca dello Stato: Rome, Italy, 2014.
57. Newton, D.; Fouseki, F. Heritage Values as a Driver or Obstacle for Energy Efficiency in Victorian and Edwardian Buildings. In Proceedings of the 3rd International Conference on Energy Efficiency in Historic Buildings, Visby, Sweden, 26–27 September 2018.
58. Fouseki, K.; Bobrova, Y. Understanding the Change of Heritage Values Over Time and its Impact on Energy Efficiency Decision-Making at Residential Historic Buildings through System Dynamics. In Proceedings of the 3rd International Conference on Energy Efficiency in Historic Buildings, Visby, Sweden, 26–27 September 2018.
59. Murillo, K.S.; Fouseki, K.; Altamirano, H. A Sociotechnical Approach to Users’ Heritage Values and Decision-Making Processes for Energy Efficiency and Thermal Comfort in Heritage Buildings: A Pilot Study in Mexico City. *IOP Conf. Ser. Earth Environ. Sci.* **2021**, *863*, 012031. [CrossRef]
60. Lucchi, E.; Polo Lopez, C.; Franco, G. A Conceptual Framework on the Integration of Solar Energy Systems in Heritage sites and Buildings. *IOP Conf. Ser. Mater. Sci. Eng.* **2020**, *949*, 012113. [CrossRef]
61. Polo Lopez, C.; Frontini, F. Energy Efficiency and Renewable Solar Energy Integration in Heritage Historic Buildings. *Energy Procedia* **2014**, *48*, 1493–1502. [CrossRef]
62. Acca Software, Software Certificazione Energetica Termus. Available online: <https://www.acca.it/software-certificazione-energetica> (accessed on 30 October 2023).
63. Italian Republic. *Law 9 January 1991 no. 10 “Norme per L’attuazione del Piano Energetico Nazionale in Materia di Uso Nazionale Dell’energia, di Risparmio Energetico e di Sviluppo delle Fonti Rinnovabili di Energia”*; Istituto Poligrafico e Zecca dello Stato: Rome, Italy, 1991.

Disclaimer/Publisher’s Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.