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Modelling decisions on energy-efficient renovations: A review

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A B S T R A C T

The buildings sector accounts for more than 30% of global greenhouse gas emissions. Despite the well-known economic viability of many energy-efficient renovation measures which offer great potential for reducing greenhouse gas emissions and meeting climate protection targets, there is a relatively low level of implementation. We performed a citation network analysis in order to identify papers at the research front and intellectual base on energy-efficient renovation in four areas: technical options, understanding decisions, incentive instruments, and models and simulation. The literature was reviewed in order to understand what is needed to sufficiently increase the number of domestic energy-efficient renovations and to identify potential research gaps. Our findings show that the literature on energy-efficient renovation gained considerable momentum in the last decade, but lacks a deep understanding of the uncertainties surrounding economic aspects and non-economic factors driving renovation decisions of homeowners. The analysis indicates that the (socio-economic) energy saving potential and profitability of energy-efficient renovation measures is lower than generally expected. It is suggested that this can be accounted for by the failure to understand and consider the underpinning influences of energy-consuming behaviour in calculations. Homeowners' decisions to renovate are shaped by an alliance of economic and non-economic goals. Therefore, existing incentives, typically targeting the economic viability of measures, have brought little success. A deeper understanding of the decisions of homeowners is needed and we suggest that a simulation model which maps the decision-making processes of homeowners may result in refining existing instruments or developing new innovative mechanisms to tackle the situation.

Contents

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1. Motivation

The buildings sector is responsible for over one third of global greenhouse gas (GHG) emissions [1]. Therefore, a critical focus on the building sector may be crucial for acting on climate change [2]. It is generally accepted that renewable energies and energy efficiency are important opportunities for mitigating GHG emissions [3–5]. Renewable energy technologies replace fossil fuel-based technologies for energy production while energy efficiency measures reduce the energy used to provide the same level of energy service. The energy-efficient renovation (EER) of buildings may address both renewable energies (e.g. installation of a heating system based on renewable energies) and energy efficiency (e.g. improvement of the building shell). Environmental benefits resulting from EERs must be seen against their environmental impacts such as the production of insulation materials, their transportation, assembling and disposal at the end of their lifecycle. Asdrubali et al. (2013) state that such a comprehensive view is of particular importance with respect to Nearly Zero Energy Buildings, „for which there is a real risk of shifting the impacts from the operating phase to the construction and end of life phases risk of shifting the impacts from the operating phase to the construction and end of life phases" [6]. Xing et al. (2011) reviews technologies applied to reach zero carbon in existing buildings [7]. EERs are economically viable in many cases and have great potential to reduce GHG emissions.

Several authors point out that there are profitable ways of reducing emissions in buildings [8–11]. Nauclér and Enkvist (2009) compared abatement costs, capital intensity and the abatement potential of different sectors worldwide projected until 2030 (see Fig. 1). The comparison shows that abatement measures in the building sector provide a comparatively high potential for reducing GHG emissions and at the same time have a large positive net profit (negative abatement costs) for the client. Nauclér and Enkvist (2009) state that upfront financing might be challenging because measures are relatively capital intensive [9].

A high potential for decreasing energy consumption at negative net cost by installing energy-efficient building elements is also acknowledged in the residential building stock of European Union (EU) Member States [12]. Of the total final energy consumption at EU level in 2010, buildings represent about 40% [13,14] of which 67% is for end-use space heating [15]. Therefore EER measures to reduce GHG emissions are very important. This is encouraged by several climate protection scenarios at national, international and global level, which suggest an increase in EER adoption rates and evidence of more large-scale refurbishment of buildings [16–18]. Baek et al. (2012) states that "existing residential buildings are expected to play an important role in enabling countries to achieve their goals of reducing greenhouse gas emissions" [19]. This was also recognised by the EU, which introduced a Directive on Energy Performance of Buildings in 2002 (recast in 2010). The directive requires member states to introduce policies on building energy efficiency [20].

In spite of recent encouraging trends, it is difficult to understand why there appears to be a reluctance to take advantage of these opportunities. In order to tackle this challenge one needs to identify and understand its root cause. A preliminary review of the scientific literature and several project reports was carried out to obtain an initial insight and understanding about the current state

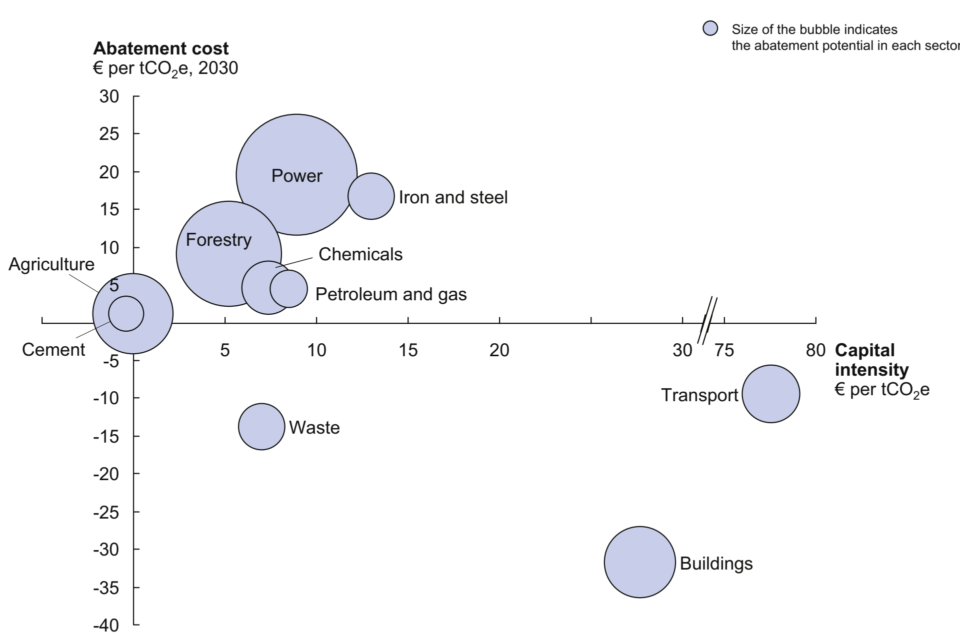

Fig. 1. Capital intensity and abatement cost across different sectors [9].