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Deep renovation of multi-storey multi-owner existing residential buildings: A pilot case study in Italy

Graziano Salvalai*, Marta Maria Sesana, Giuliana Iannaccone

Politecnico di Milano, Milano, Italy

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ABSTRACT

The present paper illustrates the Italian pilot action of the EASEE project (Envelope Approach to improve Sustainability and Energy Efficiency in existing multi-storey multi owner residential buildings), focusing on the analysis of energy refurbishment trends of the Lombardy region residential building stock.

More than 60% of the existing building stock in Lombardy region has been built before the 70 s and it is among the main responsible causes of final energy absorption and corresponding CO_2 emissions with a mean primary energy index for heating of about 202.0 kWh/m^{2}y. The promotion of renovation measures for such buildings, also through innovative solutions, is becoming increasingly important for both containing the greenhouse gas emissions and supporting the growth of the construction sector. To this topic, the work presents the energy renovation of a residential building in the Province of Milan through the application of innovative prefabricated composite panels that integrate both thermal insulation and exterior finishing with textile reinforced mortar. In detail, the paper describes, on one hand, the main design strategies following the preliminary analysis and, on the other hand, the whole installation process; besides, the performance of the retrofitted envelope is documented by the results of the monitoring campaign.

1. Introduction

1.1. EU building stock and energy renovation market

At the current state, the European Union is facing a double challenge: increasing building renovation rates while aiming at achieving “deep renovations”. Increasing the current EU renovation rate from 1.2% per annum to 2–3% is essential to meet both the EU 2020 targets and the commitment undertaken in Paris in December 2015. About 75% of the EU’s 210 million buildings are not energy efficient, and 75%–85% of them will still be in use in 2050. Ensuring a highly-efficient and fully decarbonised building stock by 2050 is a major challenge. The quality of the energy renovation of our building stock is, therefore, of paramount importance [1].

The ongoing review of the building-related EU legislation must prioritise action to decarbonize the existing building stock by speeding up the rate and depth of renovations.

The Energy Performance of Buildings Directive (EPBD) [2], with the requirement for all new buildings to be nearly Zero-Energy Buildings (nZEB) from 2021 (and from 2019 for public buildings) has raised the bar and the awareness about highly energy performant buildings in the EU. The nZEB definition ([3–9]) should be updated to reflect the new possibilities that a transforming energy market could bring as well as to include the existing building stock. This transition to an nZEB level for all buildings will help mitigate the stress put on the energy system and bring positive environmental effects through the reduction of GHGs, social benefits due to reduced energy bills as well as better living conditions and economic effects through a smarter and more dynamic energy use. Buildings account for around 40% of the total energy consumption and 36% of the CO_2 emissions in Europe and possess the biggest untapped mitigation potential. With the appropriate support, buildings could play a leading role in transforming the EU energy system increasing the speed with which the three biggest CO_2 polluters – the buildings, transport and power sectors – are reducing their climate impact. Energy will be saved, generated,

Abbreviations: EU, European Union; nZEB, nearly zero energy building; GHG, green house gas; SEN, national energy strategy; PAEE, action Plan for energy efficiency; EASEE, envelope approach to improve sustainability and energy efficiency in existing multy-storey residential buildings; BIM, building information model; PA, Public Authorities; TLS, terrestrial laser scanning; GSD, Ground Sampling Distance; ETAG, European technical approval guidelines; TRM, textile reinforced mortar; HPFRC, high performance fiber reinforced concrete; LCA, life cycle assessment.

* Corresponding author.
E-mail address: graziano.salvalai@polimi.it (G. Salvalai).

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stored and used where people spend most of their time – in buildings. A deep energy renovation of the existing building stock could reduce energy demand by 80% before 2050 compared to 2005 levels. A highly energy efficient building stock, realized by deep renovation and efficient new buildings, brings multiple benefits to demand reduction, but will also enable demand response and the integration of volatile renewable energy increase on the supply side [10].

There is no common definition for "deep renovation": "there are, however, common features among all initiatives, like the will to raise the level of ambition for achieved energy performance, to ensure consistency between short and long term measures and to align the target for the performance of individual buildings with the long-term target for the entire building stock" [11].

An energy renovation market is emerging in Europe and playing a strong role as a stabilizer of the building sector and consequently of the European economy in the period since the financial crisis. Estimates of the energy renovation market were of the order of 109 billion Euros in 2015 and it created 882,900 jobs. The Italian, German and French energy renovation markets alone accounted for almost half of the EU energy renovation market. The Italian National Energy Strategy (SEN) [12] places the energy efficiency among the priorities in the action. At this regard, the Italian "Action Plan for the Energy Efficiency" (PAEE, 2014) [13] identifies the building sector as a key element for achieving the objectives set by the country in 2020. The PAEE, among other things, establishes:(1) the strengthening of minimum energy performance requirements for new buildings and for the refurbishment of existing buildings, leading progressively to the increase of nZEBs, in line with the Directive 2010/31/EU [2] (EPBD recast); (2) the consolidation of the tax deduction system for the energy refurbishment of the existing buildings. An effective way to reduce the CO_2 emissions by means of the decrease of the energy consumption is the energy refurbishment of the existing building stocks, which present a high potential for energy savings in the European countries.

Several research works deal with this topic, presenting the impact of different energy conservation measures carried out on building stocks on the reduction of greenhouse gas emissions. Some studies introduce specific methodologies to evaluate the effects of different energy efficiency strategies and the environmental impact on residential case studies [14–17]. Ma et al. [18], with their study provided an overview of the research and development as well as application of the retrofit technologies in existing building and they defined a systematic approach to proper select and identify the most promising retrofit options for different type of existing buildings. Ruparathna et al. [19], similarly conducted a comprehensive review of contemporary approaches for improving the energy performance but focusing only on operating commercial and institutional buildings.

Corrado et al. [20] highlighted in particular that there is a considerable need for studies, which must focused on behavioral specific improvements. The user involvement is in fact a big challenge in the refurbishment process [21], Sesana et al. [22] involved engineering students with a participatory design process during their academic Integrated Design Refurbishment Laboratory. They defined a Methodology for Energy Efficiency Building Refurbishment (MEEBR) structured into four major phases, and they applied it on two campus buildings and they finally performed validation with Building Energy Performance Simulation tools (BEPS). This study remarks the importance and efficacy of computer simulation in assessing and identifying the most effective upgrades. However, adequate information regarding the building, its services and its operation are vital in achieving a robust and useful model. The same remarks was stated by Di Turi et al. [23], which highlighted the problem of lack of data in energy assessment models.

According to these published literatures, there are a large number of approaches available for improving the energy performance of existing buildings, but there are very complex and correlated issues involved in the building energy refurbishment, ranging from technic, economic, aesthetic, historical and cultural aspects.

> "Whole-of-building retrofit with comprehensive energy simulation, economic analysis and risk assessment is an effective approach to identifying the best refurbishment solution" [22].

In this scenario, the project EASEE [24] (Envelope Approach to improve Sustainability and Energy efficiency in Existing multi-storey residential buildings multy-owner), funded by the European Union under the Seventh Framework Programme for Research and Development, among its main objectives had the development of innovative systems for the reduction of energy use in residential multifamily buildings. In particular, this paper describes the results of the demonstration activities developed within the project with the application of the EASEE methodology and the envelope retrofitting solution to a residential building case study. The description covers all the process, from the modular prefabricated façade system design, through the development in lab to the integration on a demonstrative building with a monitoring campaign.

1.2. The EASEE project: concept and objectives

Buildings dated between 1925 and 1975 were built in an era where there was little or no consciousness of the need to design for energy efficient performance and therefore have the largest energy demand. A common feature of these buildings is that they are usually not forced by specific regulatory constraints for their refurbishment, differently from historical buildings, although the original appearance of the façade needs in general to be kept.

More than half of the European building stock belongs to this category, for a total of more than 80 Millions buildings. Residential buildings represent about one third of these, 10 millions of them being multi-storey buildings, with distributed ownership [25]. This type of buildings are widely diffused in the European cities centres and present common interesting features from the architectural and structural point of view. Considering the Italian existing stock and zooming in particular at regional level [26] (Lombardy region which the pilot case study belongs to), in 2013 the residential buildings were about 11.7 million, and about 49% of the total is located in the climate zones E and F (as defined by D.P.R. 412 [27]) that are mainly characterized by cold winter climates with larger demands for space heating.

Over 60% of the existing building stock has more than 45 years; most of it has been built before 1976 [28] when the first national law regarding energy saving in buildings has been introduced – and more than 25% has an annual consumption between 160 and 200 kWh/m^2y [29]. The main energy source is represented by natural gas with 46% of the total, followed by biomass (wood) with 22%, and 19.2% from electricity. In addition, data collected within the Energy Registry of the Lombardy Region [30] confirm an average primary energy demand for the heating season equal to 201 kWh/m^2y, with emissions of 43.75 $kgCO_2eq/m^2y$. Other regional data confirm that the mean thermal transmittance of the building envelope is equal to 1.09 W/m^2K, about four times the threshold set by the standard at 2021.

Considering the renovation construction processes and the impact of the retrofitting process on the life of the occupants, traditional approaches need scaffolding on the outer façade for very long times (on average between 12 and 24 months for a seven storey building due to the heavy removal of materials and the wet processes involved), requiring occupants to seal the windows and introducing safety issues. Furthermore, scaffolding creates burden