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Designing Retrofit Solutions for 1 Euro Houses in Italy: Enhancing Viability Through Energy Efficiency, Comfort, Sustainability, and Affordability.

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Abstract: In rural regions of Italy, underutilised and abandoned dwellings are increasingly being offered for the symbolic price of one euro. This initiative seeks to address the challenges of rural depopulation, stimulate local economies, and safeguard vernacular architectural heritage. However, these properties are aften characterised by outdated spatial configurations and significant structural degradation, rendering retrofitting efforts particularly complex. As such, the careful and context-sensitive redesign of one-euro houses is imperative to transform them into viable contemporary living environments that comply with current standards of energy performance, comfort, safety, sustainability, efficiency, and affordability.
This research investigates creative and innovative retrofitting strategies aimed at delivering cost-effective, scalable, and environmentally responsible architectural interventions.

Keywords: Retrofitting, Sustainability, Affordability, Comfort, 1€ Houses.

1. Introduction: The One-Euro Houses Initiative in Italy

The one-euro house initiative looks at revitalising rural and semi-abandoned areas by counteracting depopulation, boosting local economies, and preserving the historical architecture (Berti & Paoli, 2022). This dissertation develops a functional and scalable retrofitting model by analysing a one-euro house in Sardinia as a case study. The model addresses common challenges that prospective buyers frequently face, including materials, architectural elements, and structural integrity, offering potential solutions for similar projects in Sardinia and other Italian regions with comparable climates and availability of one-euro properties.

1.1 Pre-Design Research

Heritage historical buildings occupy approximately 46% of Italy's land, and 40% of the EU's energy consumption is attributed to older buildings (Selicati et al., 2020; Filippi, 2015). The proposed retrofitting model wants to incentive prospective buyers to invest in the renovation of rural historical properties, including one-euro homes.

Further research has been undertaken for a better understanding of best performing materials, eco-sustainable and energy-efficient solutions for the retrofitting of one-euro houses. In-depth analysis of insulating materials, window profiles, renewable energy systems, and HVAC options is conducted. The compatibility of these materials and HVAC systems with historic buildings is evaluated, ensuring that their application meets the required energy performance target and comfort.

2. Field Analysis and Design Research

The field analysis was conducted in Ollolai, Province of Nuoro, considered the birthplace of the one-euro houses initiative in Sardinia (started in 2016). The town offers numerous opportunities for revitalisation through this scheme.

Falling within Italy's climatic Zone E, characterised by cold winter and warm summer, a particular focus is placed on the redesign of the chimney – typically the primary heating system in these dwellings. The proposed design incorporates both passive and active energy strategies to improve thermal performance, reduce operational costs, and preserve the architectural character of the building.

2.1. Design and Engineering Principles for New Chimney

The proposed chimney was designed to combine both heating and passive cooling system. To be an efficient retrofitting procedure, the system must be easy to assemble, to operate, and architecturally appealing for prospective buyers. Therefore, the chimney flue space is re-used to allow heating system pipes to pass through and to provide passive cooling measure during summer.

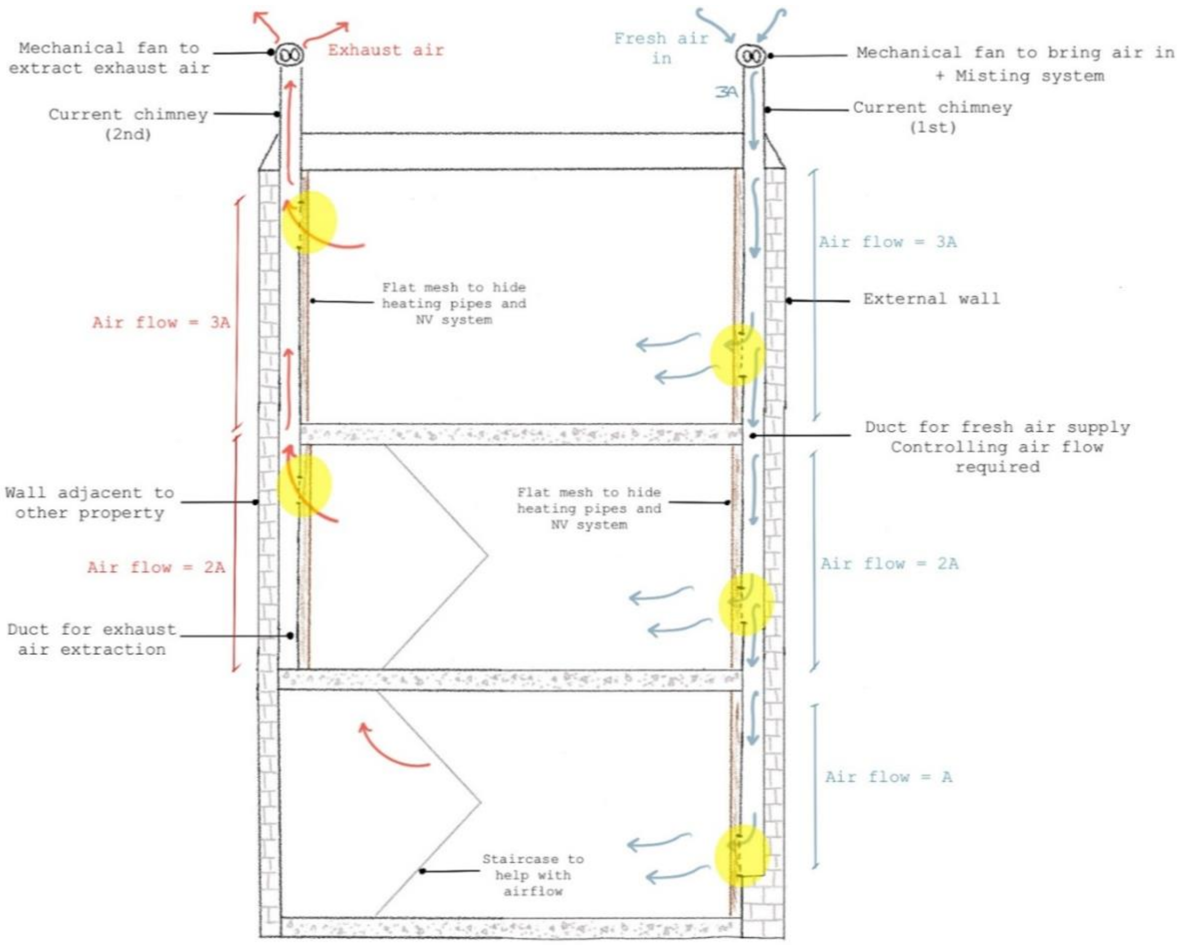


Figure 1. Design proposal for chimney retrofitting

The mesh and modular units are designed to be flat, minimising the reduction in usable floor area. The mesh engineered to act as a cover of the heating and ventilation system was developed around the interlacing pattern of typical handcraft Sardinian baskets and carpets. For air supply, an openable vent is positioned at the lower part of the mesh to control incoming NV airflow from the airducts installed in the flue, while another vent at the top of the opposite chimney facilitates the exhaust air extraction. These vents are highlighted in yellow in the sketch in Figure 1 and are designed to allow an air flow equal to A at each level.

Moreover, the use of two mechanical fans (positioned at the top of each chimney cap) assists in bringing fresh air into the house. Starting with an airflow of 3A passing through the chimney flue, to gradually decrease to 2A and A, ensuring a constant supply of fresh air (A). The same principle is applied in reverse for the extraction of the exhaust air through the mesh modular units.

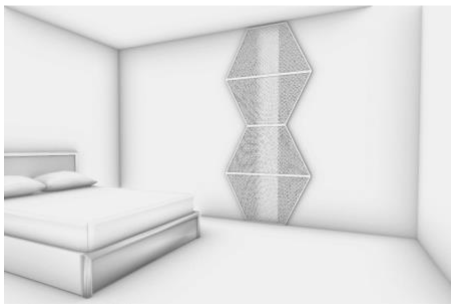
A misting system is also installed at the top of the chimney flue, just above the supply air fan. This strategic position enables evaporative cooling, which helps reducing the temperature of the incoming air before entering the house. In terms of installation, the small water pipe needed for the misting system runs through the original chimney flue. In terms of operation and control of the system, both the fan and misting system can be controlled via dedicated switch at each room level.

The flat modular mesh extends along the full ceiling height of the room, resulting in an architecturally pleasing and decorative element that hides the assisted NV system and heating pipes, while being easily accessible for maintenance.

2.2. Construction Sequence

Each unit is design to be approximately 65cm tall, for a symmetric layout across the full height of the room. The mesh frame rests on the floor and it is additionally secured to the wall via bolts at each horizontal junction with the above unit. In terms of materiality, both the frame and the mesh itself are made of wrought iron, which is locally produced. This choice helps promoting local economy, while reducing manufacturing and transportation costs.

Table 1. Summary of chimney construction sequence

Step 1 – Installation of heating pipes for radiator system, electricity pipes for general house electric current, PV panels and fan system, and water pipes. The 400mm chimney hole ensures easy installation and access for future maintenance of the system.	
Step 2 – Positioning and assembly of the air duct units inside the chimney flue. The space available after piping installation in Step 1 still ensures easy installation and access for future maintenance.	
Step 3 – Adding cellulose insulation around to thermally seal the remaining wall gap and reduce risk of infiltration coming from the chimney flue. This is also easy to remove if maintenance is needed.	
Step 4 – Installation of the mesh modular frame to cover the chimney flue, while allowing for NV system and accessible maintenance to the piping system.	

3. Energy and Thermal Performance: Design Builder Simulations

The proposed HVAC for the house consists of natural gas radiator heating system with boiler for hot water and NV (based on the chimney design) as passive cooling strategy. The improved thermal envelope of the model, Table 2, was used to test the running costs of the house and evaluate the impact of each intervention on the energy savings. This approach helps to identify which retrofitting intervention will provide the most significant benefits in terms of costs and comfort. The iterations are numbered and summarised in Table 3.

Table 2. Thermal envelope of the chosen one-euro house

	Original U – value (W/m2K)	**Improved U – value (W/m2K)**	**Target U – value (W/m2K)**
External wall	2.64	0.28	0.28
Roof	1.97	0.24	0.24
Ground Floor	1.21	0.29	0.29
Window	5.78	1.49	1.40
Airtightness	11.50 ach@50Pa	5 ach@50Pa	3 ach@50Pa LETI Guide)

Table 3. Design Builder iterations (the highlighted columns represent the final retrofitted model tested)

A.1	***A.2***	***A.3***	***A.4***	***A.5***	***A.6***	***A.7***	***A.8***	***A.7.1***	***A.7.2***	***A.7.3***
Baseline: Natural gas radiator+ boiler HW + NV	Adding double clear 6mm/13mm Argon glazing	Changing to LED lights	Improving airtightness to 5ach at 50Pa	Adding 140mm cork roof insulation	Adding 100mm cork GF insulation	Adding 120mm cellulose wall insulation	Adding 40mm cellulose and 80mm TIP wall insulation	Adding PV panels with storage	Adding PV with no storage	Adding solar collector

The graph in Figure 2 shows two significant jumps regarding annual energy consumption. The first in A.4, where the airtightness of the house is improved, ensuring it is well-sealed with minimal infiltration. The second jump is in A.7, where 120mm internal cellulose insulation was added to the granite walls. This reduction in usable floor area is necessary to meet the thermal comfort requirements and to lower energy costs. From A.7 simulation, the test results were further improved with the integration of renewable energy sources: PV panels and solar collectors. Both contribute to improve the energy class of the house, in the energy class calculation, and to lower the annual electricity costs. With the interventions outlined in Table 3, the total house energy consumption is more than 4 times lower than original value: decreasing from 626 kWh/m^2 per year to 150 kWh/m^2 per year.

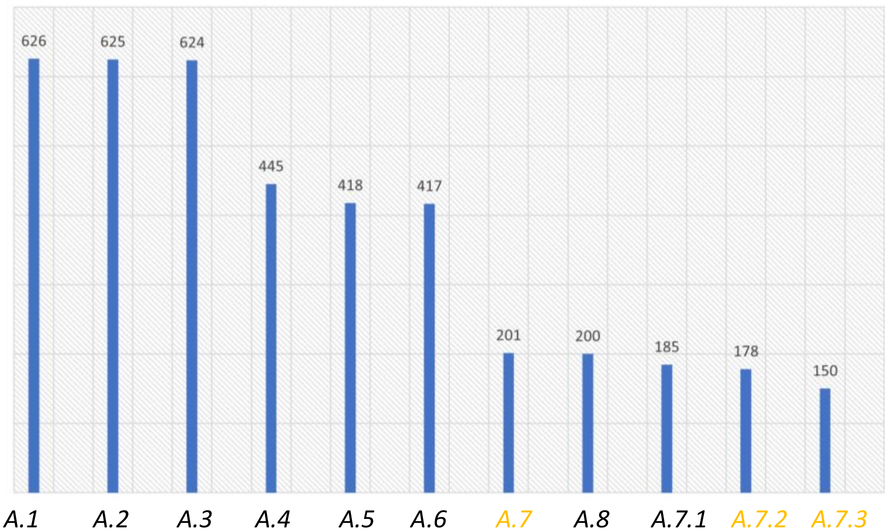


Figure 2. Total energy usage in kWh/m^2 per year with radiators + HW boiler + chimney for NV The graph in

Figure 3 provides an evaluation of the impact of each simulation conducted in Design Builder. To plot this graph, the difference in annual energy consumption ($\Delta Energy$ in kWh/year) between each iteration was calculated. This value represents the potential energy savings associated with each thermal improvement.

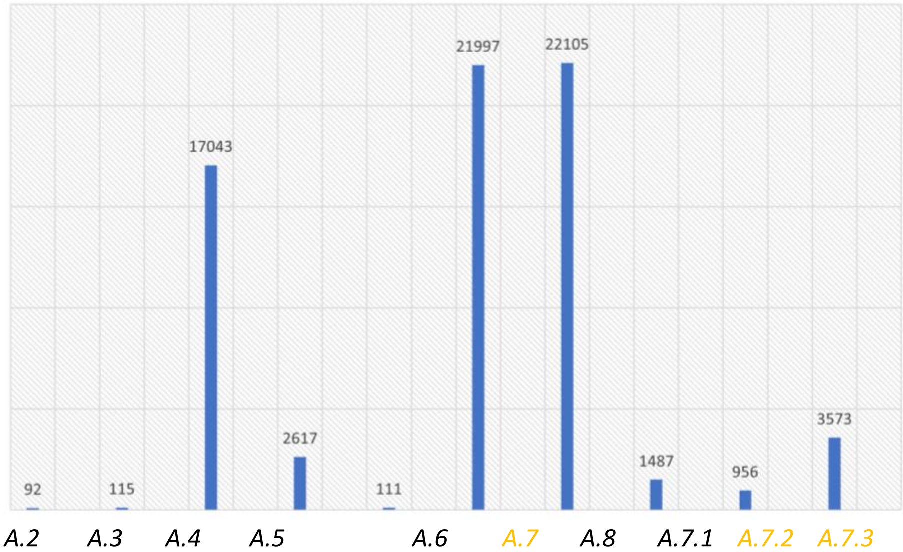


Figure 3. ΔEnergy in kWh/year between each iteration

3.1. Housing Market Assessment

A market analysis of properties available in Ollolai *(idealista.it; Immobiliare.it),* including a house with no need to be retrofitted and one requiring renovation works, was carried out to compare it with the purchase and retrofitting process of a one-euro house. This research provides insights into the potential financial benefits of investing in 1€ houses, particularly when evaluated over a 10-year period.

<u>Scanario 1</u>

Table 4. Housing Market Scenario 1

House A (in the Ollolai market) – to be retrofitted	**1€ House**
No heating system and Energy Class not available Average Market Price = 500 €/sqm Assuming same size as 1€ house = 500*88 = **€ 44,000**	88 sqm *For a better comparison, it is assumed that the same Total Figure spent for House A is also spent for the retrofitting of the one-euro house.*
Assuming standard renovation works = 800 €/sqm = 800*88 = **€ 70,400** TOTAL = 44,000 + 70,400 = **€ 114,400**	A budget equal to the total spent for House A is assumed = **€ 114,400** **€/sqm** available for retrofitting = 114,400 / 88 = **1,300**

However, under suggestion of *Abis Associati Studio (Cagliari)* it is good practice to assume a budget cost of 1000 €/sqm for the renovation works of a one-euro house. Therefore, considering the results in Table 4, € 26,400 can be saved or available for further enhancement of the house: $1300€/m^2 - 1000€/m^2 = 300€/m^2 * 88\ m^2 = €\ 26{,}400$.

<u>Scanario 2</u>

As no renovation works are needed for House B, the yearly running costs of the property are considered in addition to its market price. Although the final figure in Table 5 can be considered high for the retrofitting of a one-euro house, it highlights the potential these properties can offer when compared to the purchase of conventional houses on the market. In practice, most buyers are expected to spend significantly less than this amount, with the additional opportunity to customise the renovation works according to their personal needs and guided by the findings in Figure 3.

Table 5. Housing Market Scenario 2 (considering energy cost of €0.2 per kWh)

House B (in the market) – no retrofitting needed	**1€ House**
Working heating system and Energy Class G Average Market Price = 700 €/sqm Assuming same size as 1€ house = 700*88 = **€ 61,600**	88 sqm *For a better comparison, it is assumed that the same Total Figure spent for House B is also spent for the retrofitting of the one-euro house.*
Running costs = from A.1 simulation = 59,761 kWh/year * € 0.2 * 10 years = **€ 119,522**	Running costs = from A.7.3 simulation = 13,257kWh * € 0.2 * 10 years = **€ 26,514**
Renovation works = **0 €/sqm** TOTAL = 119,522 + 61,600 = **€ 181,122** over 10 years	A budget equal to the total spent for House B is assumed = **€ 181,122** **€/sqm** available for retrofitting = 181,122 – 26,514 = 154,608 / 88sqm = **1,757 €/sqm**

4. Conclusion

Overall, in both Scenario 1 and Scenario 2, the financial benefits for prospective buyers of a 1€ house are clear. Beyond its lower purchase price and running costs, the 1€ house initiative aims to a greater cultural purpose: preserving local architecture and protecting small towns from losing their identity. Such investment also helps contrasting depopulation and stimulate local economies by promoting locally sourced materials and industries during the retrofitting process. Moreover, in the near future, the European Union intends to introduce new regulations which will set a minimum energy class requirement for properties to be sold.

As a result, my research aims to serve as a practical tool to better understand the renovation works required in a one-euro house and support local authorities in promoting these properties over traditional housing options.

5. Reference

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