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Towards a feasible strategy in Mediterranean building renovation through a multidisciplinary approach

Antonio Serrano-Jimenez[a,*], Angela Barrios-Padura[a], Marta Molina-Huelva[b]

[a] Department of Building Construction I, University of Seville, Seville, Spain
[b] IUACC—Institute of Architecture and Building Science, University of Seville, Seville, Spain

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ABSTRACT

The energy-efficient retrofitting process of residential neighbourhoods in southern Europe has certain socio-economic and climatic uniqueness which are not included in the European guidelines, thereby rendering the corresponding action programs unviable. This research considers that an appropriate management of the energy retrofitting of buildings should not involve expensive and complex processes that are unaffordable to most residents.

The study is performed in a neighbourhood of Seville (Spain), which belongs to the Mediterranean climate, in multi-family housing, built in 1961, that presents an obsolete state of conservation and a low energy performance.

The methodology, through an energy assessment survey for residents, tries to adjust to each socio-economic situation by defining 3 levels of intervention: mild, moderate and intense; and evaluating 12 action packages from the disciplines of energy, sociology and economy.

The results show that the moderate level is the optimal level for the residents, resulting between 20 and 50% energy reduction and contributing a high socioeconomic benefit, assuming an initial cost 50% lower than other intense measures. In addition, results also make it possible to ascertain which packages are optimal for each level of intervention, thereby ensuring the success of the process.

Introduction

Tackling the climate change is a global challenge that can only be addressed effectively through a comprehensive strategy. According to the International Energy Agency (IEA), buildings in the European Union are responsible for up to 40% of total energy consumption and 36% of CO_2 emissions: a high enough proportion to justify the investment in research and development on energy renovation and its corresponding economic management (IEA, 2013b). The European Union aims to reduce emissions of greenhouse gases by up to 90% between 2020 and 2050, including the use of renewable energy and the introduction of measures for greater energy efficiency in the residential sector in 50% of all cases for 2050 (2012/27/EU, 2012; MF GE, 2014). Through the "European Directive on the energy performance in buildings (EPBD)" (2010/31/EU, 2010), the European Commission define the 'Cost-Optimal' methodology as a reference at European level in the energy retrofitting process of residential buildings.

However, the current economic situation, with its deep financial crisis and increasingly ageing population, demands new models of feasible interventions that promote an efficient regeneration of residential building stock in European cities, by considering minimum comfort conditions established in European policies and by satisfying the demands of citizens (IEA, 2013a; Sovacool et al., 2015). In this sense, certain studies consider the important role of countries and regions to carry out successful refurbishment processes in the building stock, as those that developed Caputo and Pasetti (2015), suggesting

Abbreviations: Ach/h, air changes per hour; AP, action package; B4, specific climatic zone in Spain; COP, coefficient of performance; CTE, Spanish technical building code; DHW, domestic hot water; DOE, Department of Environment; EEM, energy-efficient measure; EER, energy efficiency ratio; EIFS, exterior insulation and finishing system; EPBD, energy performance of building directive; EPS, expanded polystyrene insulation; EU, European Union; G1, group 1 of individual EEM – specific passive measures; G2, group 2 of individual EEM – global passive measures; G3, group 3 of individual EEM – active measures; HP, heat pump; HVAC, heating, ventilation and air conditioning; IC, initial cost of each EEM (€/dwelling); IEA, International Energy Agency; LCC, life-cycle cost (€); LI, level of intervention; LI-1, level of intervention 1 – mild; LI-2, level of intervention 2 – moderate; LI-3, level of intervention 3 – intense; LPG, liquefied petroleum gas: butane/propane in cylinder; MC, maintenance cost (€/dwelling year); MW, mineral wool; N0, initial energy state of reference building; OECD, organisation for economic co-operation and development; SHGC, seasonal solar heat gain coefficient of shading devices; TB, thermal-break; U, thermal transmittance ($W/m^2 K$); UC, unit cost of each EEM; α, solar absorptivity

* Corresponding author at: University of Seville, Department of Building Construction I, Reina Mercedes Avenue, nº2, 41002 Seville, Spain.
E-mail addresses: aserrano5@us.es (A. Serrano-Jimenez), abarrios@us.es (A. Barrios-Padura), martamolina@us.es (M. Molina-Huelva).

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how to overcome local restrictions in small and medium Italian municipalities, Roders and Straub (2015), proposing specific implementation strategies in social housing from Netherlands, or Aste, Caputo, Buzzetti, and Fattore (2016), studying the investments process of the energy-efficient retrofitting in buildings from Lombardy region.

According to the European Commission (2010/31/EU, 2010), the "Cost-Optimal" methodology of the European Union is defined as "the energy performance level which leads to the lowest cost during the estimated economic lifecycle, produced in a medium or long term" (15–30 years). In this way, by relating overall cost (€/m^2) and energy consumption (kWh/m^2), the best "Cost-Optimal" measures will be those with the highest levels of economic recovery and energy savings. However, EU Directive (2012/27 EU) specifies that each country and region must adjust and expand this methodology for each specific situation, by considering the most relevant climatic, social and economic factors in a successful way.

Current European research strive to generate ideas and to innovate in the energy retrofitting process by considering socioeconomic conditions of their inhabitants and the state of conservation of existing buildings. In this sense, Ascione, Bianco, De Stasio, Mauro, and Vanoli (2015) introduce a "multi-objective" methodology that compares, through an energy and economic analysis, the performance of some energy-efficient measures in different case studies. Araújo, Almeida, Bragança, and Barbosa (2016) propose a "cost-benefit" method in a case study from Portugal which includes the user's willingness, assessing the feasibility and social preferences in the energy renovation process. Kuusk and Kalamees (2015) define a "cost-effectiveness" methodology for a case study in Estonia, defining previously the energy-efficient levels to be achieved, grouping measures into packages which reach "Cost-Optimal" saving levels, and incorporating external funds to assume the investment. Ashrafian, Yilmaz, Corgnati, and Moazzen (2016) present a new method for the assessment of individual energy-efficient measures by pre-establishing three different budgets in three buildings in Turkey, and then they value each measure depending on the climatic conditions, the economic restrictions and taking into account the percentage of reduction of energy consumption. Lastly in this review, Park, Lee, Kim, Kwon, and Jeong (2016) pretend to advance in the "Cost-Optimal" methodology by highlighting the importance of using electricity bills to evaluate real consumption and to choose energy-efficient measures that guarantee success based on real economic and energy results.

However, despite having a large reduction in energy consumption and addressing issues beyond those established by the "Cost-Optimal" methodology, the advances offered in all these studies generally conclude with high investment results, and therefore these results would have no real application in Spain, and specifically in the region of Andalusia, without external assistance or public funding (Jones, Lannon, & Patterson, 2013; Vilches, Barrios Padura, & Molina Huelva, 2017).

In Spain, current legislation encourages the energy-efficient retrofitting of buildings in various laws and official regulations, but a greater coordination between administration and legal context is necessary, as proposed by Cuchí and Sweatman (2014), with which the state of buildings could be evaluated with greater accuracy. In this way, Spanish law 8/2013 on "Rehabilitation, regeneration and urban renovation in Spain" (L. 8/2013, 2013) seeks to promote the retrofitting process by eliminating some existing difficulties in current legislation and requirements, creating specific mechanisms and considering economic and sustainable aspects. In addition, to support this law, in 2014 the Spanish government introduced the "Long-term strategy for energy retrofitting in the Spanish building sector, in implementation of article 4 of Directive 2012/27/EU" (MF GE, 2014), which introduced guidelines to achieve European targets in energy retrofitting in the building sector and generated benefits for people involved in urban renovation processes. In Andalusia, the "Andalusian Energy Strategy 2014–2020" (CEEC JA, 2014) has been published, which follows the roadmap of European politics, but this has failed to have sufficiently considered the existing socio-economic situation in the region and the climatic particularities of the zone.

This European, National, and Regional regulatory framework, together with the obsolescence of the building stock in European countries, considering that over 50% of the Andalusian buildings were built before 1980 (INE, 2016), underline the need to implement protocols for a comprehensive evaluation in building renovation, to ensure viable and efficient operations, and to improve the quality of life of citizens while achieving environmental objectives.

In fact, different studies demonstrate the serious needs to renovate existing buildings in different European cities (Singh, Mahapatra, & Teller, 2013; Waddicor et al., 2016). In this sense, it is an important contribution the work developed by Singh, Attia, Mahapatra, and Teller (2016), demanding new methodologies for existing buildings prior to 1945 in Belgium, using real monitoring during some months and supplementing it with occupant surveys to demonstrate that modern comfort standards are not adapted to these old residential buildings. In fact, these authors also developed a related research based on a real monitoring in 20 buildings in Liege, Belgium, along with a questionnaire in 85 houses in order to stand out the importance to consider the occupant's preferences and expectations to improve the energy efficiency in their existing buildings (Singh, Mahapatra, & Teller, 2014).

Therefore, the present article considers that, in order to find optimized and efficient solutions in the residential energy retrofitting of buildings, is necessary to include technical, social and economic objectives in the urban renovation process so that a comprehensive viability can be guaranteed (De-Luxán, Gómez, & Román, 2015; Jensen & Maslesa, 2015)

This research, which is developed under the "(Re)Programa" research project (Barrios, González, Mariñas, & Molina, 2015), aims to focus on the design of a multidisciplinary evaluation methodology that progresses beyond the European "Cost-optimal" and considers the socio-economic and urban context of each case study, in southern Spain region, as a representative sample of the Mediterranean climate. This paper, which is applied in a residential neighbourhood of Andalusia, in Spain, considers real possibilities of intervention after a comprehensive analysis, considering the results of technical inspections, energy simulations and occupant surveys, by selecting and grouping those optimum actions in different levels of intervention, in terms of energy, social and economic parameters.

2. Energy retrofitting in the Mediterranean climate

It is necessary to point out the high potential for energy savings in the Mediterranean area, where, in spite of having mild temperatures, there is high energy consumption in winter due to the low energy performance in the residential building stock. However, current research on energy efficiency promoted in Europe generally focuses on much colder climates, where new innovative systems are successfully applied (Paiho, Pinto Seppä, & Jimenez, 2015; Tuominen, Klobut, Tolman, Adjei, & De Best-Waldhober, 2012), instead of considering the specific situation of southern European areas, with an important demand for cooling and an increased demand for heating.

In this sense, certain studies consider in their methodologies the specific situation in the Mediterranean climate. Baglivo, Congedo, D'Agostino, and Zacà (2015) show comparisons with other climatic zones and other building typologies with the same energy-efficient measures to demonstrate their energy performance variations, Domínguez, Sendra, León, and Esquivias (2012) seek to optimize the building envelope for the Mediterranean climate, ensuring from 20% to 25% of the energy reduction by acting specifically on windows, or Lizana, Barrios-Padura, Molina-Huelva, and Chacartegui (2016) who introduce a new "Multi-criteria" methodology which allows greater effectiveness in energy-efficient retrofitting measures applied to the