Residential building upgrade in Montarroio

Project summary:

Energy concept
This project assumes that well designed and constructed buildings were able to provide comfort to their users in a time when fossil fuels were not easily available. "Learning from Traditional Knowledge towards Engaged Inhabiting" (Brito et al., 2014), it is proposed that users and buildings are teams that must interact to better use the walls inertia and openings as “thermal wheels” to shift thermal loads. Acknowledging that contemporary occupation patterns vary, the building/user team is reunited using ICT management aid and solar thermal panels to provide for 85% of hot water and acclimatization needs.

A XIVth-XVIth century residential building will soon achieve the “nearly Zero Energy Building” (nZEB) standard, the minimum requirement for new buildings in 2020.

Background for the renovation – reasons
An ancient residential building located in historical centre of Coimbra, recently recognized as UNESCO Heritage area, was studied (Brito et al., 2014) and intervention options proposed having in mind that:
• this almost derelict ancient residential building represents hundreds of similar homes in Coimbra and millions across Europe, that resisted to centuries of weather and use, and are now menaced by one-dimensional (energy efficiency) renovation perspectives;
• energy efficacy can only be achieved by multidimensional approaches based on a thorough assessment of what ancient building were designed to provide, and what is now required from them;
• renewable energy and ICT can bridge the gap between what we have and know / want and expect and uphold good comfort conditions and Quality of Life with minimum primary energy needs.
This study demonstrates that demolition /reconstruction strategies are too expensive, financially and environmentally, and that the best solutions for similar climates may also be the easiest to implement.

The collective insights from the commonly developed IEA EBC Annex 56 methodology together with findings from the ongoing Ph.D. thesis on “Upgrade Opportunities for ancient buildings in city centers” are used to visualize the options and emphasize key topics for informed decision processes.

Site: Travessa de Montarroio, 2, 3000-288 Coimbra, Portugal
Altitude: 50m
Heating degree days: 1287 Kd
Cooling degree days:
Owner: Nelson da Silva Brito
Architect: modular, arq:i+d, lda

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Important dates:
Bought in 2009; initial proposals in 2012; ongoing contacts with city hall and monuments representatives.

Date completed: Expected in 2015

Building description/tipology
Ancient residential building located in Coimbra, Portugal, with strong restrictions imposed by its location facing “Jardim da Manga” National Monument, and the UNESCO protection area.
Total site area: 22 m²
Useful heated area: 36 m², potential 46 m²

Figure 1: Panorama view of the Montarroio case study and surroundings (source: author)
Building envelope, heating, cooling, ventilation and lighting systems before the energy renovation

Description of building
(building situation, building system, renovation needs and options)

The Montarroio street and its buildings are already reported in the XIVth century, while the higher level stone-embellished window and a chimney portray XVIth century exterior signs of comfort (Trindade, 2002).

It still stands in the ancient city centre of Coimbra, within the UNESCO “University of Coimbra –Alta and Sofia” (UNESCO, 2013) and “Jardim da Manga” National Monument (Figure 2) protection areas.

Building envelope before renovation

Stacked masonry walls provide peripheral support to wooden floor levels and ceilings, under ceramic roof tiles on a wood structure. Wood doors and simple glazing sash windows with interior shutters exist, with high infiltration due to lack of maintenance. The walls’ thickness reduces towards the upper levels, with growing internal areas:
• 13,7 m² (p00) in a semi-buried level with separate entrance,
• 15,3 m² (p01) on the intermediate level and
• 20,7 m² on the top level (p02).
Only 36 m² are inhabitable, as level (p00) suffers from severe humidity issues.

Due to its location, energy efficiency improvement strategies are limited: street width and fire risk hamper exterior insulation approaches, while small useful areas make interior insulation inadequate and large size equipments hard to conciliate. Architectonic constraints impose limitations on solar panels and exterior heat pump units, aggravated by the noise risk from close proximity to the neighbours.

Heating, Cooling, DHW, Ventilation and Lighting systems before renovation

Like in all neighbouring buildings, heating is achieved using electric resistance heaters (erh) converting electricity into heat through Joule effect.

Due to the high inertia of the building, cooling in not needed on the original constructions, although more recent top level extensions may require cooling devices.

Domestic Hot Water (DHW) is provided by electric storage heaters or small scale gas-based devices, using bottled gas.

Incandescent lights are still around, but will progressively be changed to low consumption alternatives when replaced.

Like in all the neighbouring buildings, natural ventilation is the current solution, with occasional occurrence of bathroom extractors.

<table>
<thead>
<tr>
<th>Element</th>
<th>Area m²</th>
<th>U-Value before renovation W/m²K</th>
<th>U-Value after renovation W/m²K</th>
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<td>Façade</td>
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<td>2.04 (avg)</td>
<td>2.04 (avg)</td>
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<td>Ceiling</td>
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<td>1.57</td>
<td>0.44</td>
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<td>Windows, doors</td>
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<td>3.22</td>
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<tr>
<td>Lower floor</td>
<td>15,6</td>
<td>1.41</td>
<td>0.4</td>
</tr>
</tbody>
</table>
Energy renovation options and technologies

Energy saving options

The Montarroio Detailed Case Study (Brito, 2015a) compiles the evaluation of five alternatives for the renovation of ancient buildings in Historic Centres, including demolition and reconstruction. To compare a wide range of strategies and renovation perspectives, some of the studied options are briefly described:

- **Opt.0** _Reference Case_: The building “as it is”, with non-energy renovation works necessary to render it inhabitable (see Anyway Measures), including the necessary equipments maintenance and/or replacement;

- **Opt.1** _Common “rehabilitation”_: Current neighbourhood practices include double glazing windows, interior insulation under plasterboard (hiding decay), and equipments maintenance and/or replacement;

- **Opt.2** _Demolition & Reconstruction_: Exterior shell/image kept, increased useful space and new construction techniques and compliance, and equipments maintenance and/or replacement;

- **Opt.3** _Upgrade without extension_: Detailed assessment to optimize the building characteristics to achieve efficacy with users. Single glazing kept, insulation only in top and bottom limits, thick walls used for thermal storage. Solar thermal heating and DHW require primary energy only for backup;

- **Opt.4** _Upgrade with extension_: Structural seismic reinforcement of “Opt.3” made financially viable by upwards area extension (IEA A50, 2011): safer users and investment, space for a small family and city centre densification.

**Building Integrated Technical Systems (BITS) options**

A large number of equipments and energy sources are available, but privilege was given to contrast commonly used solutions and available innovations. BITS options are denoted by suffix notations: “bio” for biomass; “erh” for electric resistance heater; “hp” for heat pump; “gas” for gas combustion; “st” for solar thermal, and conjunctions like “st-erh”, when backup is provided by electricity.
Achieved energy savings, CO₂ reductions and costs: informed choices

The graphs show the Initial Investment Costs (IIC) per square meter of renovation area, the value the owner pays upfront, and the Life Cycle Costs (LCC), a value comprising the IIC, the equipments maintenance / replacement (each 15 years) and the energy costs during 30 years, divided by 30 to simulate as if it was paid annually: LCC is a strong indicator of real costs of ownership and use.

Comparing both graphs demonstrates that higher IIC in efficient equipment is, most of the times, favourable on the long term LCC. The reduction of primary energy consumption seems obvious by comparison, but other conclusions emerge when tackling the LCIA analysis, on Figure 6.

Choosing options considering the baseline scenario (Ref.Case) costs of 217 €/sqm.

For a similar level of comfort the relevant energy-related renovation options are:

- **Opt.0_hp**: small investment with heat pump for relevant energy consumption reductions (276 €/sqm);
- **Opt.1_hp**: higher investment with smaller energy consumption, but reduced useful areas (474 €/sqm);
- **Opt.2_hp**: significant energy reduction, but beyond the budget and a bad investment (873 €/sqm);
- **Opt.3_st-erh**: "nearly Zero Energy Building" (nZEB) level for a very low added cost (332 €/sqm);
- **Opt.4_st-erh**: more useful area and nZEB level are a good investment on that location (408 €/sqm).

Cross-comparing graphics:

It is interesting to observe each of the options in the three proposed graphs:

- **Initial investment Costs (IIC)** gives a strong impression on the upfront investment;
- **Life Cycle Costs (LCC)** illustrates real costs in a 30 year period that include costs like monthly bills, equipment maintenance and replacement;
- **Global Warming Potential (GWP)** illustrates the overall long term impacts on environment.

Figure 6: Environmental impacts comparison. The reference case (Opt.0_erh, black circle) illustrates the current situation. The less expensive solution (Opt.0_hp, grey circle) has significant impact, but does not reach nZEB levels.
Chosen option overall improvements

The owners preferred solution is “Opt.4_st-bio_Upgrade with extension”, achieving “nearly Zero Energy Building” (nZEB) levels with very low energy consumption: this is not the least expensive cost-optimal choice (Opt.3_st-ehr), but paying around 450 €/sqm for structural reinforcement towards increased seismic safety for users/investment and added floor area (10sqm) would make this a good investment in this location, or in other similar areas. The extension allows for a small city apartment in a central area, with the comfort of a wooden stove for heating and cooking in the winter.

Energy benefits: from “D” to “A+”

The winter-needs dimensioned solar thermal panels provide for the majority of heat necessary for domestic hot water and acclimatization throughout the day, stored in tanks and high inertia walls, and discharged in the night period. Excess heat production is channelled to a small adsorption unit to produce ice at night for cooling needs, or other domestic uses. Highlights are:

- **Reduced energy needs:** from (calculated) 214 to 135 kWh/m².a (-40%);
- **Solar thermal (7sqm) and biomass:** 95% reduction, only 13 kWh/m².a

Economics

Renovation interventions for less then 450€/sqm (Opt.4) or less then 340€/sqm (Opt.3) demonstrate that significant cost reductions can be achieved if a proper assessment is made on the existing buildings characteristics, their users’ habits and expected needs. Although currently these assessment costs are high, published information (Brito et al., 2014a) shows that such costs can be lowered to feasible values.

Decision process – barriers overcome

The IEA EBC Annex 56 methodology, commonly developed during the evolution of this process, was important on two main levels:

- **Helping to evaluate parameters like IIC and LCC**, and their cross-connected implications allowed for a better planning;
- **Providing means to visualize options to municipal stakeholders**, thus helping them to understand the individual and collective implications.

Non-energy benefits

After completion, Opt.4 will be able to provide other non-energy benefits:

**Material benefits**

Increased seismic safety, energy performance and more area (from 36 to 46sqm) increase the value of the building, and potential rent value;

**Immaterial benefits**

By keeping and upholding Traditional Knowledge for a valuable cost, this strategy refrains renovations that completely demolish the buildings and keep only the outer shell: although sometimes necessary, most of the times stakeholders just don’t know better.

By fostering Traditional Knowledge maintenance habits and materials that kept this building alive for more than 700 years, this strategy preserves knowledge, professions and the resurgence of (old) new jobs.

Alternative renovation processes allow for new insights on collective energy efficacy, and Energy Service Companies (ESCO’s) role to foster them (Brito 2015b).

**Neighbourhood benefits**

By renovating towards nZEB goals, the neighbouring owners can realize about the potential of their buildings, and engage in their renovation;

By fostering maintenance practices, local jobs are encouraged.
Summary

An ancient building located in the highly restricted UNESCO area of Coimbra city centre is used to depict several intervention options, and the IEA EBC Annex 56 methodology used to visualize their costs, economic and environmental.
This “shinning example” demonstrates that a detailed assessment of the existing conditions can help overcome generic misconceptions, and significantly reduce intervention costs.
The Traditional Knowledge embedded in ancient constructive solutions (Brito et al., 2014c), single glazing thermal behaviour enhancement strategies (Historic Scotland, 2010) and current building use patterns can be intertwined with ICT to create new opportunities for lower cost intervention alternatives.

Acknowledgements

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References


Figure 9: An image of Montarroio Case Study from “Jardim da Manga National Monument, illustrating that several perspectives must be intertwined in order to achieve energy efficacy in ancient Historic Centres reuse and densification.