Journal of Cleaner Production 123 (2016) 88–100

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Review

The challenge of sustainable building renovation: assessment of current criteria and future outlook

Olatz Pombo [a, *], Beatriz Rivela [b], Javier Neila [a]

[a] Department of Construction and Technology in Architecture (DCTA), School of Architecture (ETSAM), Technical University of Madrid (UPM), Avda. Juan de Herrera 4, 28040 Madrid, Spain

[b] National Institute of Energy Efficiency and Renewable Energy, Ecuador, Avda. 6 de Diciembre N 33-32 e Ignacio Bossano, edificio Torre Bossano, 2do piso, Quito, Ecuador

A R T I C L E I N F O

Article history:
Received 25 February 2015
Received in revised form
26 May 2015
Accepted 24 June 2015
Available online 6 July 2015

Keywords:
Housing renovation
Retrofitting
Sustainability
Life cycle assessment
Life cycle cost

A B S T R A C T

The building sector is one of the key consumers of energy worldwide. Thus, the retrofitting of existing buildings provides excellent opportunities for reducing energy consumption and greenhouse gas emissions. This paper presents a critical review of the research undertaken on housing retrofits and discusses the approaches driving the assessment of energy-efficiency measures. It is clear from the existing literature that many retrofitting strategies are quite similar in their approaches, the most common of these being passive strategies such as insulation of the envelope, replacement of windows, and air sealing. However, the assessment methodologies differ broadly and widely, which restricts a comparison of the results across various studies. This current state of the art review highlights the need to apply a life cycle approach in order to find the optimal retrofitting solutions, and to identify the real improvement potential of housing renovation. Life cycle assessment and life cycle cost methodologies have been analyzed by discussing the existing limitations, which can be mitigated by sensitivity analysis. Finally, whilst social impacts were addressed in a few studies, life cycle social assessment was not conducted in any of the papers reviewed.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

Buildings account for 16–50% of total worldwide energy consumption (Saidur et al., 2007), with 40% of Europe's energy consumption being building-related (European Parliament and Council, 2012). The majority of the current European residential building stock was built during the 1940s–1970s, and is of a low standard, especially with regard to energy performance (Häkkinen, 2012). However, the replacement rate of existing buildings in Europe is approximately only 1.0–3.0% per year (Barlow and Fiala, 2007; Roberts, 2008). Therefore, the current challenge is to take action in this stock, which is a consequence of the high demand for housing which existed in the middle of the last century in Europe, where there was low industrial production and no standards of comfort.

It is well known that the retrofitting of building stock is a priority for both Europe and developed countries. However, there is a key issue that must be properly addressed. In particular, it is important to know which are the criteria currently used for assessing energy-efficiency measures. In recent years, many authors have analyzed the potential for renovating existing housing stock in terms of energy saving and reducing CO_2 emissions. However, whilst assessment criteria differ, retrofitting strategies are broadly similar. Nemry et al. (2010) analyzed the potential of residential buildings in Europe to reduce environmental impacts and financial costs through the life cycle approach. The improvement of the envelope (additional roof insulation, additional facade insulation, and new sealing to reduce ventilation) yielded a significant potential for environmental improvement. For the majority of buildings, it represented at least 20% compared to the base case. Using a case study in Italy, Dall'O et al. (2012) developed a procedure to evaluate the potential energy savings of retrofitting residential buildings in a municipality, and found that the BAU (business as usual) scenario achieved only a reduction of 2.7%, while with the optimal scenario it was possible to reach 24.8% of energy savings. Ahern et al. (2013) estimated the benefit of thermal retrofit measures for Irish housing stock, including fabric improvement measures and inflation rate measures. Heating costs

* Corresponding author. Tel.: +34 91 336 38 89.
E-mail address: o.pombo@alumnos.upm.es (O. Pombo).

http://dx.doi.org/10.1016/j.jclepro.2015.06.137
0959-6526/© 2015 Elsevier Ltd. All rights reserved.

and CO_2 emissions were based on Ireland's national Dwelling Energy Assessment Procedure (DEAP). According to their study, thermal retrofit measures in the detached housing stock had the potential to reduce heating costs and CO_2 emissions by almost 65% for houses built before 1979, and around 26% for newer homes. Mata et al. (2013b) employed a bottom-up method (Mata et al., 2013a) to assess the application of a spectrum of energy saving measures (insulation of envelope, replacement of windows, reduction of the indoor temperatures to 20 °C, heat recovery systems, etc.). These measures had the potential to reduce the final energy demand of the Swedish residential sector by 53%. The measures that provided the greatest savings were those that involved heat recovery systems (22%) and a reduction of the indoor temperature (14%). However, this is due to the higher indoor temperature over the day during the heating period, which, according to the measurements is 21.2 °C in single-family dwellings and 22.3 °C in multi-family dwellings (Boverket, 2009). Upgrading the U-values of the building envelope and windows had a lower impact on annual energy savings (Mata et al., 2013b), which is attributable to the superior building envelopes used in northern European countries (Balaras et al., 2007).

The construction sector plays a key role in global sustainable development. Strategies to make buildings more sustainable rely mostly on life cycle approaches, covering the three main aspects of sustainability: environmental, economic, and social (Gervásio et al., 2014). The use of such an approach at the beginning of a design process has been identified as a decisive tool in the pursuit of sustainable construction. Most fundamental decisions influencing the life cycle performance of a building are taken in the very beginning of the design process. If, for example, LCA is used at the end of a project, the environmental optimization potential cannot be exploited (Wittstock et al., 2012). As shown in Fig. 1 (Kohler and Moffatt, 2003), the earlier the assessment, the higher is the potential to effectively influence the life cycle performance of the building.

The aim of this paper is to review, analyze, and compare the methods and tools that are currently used to evaluate housing building retrofits (i.e. energy assessment, life cycle assessment, life cycle cost, multi-criteria optimization methods, etc.), as well as to provide an overview of the main energy-efficient measures applied. The final objective of the paper is to serve as a basis for the development of a sustainability assessment methodology for the evaluation of energy saving measures. To this end, the paper has four chief aims: 1) to provide an overview of housing renovation studies reported so far, comparing the methods, assessment criteria and main energy-efficiency measures; 2) to summarize the main results of the studies; 3) to draw general conclusions on whether sustainability is evaluated in housing retrofitting; and 4) to recommend further developments for sustainability assessment methodologies, including environmental, economic, and social aspects through the life cycle approach.

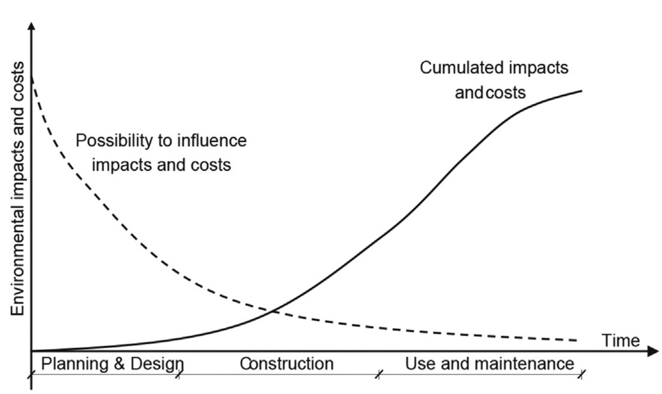

Fig. 1. Influence of design decisions on life cycle impacts and costs (Kohler and Moffatt, 2003).

2. Methods and scope

As mentioned above, the purpose of this paper is to provide an overview of existing housing renovation studies in order to know how sustainability is assessed, by focusing on the state of the art of retrofitting residential buildings. The review is based on a worldwide literature search, sourced mainly by the Scopus database. The research under review covers studies that have analyzed various energy saving measures, works developing assessment methodologies for housing renovation, and macro-scale level research analyzing the potential for energy savings and reducing CO_2 emission in the existing housing stock. Since this topic is still under development, we include not only work reported in peer-reviewed journals, but also studies reported in technical journals, books, conference proceedings and available reports. In order to provide an overview of the research conducted on this topic, works that defined the evaluation method, retrofitting strategies, and the application to a case study were considered. Table 1 summarizes 42 relevant studies identifying the type of housing, assessment criteria and energy-efficiency measures. Housing types have been classified into single-family houses, multi-family houses, and housing stock, which covers macro-scale analysis where the type of housing is not identified. The assessment criteria have been gathered in three groups according to the pillars of sustainability: environmental, economic, and social. Finally, energy-efficiency measures are categorized in the retrofitting of the building envelope, improvement of the building service systems, and implementation of renewable energy. The authors are sorted by the year of the research in order to see whether there has been any development of the criteria of assessment methodologies and the types of retrofitting solutions. The timespan considered to select the relevant literature is post-1980s, where after the first oil crisis a number of studies identified both the opportunities for, and barriers to energy conservation in multi-family houses (Bleviss and Gravitz, 1984; OTA, 1982).

Given that the final objective of the paper is to determine the future outlook for sustainable building renovation, an in-depth comparison of a selection of works was conducted, based on the three assessment criteria: environmental, economic, and multi-criteria. Indicators considered by the authors and energy-efficiency measures have been identified and compared. Moreover, the assumptions made in life cycle approaches, mainly in Life Cycle Assessment (LCA) and Life Cycle Cost (LCC) in terms of lifespan, system boundaries, calculation methods, impact categories, and units (among others) have been compared and discussed. Finally, the different combination methods of life cycle approaches to assess sustainability have been analyzed in order to find both common features and inconsistencies among them. This analysis is reported in Section 3. A discussion of the findings is provided in Section 4 in order to discuss the future outlook and draw some conclusions regarding these methodologies.

3. Approaches and criteria for the assessment of retrofit alternatives

Tables 2–4 summarize illustrative works on the topic of housing retrofitting measures. It is clear that renovation strategies are similar across the works analyzed, whilst, assessment methodologies vary considerably. As previously mentioned, for the purpose of the present review, the research works have been classified

Download English Version:

https://daneshyari.com/en/article/1744222

Download Persian Version:

https://daneshyari.com/article/1744222

Daneshyari.com