Deep energy retrofit of vernacular housing


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An existing ruin of a vernacular house located in a rural area of Portugal is being renovated, aiming for architectural identity preservation and low environmental impact, to offer suitable comfort conditions for tourism exploitation. Calculated global energy consumption reduction is 94% of the calculated current energy use of the building

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Figure 1. Country house southeast and southwest facades.

Much has been done over the last decades regarding the improvement of energy performance in buildings and sustainable construction [1]. Nevertheless, for the case of existing buildings, the constraints are very relevant [2], not only for technical reasons, but also because of the risk of compromising significantly the identity of the building. In these cases, the technical and identity qualities should be carefully weighed with all the possible measures being evaluated from both perspectives.

Taking advantage of the recent growth in tourism activities in rural regions of the north of Portugal, the renovation potential of a traditional abandoned house has been analyzed to be used for sustainable tourism activities [3]. It aims at providing accommodation with sustainability principles, which means optimal use of environmental resources, respect and interaction with the host communities and viable, long-term economic operations providing fairly distributed socio-economic benefits to all stakeholders.

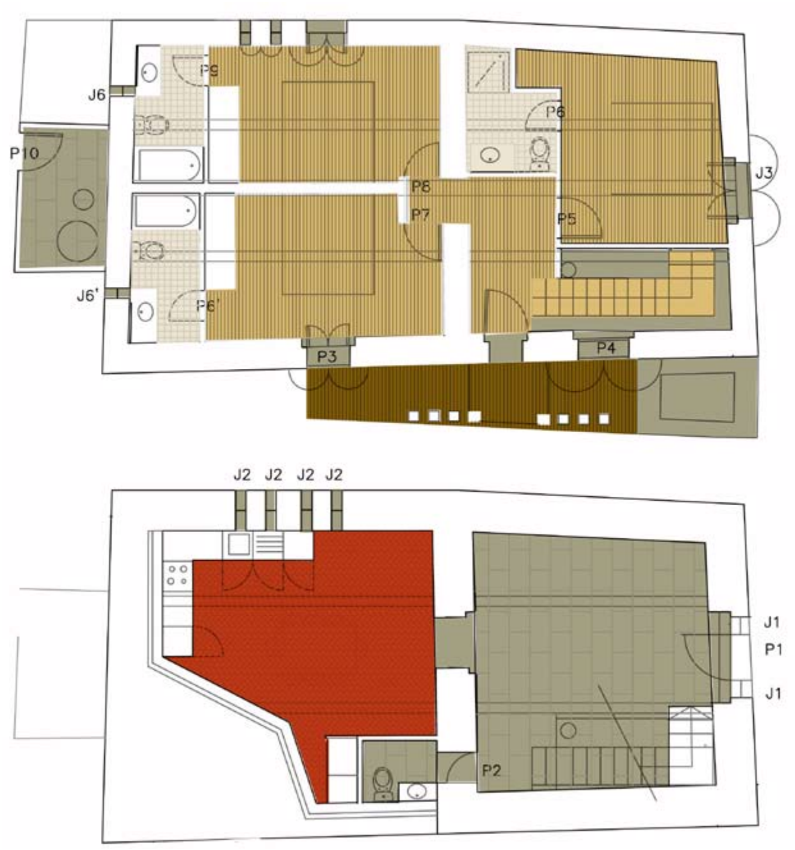


Figure 2. Upper (above) and lower (below) architecture plans of the retrofitted house.

The house was originally built in 1940 with traditional vernacular principles (**Figure 1**), presenting uninsulated granite stone walls, wood structure floors and roof, ground floor in direct contact with soil (animal shelter) and single glazed windows with wooden frames. The external walls are massive but they are loosely arranged in some areas in need of structural reinforcement.

It is located in a small rural village in the hills of Peneda, at an altitude of 726 m above sea level and the local climate presents 2 770 heating degree days for a reference temperature of 20°C. The house is not served by any support system, including lighting, water supply and sewerage. There is no electricity or phone access and heating, during the time it was habited, was provided by a fireplace which was also used for cooking.

Its current state is almost of ruin, severely degraded in its wooden elements, lacking windows in some places and affected by rot and moisture. Inside temperatures closely follow exterior variations and chilled air drafts are frequent. Moisture deterioration is present in wood structures, both in floors and roof, and also through leakage and condensation on walls.

Objective

The building has a strong architectural image, very much linked with the traditional life style and architecture of the region, but without suitable comfort conditions it will not attract visitors.

The global intention of the renovation is therefore to provide that comfort, at a minimum energy and resource expenditure, according to construction sustainability principles, while maintaining the building's identity and historical features (**Figure 2**). Understand the potential of retrofitting in vernacular construction may be an important contribution to promote other eco-tourism projects.

The renovation works are planned to be completed before the end of 2014.

Methods

In order to reduce the impacts of renovation measures, sustainable retrofitting actions have been considered. New construction was avoided to reduce the environmental impact and preserve the vernacular materials and principles, local based materials and others derived from wood wastes (MDF and OSB panels) were chosen due to its low embodied energy, as well as concrete bricks (which are less energy intensive than ceramic bricks) and lime base mortar. In **Figure 3** the relevance of materials selection in reduction of embodied energy and environmental impacts is shown. To improve the energy performance of the building envelope, cork insulation boards have been used. In the building integrated technical systems priority was given to the use of renewable energy sources.

Energy renovation features

The main principles of the energy saving concept were limiting the heat losses during winter, use energy efficient heating equipment and take advantage of the sunlight to capture the thermal energy.

In order to prevent the energy losses during winter, different solutions were chosen to upgrade the building envelope, relevant not only to improve the energy performance but also to improve the thermal comfort.

The solution chosen for the walls was the creation of an interior closed air space and the placement of insulation cork boards (ICB) covered by light elements such as MDF boards over a wooden support. This solution allows maintaining the existing materials and avoids new construction while preserving the external architectural identity of the building.

For the roof, the solution was to create a wooden false ceiling, with structural oriented strand boards (OSB), placement of ICB insulation and a water tight covering.

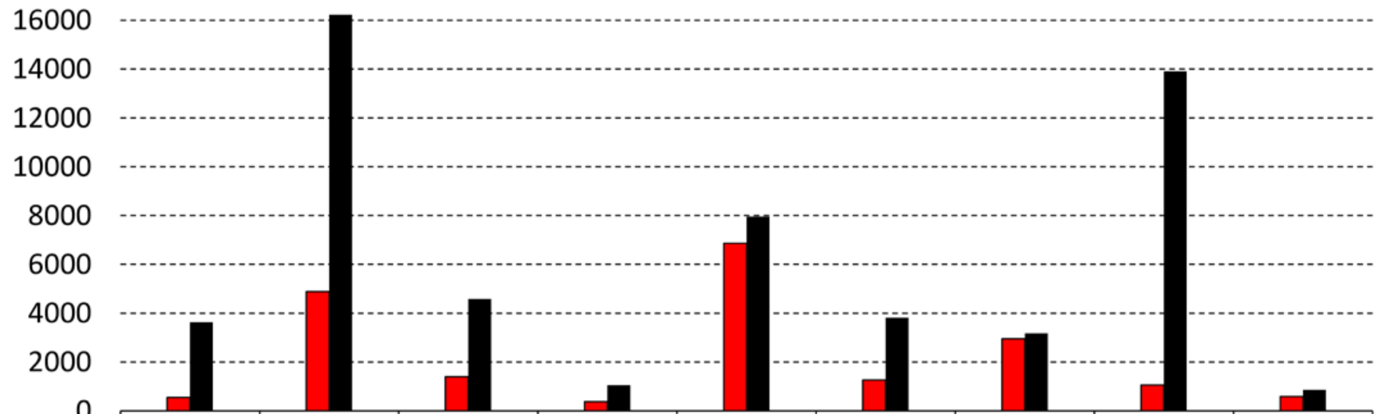
For the windows, the solution consisted in replacing the existing ones by new ones with wooden frames and double glazing (4 + 6 mm) with a 16 mm air cavity between the glasses.

The building is equipped with mechanical systems for heating, air extraction in sanitary installations, air insufflation in main areas and centralized DHW generation. No mechanical system for cooling is provided due to the small area of glazing, low thermal transmission of exterior opaque elements (after rehabilitation) and the guarantee of a significant indoor thermal inertia. In this case, and given the mild summer climate of the region, natural ventilation and rational use of shutters shading are enough to achieve indoor summer comfort, both day and night.

The system for space heating and DHW is a 16 kW geothermal heat pump with its main features described in **Table 1**. Its primary circuit is placed in contact with the underground water level in open operating mode. It includes a weather compensated digital heat pump control unit RVS 61 with integrated cooling control function "passive cooling".

Table 1. Geothermal heat pump main features.

Heating capacity	15.71 kW
Input	3.49 kW
COP	4.5
Flow temperature maximal	+55°C
Refrigerant	R407c
Compressor (count)	Copeland SCROLL (1)
Voltage	3 x 400 V / 50 Hz



Kg CO_2 eq.	Windows and doors	Structure	Nonstructural suports	Paints and varnishes	Cladding	Plaster and mortar	Water proofing screens	Insulation	Bricks and Blocks
Current solution	3631	16233	4588	1049	7953	3815	3177	13917	859
Alternative solution	546	4881	1400	376	6862	1265	2950	1062	586

Figure 3. Embodied CO_2eq. amount for current (materials currently used in building renovation in Portugal) and alternative material selection (materials selected for this renovation project to reduce embodied energy and environmental impacts).

For heating, the emission is provided by radiators. For DHW, the main power supply is the thermal solar system with three solar panels connected in series with a total area of 6.78 m² and connected to a 300 litre electric storage tank that also receives the water heated by the geothermal heat pump. The solar panels are installed with a 35° inclination facing south and the annual expected contribution of solar thermal energy is 4.2 MWh/y which accounts for 69% of the total energy needs for DHW.

Mechanical ventilation with a heat recover box with 91% efficiency, guarantees fresh air supply and exhaustion to all spaces, with insufflation provided through the rooms, living room and kitchen and extraction through bathrooms and entrance. The totality of the extracted air is guided to the heat recover box, with its main features described in **Table 2**.

It is a compact unit, vertical, leaning on the pavement. Heat exchange is accomplished through a counterflow plates recuperator, wherein there is no contact with the insufflated air against extracted air. Given the configuration of the HVAC system design, the equipment will not be provided with battery for heat or cold transmission, carrying only ventilation and heat recovery above described. It will bypass the heat exchange to enable free-cooling, and will have integrated control and condensate tray. Ventilation will be performed using filtering with F5 quality for insufflation and extraction.

Lighting will be assured by fluorescent and LED based lamps.

In brief, the adopted energy renovation features are the following:

Technologies:

- Interior insulation cork board
- Wooden framed double glass windows
- Mechanical ventilation with heat recovery
- Geothermal heat pump
- Thermal solar panels (for DHW)

Systems:

- Heating and DHW: 16 kW geothermal heat pump
- Cooling: Natural ventilation and wooden shutters on windows
- Ventilation: Heat recovery box with 91% efficiency. Fresh air supply and exhaustion of all spaces
- Lighting: Up to date fluorescent and LED based lighting

Renewable Energy Systems:

- Thermal solar panels for DHW preparation

Table 2. Heat recover box main features.

Model	Power Box 95 V700 / France Air
Air insufflation	620 m³/h; 180 Pa; 355 W
Air extraction	530 m³/h; 250 Pa; 355 W
Efficiency	Up to 91%

Table 3. Thermal characterization of the building before and after the renovation.

Element	Area (m²)	U-value before renovation (W/m².°C)	U-value after renovation (W/m².°C)
Exterior Walls	85.0	1.82	0.45 (average)
Ground floor	54.0	Direct contact with soil	0.50 (average)
Roof	80.4	4.55	0.23
Doors	3.0	2.70	0.81
Windows	7.8	4.60	2.05

Regarding the thermal quality of the envelope, comparing the U-values proposed for the renovation (**Table 3**) with the reference values from the recently published building thermal regulation (D.L. n.° 118/2013 from 20th of August), only for the case of the external walls the proposed values are above the reference (0.45 for the case study and 0.35 in regulation for new buildings), with all the other building elements under the reference and well under the maximum allowed values.

Impact of the retrofitting

With the chosen renovation solution there are significant comfort improvements. Regarding the energy performance of the building, only the calculated values of the energy needs are possible to present once the original building didn't have non-renewable energy consumption and wasn't able to provide comparable thermal comfort conditions. Therefore, the calculated heating needs are reduced in 74%, the cooling needs in 14% and the DHW needs in approximately 95%. **Table 4** summarizes the impact of the retrofitting measures on the heating, cooling and DHW needs including the contribution of the solar thermal panels. The table also presents the energy label.

In Portugal, the energy certification scheme ranks the energy performance of buildings from level G to level A+, where G is the less efficient. The A+ label means that the calculated primary energy needs are less than 25% of the maximum allowed value.

Overall improvements

The renovation intervention will allow providing the necessary comfort for tourism accommodations in all the seasons of the year, providing an indoor climate absence of drafts, condensation phenomena and assuring the control of the users over the indoor temperatures.

On a broader level, an intervention driven with these sustainable construction principles is always good for the local economy. Tourists enjoying nature can be housed enjoying comfortable conditions with minimum environmental impact, leading to further attraction of more tourists with interest in eco-tourism and as consequence it helps to develop the local economy. Furthermore, these broader economic benefits may also result as a trigger for more retrofitting of local vernacular buildings.

Table 4. Summary of the energy renovation impact.

		Before renovation	After renovation
Energy needs ($kWh/m^2.y$)	Heating	477.9	123.8
	Cooling	12.1	10.4
	DHW	54.8	3.0
	Reduction	-	75%
Energy label		F	A+
Primary energy use*		543.1	34.35
Primary energy use reduction		-	94%

* Calculated primary energy use considering the use of most common electrical building integrated systems, for heating, cooling and DHW, in Portugal.

Barriers

The implementation of energy renovation projects in the building sector is not just a technical matter. It involves the economical context, lack or misleading information to the decision maker and sometimes ownership issues with different persons paying the investment and saving from the better energy performance (split incentives).

Energy renovation projects often run into barriers that may hold up the project. It is then necessary that owners, technical consultants and other entities involved in the process find solutions to overcome these barriers.

The main barriers in this case were related with the bureaucracy for obtaining the building permit, finding funding sources for the renovation works and some miss information between owners and technical consultants.

The bureaucracy for obtaining the construction permit from the municipality and national tourism entities is still a time consuming process that causes delays and doubts for project planning.

The details of a deep energy retrofit usually carry extra costs, which are not always well understood by the owners. Strong commitment between the owners and technical consultants is crucial for finding the best possible solution within an affordable budget, considering not only the investment costs but taking into account a life cycle costs perspective.

Conclusions

The offer of comfort conditions for tourism exploitation, with architectural preservation and low environmental impact, were the main driving forces for the development of this project.

The global energy consumption reduction reaches 94% when compared to the hypothetical use of the house, on its current state. Even for building renovation, the materials selection might have significant relevance for reducing embodied energy and environmental impacts.

Although the definition for nearly zero energy buildings is not completely established in Portugal, current case study shows that it is possible, even for existing buildings located in the coldest areas of the country, and taking into account the preservation of architectural values, to renovate towards very low energy use using existing technologies, with significant emphasis to the HVAC system solutions. ■

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