Articles

Towards nZEB buildings: a historical building case study

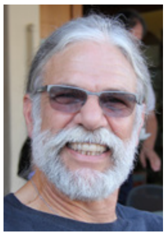
The recast of EU Directive 2010/31 introduced the concept of (nearly) zero energy building (NZEB). In Italy this challenge is remarkable: existing buildings stock (mainly residential) is also historic, so it's subject to environmental constraints or architectural-artistic value. A case study of a radical refurbishment with NZEB as target is Ca' S. Orsola in Treviso.

TIZIANO DALLA MORA
Department of Design and Planning in Complex Environments, University IUAV of Venezia, Italy
tiziano.dallamora@iuav.it

FRANCESCA CAPPELLETTI
Department of Design and Planning in Complex Environments, University IUAV of Venezia, Italy
francesca.cappelletti@iuav.it

FABIO PERON
Department of Design and Planning in Complex Environments, University IUAV of Venezia, Italy
fabio.peron@iuav.it

PIERCARLO ROMAGNONI
Department of Design and Planning in Complex Environments, University IUAV of Venezia, Italy
pierca@iuav.it



FRED BAUMAN
Center for Build Environment
University of California, Berkeley, California, USA
fbauman@berkeley.edu

Keywords: energy renovation, historical building, refurbishment, energy savings.

The case study

As it happens in several Italian cities, the downtown of Treviso, in North East of Italy, is characterized by the presence of historical buildings. Ca' S. Orsola building is a typical example: the building is located very close to the city Cathedral. Originally it was a convent: it was the old seat of Polish Institute of the Orsoline Sisters. Now it is a building listed by Historical and Architectural Heritage Superintendence of Veneto Region.

The building was inhabited until 2000 and during the time it keep intact the original structure and architectural distribution. Then it was bought in 2007 for acting a deeply renovation and converting it in a prestigious residential building; this renovation has been completed in 2012. The whole building (**Figure 1**) is a gross volume of 6 300 m³ and an area of 4 500 m².

At the beginning of construction phase the structure revealed a quite ruined state of conservation: walls are crooked and presented different solutions, moisture affected wooden elements in the floors and in the roof. There was a heritage architectural restriction about the external envelope. Specific goals of renovation project were:

- to achieve the A class energy classification according to Italian regulations;
- to consolidate and to reinforce the building structure;
- to improve the indoor thermal and acoustic quality;
- to transform it in a prestigious residence with all comforts.

The building refurbishment was developed with a particular regard on thermal insulation of the building envelope and special attention has been paid to the mechanical ventilation and the renewable energy utilization (both solar thermal and photovoltaic system).

The adopted requirements follow the legislative references as stated in national Italian laws before the 2012.

Before and after the renovation: the envelope and the technical systems

Building envelope before renovation presented a traditional construction system, based on bearing masonry with covered solid bricks. The floor had a wooden structure, while the ground floor leaned directly on soil. The roof is made of hollow tiles sheets with a wooden structure and a lightweight ceiling slab (**Figure 2**).

The windows frames were made of wood and the windows used to have a single glass. There is no insulation in the external walls, roof and floors (**Table 1**).

Table 1. Thermal characteristics of the building elements.

Element	Area (m^2)	U-value before renovation (W/m^2K)	U-value after renovation (W/m^2K)
Facade	1 300	0.90	0.18
Ceiling	508	1.65	0.788
Windows, doors	140	2.70	1.948 – 2.035
Roof	508	1.09	0.158

Figure 1. General view of the building before (left) and after the intervention (right).

Originally, no heating and cooling systems were installed. Heating was provided by a fireplace, also used for cooking, occasionally an electric heater or portable fan coils was placed in any room. The domestic hot water was supplied by electric heaters with storage tank; no ventilation system was present.

Energy renovation features

If we analyse this case study in terms of environmental sustainability, there are several challenges ahead. A first challenge was addressed at the level of structural consolidation then at the level of energy and indoor quality.

Technologies measures aimed to achieve an energy class as proposed by the Italian legislation before 2014; several design topics were adopted among which high insulated windows, high level of opaque walls insulation, mechanical ventilation system with heat recovery, solar thermal panels and PV systems, water to water heat pumps and chillers.

The first step has been taken the measures to consolidate the building structure. Subsequently a detailed study on thermal and acoustic bridges has been developed with the aim to improve the indoor thermal and acoustic quality.

In the external walls the insulation is placed on the inner part (**Figure 3**) and this solution meet the requirements of the Superintendence of Veneto Region, preserving the existing materials and the external architectural identity of the building. Specifically, two types of insulating are used: an expanded polystyrene (EPS) foam, placed directly on masonry, and a rigid mineral wool panel with a plasterboard cover. Roof was replaced with a new wooden structure and it was insulated with wood fibre and water tight covering. All existing windows are replaced with a low-energy double layer ones within wooden frames.

Figure 2. Building envelope before renovation: crooked walls (left), demolished partition walls left and used as a substrate (center), beam support in the perimeter wall (right).

Figure 3. Insulation on internal (left) and external walls (right).

Figure 4. Radiant system: collectors (left) and TNT underflooring above system (right).

Figure 5. Mechanical ventilation system: ducts and Heat Recovery.

About technical systems, the HVAC generation system is a water to water centralized heat pump/chiller. The underlying well is the hot/cold water source and internal comfort is achieved exploiting a radiant system (**Figure 4**) installed in the floor together with a dehumidification system for the summer period.

For heating and cooling the system adopted is a 32 kW heat pump with a distribution by radiant floor system; another heat pump (20 kW) is installed for domestic hot water requirement (DHW); mechanical ventilation (**Figure 5**) is provided by a system with heat recovery box (95% efficiency).

Table 2. Energy savings and CO_2 reduction.

Energy need		Before renovation	After renovation	Saving
Heating	kWh/m²y	342.7	42.3	88%
DHW	kWh/m²y	44.4	33.6	24%
Electricity	kWh/m²y	45.0	20.0	56%
Total	kWh/m²y	432.1	95.9	92.5%
Energy label		G	A+	
Carbon emissions	kg CO_{2Eq}/m²y	29.8	5.8	81%

Renewable energy systems have been installed after renovation: thermal solar panels for DHW production (20 m²) are located in vertical position and a photovoltaic power plant (18.85 m²) producing 3 300 kWh of total annual energy. These panels are installed on the roof and oriented to the south.

Achieved energy savings, CO_2 reductions and costs

Energy needs values before renovation have been evaluated by means of dynamic simulation: the results are showed for comparing thermal the different conditions after and before the retrofit measures. It should be stressed that values for DHW need already include the solar thermal contribution and the amount of renewable energy was zero before renovation (**Table 2**).

Construction costs of renovation (**Table 3**) exclude the costs for heating and DHW equipment, so the costs are related to the purchase of the area, charges, interest, taxes.

The contribution of renewable energy resources is given in 6.56 kWh/m²y: calculation and monitoring gives a production of about 3 300 kWh for photovoltaic system and 8 500 kWh for solar thermal.

Overall improvements

The major benefit given by renovation measures is obtained evaluating the energy saving: the energy need for heating was 432.1 kWh/m²y, including heating, DHW, ventilation systems. The interventions allowed to reduce the Energy need by 93%. The Energy class improves to G to A+.

At the same time, the indoor climate was improved due to the upgrade of the control of indoor temperature and humidity without relevant energy costs. The standard energy performance for new buildings in Italy has been achieved by several factors such as the reduction of losses through the walls insulation, roof and the installation of new window. The reduction

Table 3. Renovation costs.

Costs	EUR	EUR/m²
Craftsmen	2.94 million	1 463.41
Consultants	130 000.00	64.71
Electrical and Plumbing	700 000.00	348.43
Total construction	377 million	1 876.56
Thermal solar and PV system	32 000.00	15.92
NPV	13 Years	

of the thermal bridges allows to eliminate related condensation problems and also the mechanical ventilation is balanced with heat recovery and with a carefully adjusted supply temperature. From economic point of view, renovation of existing buildings, especially if listed, is too much expensive than standard, because it needs specialized operations and the preliminary count evaluation is upset during the construction phase. After intervention, however, market value increased for this property and also for the surrounding area: in this case study all apartments have been sold by the end of the construction phase (**Figure 6**).

About decision process during building phases, the investment costs were incurred by the contractor, that is also the owner: in this particular situation themes such as sustainability and energy retrofitting were understood and applied. The major overcome barriers were essentially related with the bureaucracy for obtaining the permission by Historical and Architectural Heritage Superintendence of Veneto.

After the retrofit intervention it's possible to underline also non-energy benefits, rather factors that can be brought back to social and economic aspects in the long term. For example, this radical renovation transformed this historic building in a prestigious


Figure 6. The residence after intervention: Courtyard from west perspective (left); Typical living room in a dwelling (right).

and comfortable residence. A better living conditions is enriched with more qualified living spaces and privacy to the occupants are ensured by a reached acoustic first class according to national standard UNI 11367. The improved structural conditions in an uninhabited and listed building implemented a seismic consolidation and an aesthetical improvement returned the identity of the original building and increased the market value.

Some remarks

The proposed renovation is aimed to redefine the indoor environmental quality with a particular attention to the energy and acoustic targets. Moreover, as requested by Italian laws, the building structures must be certified by seismic point of view.

The adopted measures for envelope and technical system, as low-e energy glasses, the high performance insulating layer, the installation of a mechanical ventilation system with heat recovery, the integration of solar panels for DHW, allowed to achieve that the apartments of the block have been certified in A Class.

Living environmental quality is assured by the use of indoor materials with low harmfulness and because of the installation of underfloor winter heating and summer cooling with humidity control. Renovation measures decreased global energy consumption, reducing up to 90%; the use of renewable (solar and photovoltaic systems) contributed to minimized energy consumption.

A prestigious location, a renovated historic building with the most innovative technical solutions made a safe and long-lasting investment. ■

Acknowledgements

Special thanks belong to:

Cazzaro Costruzioni Staff for interest in collaboration on this project.

Ing. Vincenzo Conte for sharing the necessary data about heating system.

Apartment inhabitants for cooperation during in-situ inspections and interviews.

References

[1] http://www. http://iea-annex56.org/

[2] CASA&CLIMA, n.47, "Storico, antisismico e in Classe A", pg. 36-44, Quine Business Publisher Edition, 2014.

[3] UNI 11367, Building acoustics - Acoustic classification of building units - Evaluation procedure and in situ measurements, 2010.

[4] UNI TS 11300, Energy performance of buildings. Part 1: Evaluation of energy need for space heating and cooling, 2014.

[5] UNI TS 11300, Energy performance of buildings. Part 2: Evaluation of primary energy need and of system efficiencies for space heating, domestic hot water production, ventilation and lighting for non-residential buildings, 2014.