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NZEB target for existing buildings: case study of historical educational building in Mediterranean climate

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Abstract

A key element of the Energy Performance of Building Directive 2010/31/EU is the introduction of nearly zero energy building (NZEB) standard for new constructions. However, considering the very low rate of new built volume, the major change for achieve the sustainable grow of the European economy, appears to be the renovation of existing building stock. But, is it possible to reach very low or nearly zero energy standard during refurbishment design?
Proposed paper tries to answer this question, evaluating if the refurbishment of historic architectures to very low energy need is possible and economically feasible. With reference to a case study, this paper investigates the cost-optimal energy refurbishment of a Renaissance-style palace, located in the center of Naples, South Italy.
The adopted methodology consists of various steps. Firstly, a model of the building has been accurately built and calibrated. Then, it has been used to evaluate possible interventions concerning both the envelope and the energy systems. The best solutions, chosen according to the European methodology of cost-optimality, have been combined in a last simulation. The results show that great energy savings as well as economic and environmental improvements are possible, although heritage buildings present a less flexibility in the proposal of energy efficiency measures.

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Keywords: Historical buildings; Dynamic simulation; Energy retrofit; NZEB; Cost-optimal; Calibration of energy models.

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1. Introduction: energy efficiency and historic buildings

The aim of the European Council is to reduce the greenhouse gas emissions by 80-95% by 2050, compared to levels of 1990. About it, a better construction activity and use of buildings would influence the 42% of final energy consumption and about 35% of CO_2 emissions [1].

Given the low turnover rate of the building stock, the greatest challenge is the refurbishment of the existing buildings, even more than the construction of nearly zero energy buildings; recent statistics, indeed, reveal that 14% of EU-27 building-stock dates before 1919, about 12% between 1919 and 1945.

For what concern historic buildings, at present time, the only European regulation, dealing with Architectural Heritage, is the "Convention for the Protection of the Architectural Heritage of Europe" [2] which does not provide limits about the energy performance of historic buildings. For this reason, energy retrofit is not mandatory for historical buildings and these are excluded from the energy regulations measures if the refurbishment induces prejudice of the historical value.

Nomenclature

A_{month}	mean of the monthly utility bills
ACH	air changes for hours (volume/h)
CE	Exercise costs (€)
$CV(RMSE_{month})$	coefficient of variation of the root mean squared error (%)
DPB	discounted pay-back period (years)
EP	primary energy demand (kWh or MWh)
ERR_{month}	error in the monthly consumption (%)
ERR_{year}	error in the annual energy consumption (%)
M_{month}	measured electric consumption (kWh)
N_{month}	number of utility bills in the year
NPV_{20}	Net Present Value (lifetime equal to 20 years) (€)
RMSE	mean squared monthly error
S_{month}	simulated electric consumption (kWh)
S/V	dispersing surface to conditioned volume ratio(m^{-1})
U	thermal transmittance value ($W/(m^2 K)$)
U_w	window transmittance value ($W/(m^2K)$)
V	volume (m^3)

A number of previous studies provided examples in which the possible coupling of protection of Cultural Goods and sustainability of the renovation design have been developed suitably. With reference to warm climates, De Berardinis et al. [3] have investigated various masonry buildings damaged by the 2009 earthquake in Abruzzo. Ascione et al. [4] applied the cost-optimal analysis of energy conservation measures to an ancient building (XV century) located in Naples. Dalla Mora et al. [5] and Bellia et al. [6], have proposed other examples of energy-oriented refurbishments of historical buildings, Papadopoulos et al. [7], for a medieval tower in Northern Greece, recently converted in a museum, Pisello et al. [8] have investigated the energy refurbishment of 'Palazzo Gallenga Stuart', a historic university building located in Perugia. About the achievement of NZEB target on a historic building for tertiary use, Mauri [9] has shown that by retrofitting the existing with common technological solutions in Agrigento, it is possible to reduce energy of about 30%. However only using on-site renewable sources, the budget can ensure the achievement of the NZEB target.

For what concerns the methodology of analyses, few works study refurbishment solutions through the use of dynamic simulation and indoor climate measurements. Ascione at al. [10] used EnergyPlus to model historic buildings in Benevento. Todorovic et al. [11] proposed a holistic and sustainable approach for the refurbishment of the Aviation