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Deep energy renovation strategies: A real option approach for add-ons in a social housing case study

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ABSTRACT

In this paper a techno-economic evaluation method for deep renovation of buildings is introduced. We study the validation of an integrated design methodology based upon the creation of additional volume on existing buildings (Add-Ons) intended as roof-top or aside extensions, enclosures, parasites or façade transformations. Energy price uncertainty is modelled through a mean-reverting stochastic process, which well fits the data for natural gas prices, and the proposed evaluation method is based on real-option theory, which is an advancement of standard cost-benefit analysis, to be employed whenever uncertainty has a significant impact on the investment option. The new method to evaluate the economical feasibility of the Add-ons strategy for Deep Energy Renovation is tested through design experiments on a real case study of social housing in Reggio Emilia (Italy).

1. Introduction

The main European energy challenge currently concerns the energy efficient renovation of the existing building stock, which counts for two thirds of the overall European energy consumptions; and yet, until today, only 1,2% of existing buildings gets renovated every year [1–3]. The actual investment gap in the building renovation sector is due to the fact that consistent investments are required up-front and are generally characterized by a high degree of uncertainty in expected returns and long payback times.

The expression Deep Renovation (DR) – or Deep Energy Renovation (DER) – refers to those energy renovations that instead of focusing on standard separate renovation measures capture the full potential of improvements in energy efficiency by combining several simultaneous measures into one integrated strategy acting upon the building envelope and installation system. According to the definition provided by the Global Building Performance Network (GBPN), the yearly primary energy consumption after DER, which includes, inter alia, energy used for heating, cooling, ventilation, hot water and lighting, should be less than 60 kWh/m^2 [4].

DER for residential buildings is a composite process including significant, articulated, interconnected – and sometimes conflicting – sets of requirements. In order to optimize these different requirements, the goal is to capitalize on all existing technological solutions in a win–win perspective that can be achieved only by the mutual collaboration of energy and non-energy related components, based upon the residual transformation potential of existing buildings. Given the undeniable costs of deep renovations, energy requirements need also to be explained in a convincing way and made attractive to final users and key decision-makers [5]. Thus, the focus should shift towards the willingness to pay rather than the mere investment rate of the proposed intervention with the aim of providing an integrate system which may accelerate the uptake of the DER [6,7]. In fact, the core element of every re-development is the increase in value for the client (investor, building owner, and tenant), since "focusing solely on the optimization of energy efficiency is ineffective, and does not meet overall requirements" [8].

Although recently introduced technologies and products provide promising solutions to improve the energy efficiency of buildings, the process of decision-making to identify the most technically favourable and cost-effective action is a complex task. It requires both a preliminary detailed technical evaluation to identify the energy-saving potentials and an appropriate economic evaluation, comparing the investment expenditures with expected cost savings. The economic evaluation has to be performedunder conditions of uncertainty and irreversibility of costs.

The purpose of this paper is to elaborate a techno-economic evaluation method for DER of buildings, which takes into account the above-mentioned shortcomings. The paper illustrates an integrated design methodology based upon the creation of additional

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volume on existing buildings (Add-Ons) intended as roof-top or aside extensions, enclosures, parasites or façade transformations. Add-Ons may represent an innovative strategy that can possibly overcome the actual barriers, increase the feasibility of energy renovation in the residential field and ultimately foster the building renovation market.[1]

Our research hypothesis is based on the assumption that an empowering synergy can be created between the old and the new, not only in structural, functional and architectural terms, but also in economic terms. Our goal is to test and prove the feasibility of the Add-ons strategy for DER through design experiments carried in on a real case study.[2] Therefore, by combining technical and economic issues of building renovation we select an appropriate solution, based on optimal environmental performance and investment returns. The economic analysis included in the proposed evaluation method is based on the real-option theory [11], which is an advancement of standard cost-benefit analysis, to be employed whenever uncertainty has a significant impact on the investment option and consistent up-front (irreversible) costs are required.[3]

To the best of our knowledge, this is the first study employing a real option methodology to Add-ons strategies. Although our paper is based on a specific case study, our main objective is the development of a method, which is sufficiently general and can be applied in other contexts as well.

Our case study experiment shows that the beneficial effect of the Add-on depends on the balance between the cost of construction and the real estate value, as well as the energy prices and reduction potential. Moreover, the results in terms of efficacy and payback times are affected by the market parameters and the high degree of uncertainty, characterizing in particular energy prices. This is usually neglected by standard methods from engineering-economics. To deal with uncertainty we employ real option analysis and focus on stochastic energy prices, modelled as a mean-reverting process, as most literature on natural gas suggests (see, a.o., [13–16]). The method of real options allows us to compute the value of the project, as a function of energy savings, and to find the threshold value of energy savings above which it is optimal to invest in Add-ons.

The paper is organized as follows. In Section 2 the Add-ons strategies are introduced with reference to a case study for social housing. Architectural aspects are illustrated in Section 2.1 while Section 2.2 addresses the economic impact of the proposed approach. Section 3 presents the economic methods and elaborates details of real options investment appraisal to evaluate the project. Section 4 applies the new method to the case study and, finally, Section 5 contains a discussion of the results from application, and indicates further avenues of research.

2. The viale magenta case study

The selected case study is located in a social housing area in viale Magenta, Reggio Emilia (Italy), whose construction goes back to 1920, when the IACP – Istituto Autonomo Case Popolari – was created in Reggio Emilia as an answer to the housing emergency. The primary goal of the new-born public institution consisted in developing and renewing social housing compounds to ensure decent dwellings to the low income classes [17]. The building object of the analyisis was built in 1936 and its current conditions require consistent renovation works. Cladding is falling off from the facade, the existing windows are not meeting the mínimum requirements set by law and the salubrity of the indoor dwelling has been severly compromised by the lack of insulation and mantainance throughout the past twenty years. Via Magenta building is characterized by an internal courtyard and two identical building blocks creating a U shape.

The street front is only one storey high while the other parts of the building are four storeys high. The front part of the building is dedicated to commercial activities while the rest is residential. Each staircase serves eight apartment units facing mainly east and west. The dwellings are located to have mostly cross ventilation and good exposures.

The original loggias have already been transformed throughout the past thirty years by several owners in winter gardens. Thus the elevations are currently not homogeneous and vary in different shading and enclosure systems. The building remission of 1985 (condono edilizio) authorised the inhabitants to also legalise these informal actions by paying a fee and the majority agreed to officially register the transformation by the ACER.

There are three main blocks and five separate staircases that serve in total 49 dwelling units, divided into two different layout schemes: one-bedroom apartments or two-bedroom apartements. The total heated surface is equal to 2.984 m^2 and the total heated volume is 8.087 m^3. The home property regime of the building is mixed: almost two thirds of the dwelling units are rented by ACER —the housing association currently in charge of the management of the building- and the remaining one third of the units is privately owned.

We chose this simple building as a pilot case study, for the following reasons: i. Availability of data (energy bills, technical information, original drawings, market survey); ii. Cooperation with the local Social Housing institution that provided support and helped in the negotiation with the inhabitants; iii. Low density urban area that could host an increase of urbanistic load and the necessary additional service requested bythe new inhabitants that would live in the building. Moreover, from an economic survey of the real estate market in Reggio Emilia, it emerged that the location of the case study close to the city centre offers a great potential for investments and could pay off the energy renovation costs of the entire building despite the socially disadvantaged groups living in the building and its surroundings. The application of the Add-ons' strategy through deep architectural and technological renovation measures directly on the pilot case study will show the possible outcomes and underline the key aspects of the proposed approach. The method can also be replicatedin other economic and urban contexts tobe tested and evaluated at the European level (Fig. 1).[4]

[1] Studies identifying key categories of hurdles (economic, technical, related to credibility, social, legal) in delivering deep buildings' energy renovation are contained in: 1. A guide to developing strategies for building energy renovation: Delivering Article 4 of the EED, BPIE, Published in February 2013 by the BPIE. 2. Studies of financial institutes (e.g. KfW in Germany); 3. The EU multiannual Roadmap for the EeB PRP, led by E2B consortium providing recommendations for building energy renovation. 4. Guidelines for strategies on renovation provided by the concerted actions EPBD, EED and RESD 5. EU projects (FRESH, SURE-FIT, SHELTER, RESHAPE, TRAINREBUILD, iNSPiRe and POWERHOUSE) [9].

[2] Preliminary energy simulations performed by the research team of the Department of Architecture of the University of Bologna on several case studies and buildings [9] have demonstrated that enclosing the existing building structure with additional volumes, for example transforming existing balconies into winter gardens or rooms extentions may provide energy reduction up to 75% in winter season. Similarly, the additional volumes could be designed including shading systems that could significantly reduce the direct solar gains and increase natural ventilation rates: in this case it is possible to achievea 35%average reduction in primary energy consumptions duringthe summer period. See also [10], confirming the energy reduction potential of these types of interventions.

[3] For a discussion of the impact of uncertainty on economic sustainability see, e.g. [12].

[4] The building presented in this paper is also a pilot case for ABRACADABRA (Assistant Buildings' addition to Retrofit, Adopt, Cure And Develop the Actual Buildings up to zero energy, Activating a market for deep renovation), a European Project funded by the Horizon 2020 Programme, based on the prior assumption that sub-