Strategie di retrofit per la riqualificazione energetica negli edifici storici: un compito impegnativo. Il caso di studio del Monastero di Santa Maria de Monfero in Galizia

Envelope retrofit strategies for energy refurbishment in historic buildings: a challenging task. The case study of Santa Maria de Monfero Monastery in Galicia

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La riqualificazione energetica degli edifici storici non è semplicemente uno sforzo per ridurre il consumo energetico, ma è parte integrante di un più ampio processo di conservazione e protezione. Il caso del Monastero di Santa Maria de Monfero in Galizia, Spagna, funge da esempio illuminante, bilanciando un approccio di "riuso adattivo" con le migliori pratiche di ristrutturazione energetica in accordo con le linee guida di conservazione per gli edifici storici. Per il complesso monumentale, abbandonato e parzialmente in rovina, una ricerca ha valutato diverse soluzioni di riqualificazione dell'involucro. Il progetto qui analizzato è il risultato di un concorso internazionale di idee che ha assegnato il 1° premio agli architetti spagnoli Sabin Blanco, direttamente coinvolti in questa ricerca.

The energy retrofit of historic buildings is not merely an effort to reduce energy consumption but is an integral part of a broader conservation and protection process. The case study of the Santa Maria de Monfero Monastery in Galicia, Spain, serves as an insightful example, balancing an "adaptive reuse" approach with the best practices of energy refurbishment in line with conservation guidelines for historic buildings. This monumental complex, abandoned for over two centuries and partially in ruins, was the subject of a research aimed at assessing different envelope retrofit solutions.
The project analysed in this study was the result of an international ideas competition that awarded first prize to Spanish architects Sabin Blanco, directly involved in this research.

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Introduction[1]

Every intervention in cultural heritage, particularly those focused on energy efficiency and sustainability, carries significant cultural importance. Even projects based on conservation principles inevitably alter the building's physical – and often intangible – form. Therefore, how can we balance the dual objectives of preservation and energy refurbishment? According to fundamental conservation principles, the goal must be to safeguard the historical and aesthetic value of the building without compromising it, ensuring its transmission to future generations.

When it comes to energy considerations, historic buildings form a substantial part of the existing building stock in many European cities, especially if related to residential buildings. In Europe, the most significant portion of covered floor area in the service sector is related to buildings erected before 1945, with a percentage ratio of 29%. Buildings constructed in the 2000s occupy just 17% of the covered floor area[2]. This building stock is not only a cultural and material asset but also a "public good" and a reflection of local historical memory.

Additionally, existing buildings offer significant potential for energy savings, making their retrofitting crucial with a view to meeting the goal of reducing greenhouse gas emissions by 40% by 2030. Several studies indicate that the energy-saving potential of older buildings exceeds 60%[3]. For this reason, retrofitting building envelopes has been identified as one of the most effective solutions, serving as a dual tool for improving both energy efficiency and building conservation.

The preservation of such buildings offers numerous benefits. It promotes respect for future generations, fosters cultural and historical appreciation, and stimulates heritage tourism and the associated economy.

One way to ensure the preservation of a historic building is through 'adaptive reuse', in which the structure is adapted to meet modern needs. According to ICOMOS (2010), a successful heritage adaptive reuse project modifies a place or building for a compatible use while retaining its cultural heritage value[4]. Retrofitting can revitalize an old building, but the process is complex and requires specialized expertise: a close collaboration is demanded between all the stakeholders involved, i.e. building and service systems engineers, architects, restorers, representatives of Institutions, all of them involved at the same time in the building envelope and systems requalification and in cultural heritage conservation[5]. This is a complex task because it has to increase the building performance while preserving its historic and architectural expression and respecting the legislation in force. Often, a balance can be struck between preserving the heritage value of the building and implementing energy-saving interventions that reduce environmental impact, lower operational energy costs, and enhance occupant comfort, thereby ensuring the long-term viability of these structures. Retrofit actions can also help prevent common structural issues found in historic buildings.

One of the major challenges of retrofitting is that the building's exterior envelope cannot be altered due to its architectural significance. As a result, internal insulation strategies are often viewed as more feasible, though they can still be invasive. These strategies might involve introducing new materials, replacing historical finishes or altering internal features such as joinery, which may disrupt the original room proportions and may only be suitable for certain buildings. Another concern with internal insulation is its compatibility with traditional construction

1 This paper presents the results of a research carried out within a Master's Thesis by Ivana Mattea Lisitano and Deborah Laggiard, under the supervision of Valentina Serra, Carla Bartolozzi and Stefano Fantucci (Politecnico di Torino), Enrique M. Blanco and Patricia Sabín Díaz (University of A Coruña). Deborah Laggiard, Ivana Mattea Lisitano, *Il retrofit energetico in edilizia storica, il caso studio: Il Monasterio de Santa María de Monfero, in Galizia, Spagna*, tesi di laurea magistrale in Architettura per il Progetto Sostenibile, Politecnico di Torino, relatori Valentina Serra, Carla Bartolozzi, Stefano Fantucci, Enrique M. Blanco Lorenzo, Patricia Sabín Díaz, 2017.

2 Aleksandr Gevorgian, Simon Pezzutto, Stefano Zambotti, Silvia Croce, Ulrich Filippi Oberegger, Roberto Lollini, Lukas Kranzl, Andreas Müller, *European Building Stock Analysis*, Eurac Research, Bolzano, Italy 2021.

3 *Does one size fit all? Impact of Minimum Energy Performance Standards in the revision of the Energy Performance Building Directive*, Danish consultancy, Copenhagen Economics, Published in Energy, Future of the EU & Housing, Online 9 December 2021.

4 Fatemeh Vafaie, Hilde Remøy, Vincent Gruis, *Adaptive reuse of heritage buildings; a systematic literature review of success factors*, in «Habitat International», vol. 142, 2023..

5 Francesca Romana d'Ambrosio Alfano, Livio Mazzarella, Piercarlo Romagnoni, *Preface to the Special Issue: Designing the Retrofit*, in «Energy and Buildings», vol. 95, 2015, p. 1..

methods. Altering the balance of heat, air and moisture within the walls can significantly affect the building's structural integrity. For example, internal insulation could lead to the accumulation of moisture, interstitial condensation, frost damage, timber decay and mold growth[6].
Given these challenges, the goal of any retrofit project in a historic building should be to prioritize energy efficiency and occupant comfort while respecting the building's aesthetic and structural integrity. The restoration project of Santa Maria de Monfero in Galicia represents a good opportunity to develop research into feasible building envelope retrofit solutions to be applied to a real case study. The research was carried out within a Master Thesis developed through an ERASMUS Agreement between the Politecnico di Torino (Department of Energy and Department of Architecture and Design) and the University of A Coruña (Department of Architecture and Urbanism and Department of Construction and Architecture Structure, Civil and Aeronautic), in a joint team combining different skills, aimed at defining a methodology and testing its results[7]. Specifically, an integrated approach was adopted considering factors such as boundary conditions, climate, moisture behaviour and the interaction and compatibility be-tween materials.

6 Ivana Mattea Lisitano, Deborah Laggiard, Stefano Fantucci, Valentina Serra, Elisa Fenoglio, *Evaluating the Impact of Indoor Insulation on Historic Buildings: A Multilevel Approach Involving Heat and Moisture Simulations*, in «Applied Sciences», vol. 11, n. 17, 2021.

7 Ivana Matteo Lisitano, Deborah Laggiard, Stefano Fantucci, Valentina Serra, Carla Bartolozzi, Enrique Manuel Blanco Lorenzo, Patricia Sabín Díaz, *Energy in cultural heritage: the case study of Monasterio de Santa Maria de Monfero in Galicia*, 7th REHABEND Congress, Caçeres (ES), 2018.

1. The Case Study

The Monastery of Santa Maria de Monfero in Galicia, Spain, provides a compelling case study for exploring the balance between an 'adaptive reuse' project and the best practices of energy refurbishment in line with conservation principles for historic buildings. This research focuses on the monumental complex, which has been abandoned for over two centuries, with significant portions now in ruins. The project used for this analysis stems from the winning entry in an international ideas competition, which sought to give the monastery a new cultural and touristic purpose. The competition was won by Spanish architects Patricia Sabin Diaz and Enrique M. Blanco, directly involved in this study.
The central focus of the research is the investigation of the impact of different internal retrofit interventions on the monastery's building envelope. These interventions are assessed based on their potential for reducing energy demand, improving thermal comfort, and ensuring hygrothermal compatibility between the existing walls and the new insulation materials. Extensive analyses were carried out on the

Fig. 1 – View of the complex, in grey and brown the area interested by the study.

Fig. 2 – The monastery and the surrounding environment.

local climate, building history, materials and features of the monastery. Following this, a series of simulations were performed using Wufi Pro and Wufi Plus (Fraunhofer IBP) software to model and assess the retrofit scenarios.

Santa María de Monfero Monastery is situated in the northwest of Spain, in Galicia, within the municipal district of Monfero. Nestled in a natural rural environment, the monastery serves as a gateway to the Fragas do Eume natural park, home to the best-preserved Atlantic coastal forest in Europe.

The exact historical origins of the monastery are uncertain. It is believed to have been constructed in the 12th century on the ruins of the ancient Saint Marc's hermitage. The monastery faced a period of decline during the Middle Ages, which lasted until the 16th century when Catholic rulers implemented a policy of restoration and expansion. However, the War of Independence in 1820 triggered another crisis and, due to robberies, the nuns abandoned the monastery. Since then, the building has remained uninhabited and has fallen into a state of ruin.

The monastery consists of three cloisters and a church (Figure 1). The first cloister, known as the *Claustro de las Procesiones*, was built in the 16th century. Its ground floor features Gothic-style architecture with a porch adorned by a ribbed vault, while the first floor showcases Renaissance elements with Tuscan columns. The second cloister, constructed by stonemasons during the 18th century, has a stark, austere design. The church's construction began in 1620, with an interior layout forming a Latin cross, including a single nave, a transept covered by a dome, and a presbytery. Today, the church is the only

accessible part of the building, while the rest is overgrown with vegetation, with many of the roofs missing. The final cloister, built atop the Renaissance cloister in the early 19th century, was never completed due to the onset of the War of Independence.
In July 2004, the *Consellería de Cultura, Comunicación Social e Turismo* launched a competition for ideas to rehabilitate the monastery as a hotel and spa. The project, led by Architects Enrique Blanco and Patricia Sabín Díaz, won first prize, competing against notable architects such as Labics from Rome, Francisco Mangado from Navarra, and Estudio Cano Lasso from Madrid.
The primary goal of the designers was to preserve the monastery's original aesthetic, ensuring that visitor perception and experience of the building remained authentic. Their initial steps involved cleaning the structure and securing unstable sections. The project called for minimal intervention, prioritizing the preservation of the existing masonry. New openings for windows and doors were only created when absolutely necessary, and roofs were restored where missing.
The project's broader aim was to maximize the potential of this heritage site, leveraging its surroundings to develop high-quality, sustainable tourism.
Monfero, located in the northwest of Spain, enjoys an oceanic climate marked by frequent rainfall and strong winds (Figure 2). This type of climate is characterized by mild temperature variations and regular rainfall throughout the year. Monfero is particularly exposed to driving rain, with an estimated annual rainfall of 1300 mm and around 130 days of driving rain annually. This makes the impact of driving rain significant for the hygrothermal performance of buildings, posing a high risk of damage to the stone materials used in local construction.

1.2 Building envelope retrofit solutions

The primary aim of the study was to assess the impact of new insulation materials on the hygrothermal behaviour of the existing building envelope, while simultaneously evaluating their effects on energy demand and thermal comfort. Two different internal wall retrofit solutions were analysed: counter-wall insulation, as proposed by the architects in their project and thermal insulating plasters, proposed as alternative solution (Figure 3).
Thermal insulating plasters were selected due to their versatility and thermohygrometric performance, particularly effective in reducing thermal bridges and managing moisture. Counter-wall insulation was chosen, as it is a common solution in the restoration of historic buildings being easily removable and offering higher flexibility.
The study was conducted at two levels: at component level, focusing the analyses on the thermal performance and moisture retention of the retrofitted walls and at building level, assessing the energy demand reduction and thermal comfort throughout the year. The results, obtained through models coupling Heat and Moisture Transfer (HMT), WUFI®pro and WUFI®plus software, allowed for the comparison of different solutions, identifying those that performed best throughout different seasons and under various conditions.
The perimeter walls of the Monastery of Santa Maria de Monfero are irregular (31 cm to 90 cm). Four formulations of thermal plasters were analyzed, each using different lightweight aggregates to improve thermal properties (expanded Polystyrene, expanded perlite, granulated cork from bottle stoppers and aerogel granulates). For the counter-wall

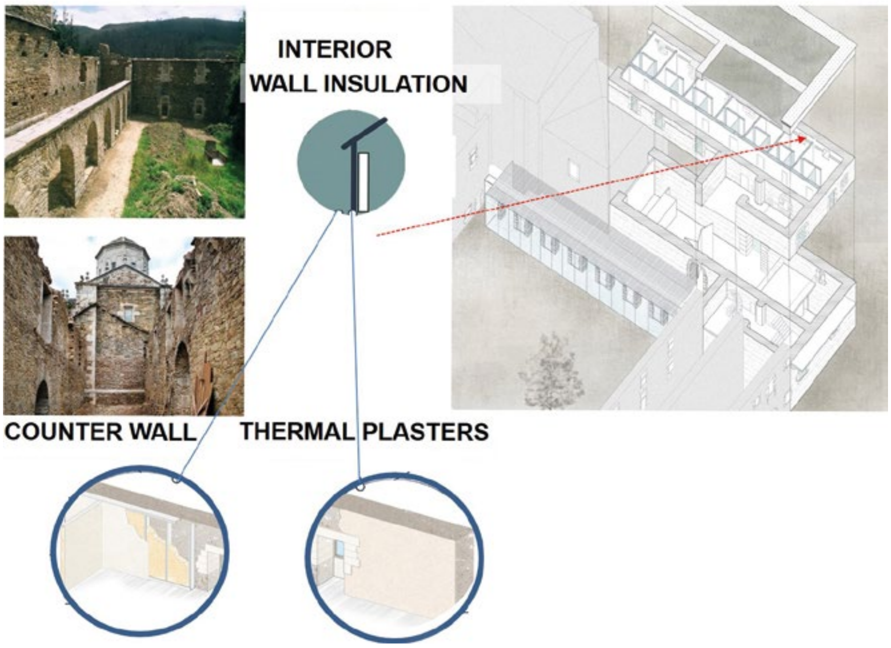
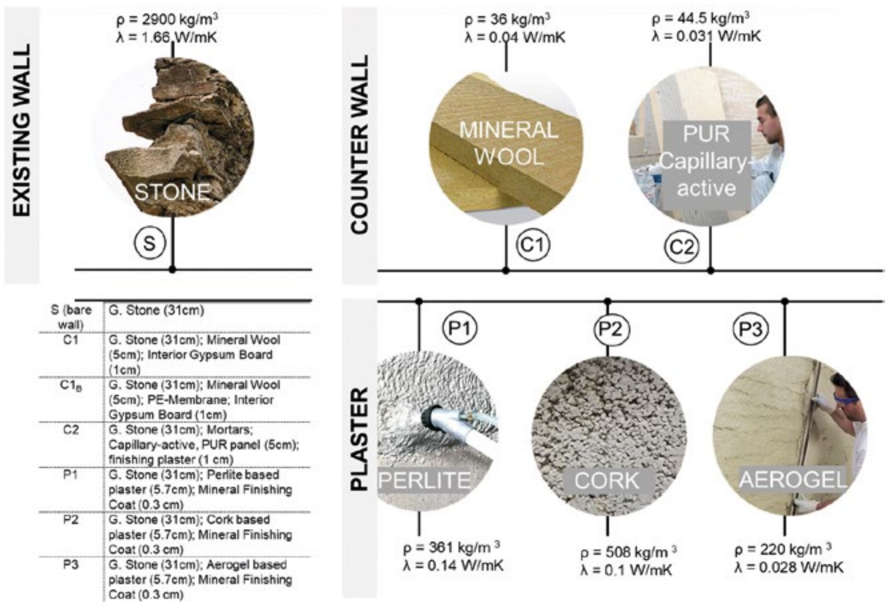


Fig. 3 – Energy retrofit strategies and location of the analysed walls.

systems, the performance of mineral wool and plasterboard was also considered, assessing the effect of applying a vapour barrier and of a capillary-active, rigid polyurethane (PUR) foam panel (Figure 4).
The moisture content within each layer of the wall and the related variation in thermal conductivity affecting the insulation capability represents a key factor in the analyses. Wind-driven rain, which plays a crucial role in this specific context was also taken into account. As can be expected, the results show that the thermal plaster configurations have a significantly higher water content (5 to 10 times) than counter-wall systems, because thermal plasters have a greater capacity to absorb and retain moisture. Additionally, the analysis related to the thermo-hygrometric behaviour of the various solutions provided insights into the use of vapour barriers. In the case of the counterwall, the adoption of a vapour barrier between the plasterboard and the mineral wool layer, which is usually a good solution, led to an increase in moisture content, due to the specifity of this case study (unprotected external walls exposed to driving rain), as the presence of water vapour prevented moisture from re-evaporating on the interior side.



S (bare wall)	G. Stone (31cm)
C1	G. Stone (31cm); Mineral Wool (5cm); Interior Gypsum Board (1cm)
$C1_B$	G. Stone (31cm); Mineral Wool (5cm); PE-Membrane; Interior Gypsum Board (1cm)
C2	G. Stone (31cm); Mortars; Capillary-active, PUR panel (5cm); finishing plaster (1 cm)
P1	G. Stone (31cm); Perlite based plaster (5.7cm); Mineral Finishing Coat (0.3 cm)
P2	G. Stone (31cm); Cork based plaster (5.7cm); Mineral Finishing Coat (0.3 cm)
P3	G. Stone (31cm); Aerogel based plaster (5.7cm); Mineral Finishing Coat (0.3 cm)

Fig. 4 – Investigated building envelope energy retrofit alternatives.

Coming to the variation in thermal transmittance during the winter period the results highlight how much the water content within the insulation layer can affect the performance. A clear distinction was observed between the thermal transmittance calculated according to the Standard (EN ISO 6946:2007) and based on properties of dry materials and the actual thermal transmittance (in the worst case achieving +33%). All retrofit configurations significantly reduce the value of the bare wall value with reductions ranging from 60% to 80%.
Dynamic energy simulations were then performed on the hotel room area to assess the thermal comfort without a cooling system (free running) and exploiting night ventilation and to assess the heating and cooling energy needs, assuming an ideal HVAC system maintaining temperatures at 20°C in winter and 26°C in summer.
In terms of comfort, temperatures move outside the comfort zone for only a few hours a year in summer (PMV above 0.7), with plaster-based solutions offering better performance and making it possible to avoid the installation of cooling systems, with some advantages in term of space saving, issue with the installation of HVAC elements and as far as economic aspects are concerned.
Regarding energy-saving potential, while the overall energy demand is low for counter-wall based solutions, plaster performs better during the cooling season, with energy demand tending to be nearly zero.

Conclusions

The methodology proposed offers a support tool for establishing guidelines based on a case-by-case approach, through collaboration between experts in building physics and cultural heritage conservation from the early stages. This study explored various technologies and step-by-step strategies for retrofitting challenging historic buildings, with a focus on feasibility, compatibility, hygrothermal performance, operational energy demand and indoor thermal comfort. Santa Maria de Monfero Monastery in Galicia, Spain, served as the case study, showcasing the balance between adaptive reuse and energy retrofit best practices.
Findings suggest that dynamic heat and moisture transfer simulations, along with building-scale energy performance assessments, are valuable in selecting appropriate retrofit strategies. Comparing internal insulation strategies of thermal plasters and counter-walls, the study highlighted that thermal plasters have a higher moisture content in winter, leading to higher thermal transmittance and heating demand but better indoor humidity regulation, while counter-walls offer lower thermal comfort in summer and increased cooling energy demand.