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Review

User-driven energy efficiency in historic buildings: A review

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ABSTRACT

The paper draws from the general literature on energy efficiency and historic buildings to explain the importance and potential of user-driven energy efficiency in historic buildings. It is the first review that places the user as a central object of study in the research field of historic buildings and energy efficiency. Relevant interdisciplinary topics and research results that make up the core of the field are presented and discussed in relation to user behaviour and its impact on energy consumption. The paper also investigates how user behaviour aspects can be integrated in a procedural approach to energy refurbishment in historic buildings. Research and experience from the building stock in general clearly shows how a user's awareness and behaviour, such as choice of temperature, zone heating and controlled airing, can have a significant effect on energy demand yet have no physical impact on the building. However, this has not received enough attention with regards to the historic building stock, where many physical energy efficiency measures can have negative impacts on the historic qualities of the building. Modification of user behaviour can therefore be a way not only to reduce energy demand but also to minimise the physical impact of increasing energy efficiency on historic buildings. The paper concludes that the current research agenda on historic buildings and energy efficiency has broken much ground but remains focused more on technical solutions than bottom-up user perspectives. Two main topics are identified as key barriers and future research fields: First, energy performance modelling is identified as a general barrier to developing sustainable strategies that promote user impact in historic buildings. Accurate energy modelling of historic buildings is a complex field reliant on the thermal interplay between user-building and building-district. Improved knowledge and intensified research is necessary to avoid distorted energy modelling results and unwanted rebound effects. Practical tools also require that the modelling can be used for trade-off scenarios where other sustainability aspects such as cultural heritage and economy are weighed in. Second, awareness raising in order to foster a deeper understanding and knowledge about the construction, system and cultural heritage values of a building is proposed as a key ingredient and driver for improved and sustainable energy behaviour. The paper argues that while user-driven energy efficiency represents an important resource for fostering less energy-demanding and less intrusive interventions in historic buildings, there are no guarantees for achieving the planned level of energy efficiency without taking into account user behaviour and the actual operation and energy performance of the historic building. To do this without risking negative consequences, improved decision-making processes are needed on policy, building and user level. An interdisciplinary bottom-up approach to energy refurbishment is presented. The essence of the model is that users and residents should always play a central role in the decision-making process because the well-being of the historic building will always depend on its day-to-day users, and vice versa.

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1. Introduction

Although energy efficiency has improved considerably over recent years, the European Union (EU) assumes that it is technically and economically feasible to make further progress by using different strategies across all active sectors. According to the EU, buildings represent the most promising target for energy efficiency improvements. Despite the fact that user behaviour is a major

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determinant of energy use in buildings, the energy saving potential of behaviour is often neglected or considered unimportant relative to the energy savings of technology.

Improving energy performance in historic buildings requires a deliberate balance between societal and climate goals for energy efficiency and building conservation. To reach societal climate and energy goals, different energy efficiency measures for buildings are produced and performed. These energy efficiency measures do not necessarily take building conservation or cultural heritage into consideration. In most cases, they are designed to improve the energy performance of buildings without giving consideration to historic or aesthetic values. For instance, a common technical energy efficiency measure such as upgraded windows can have a negative impact on the historic fabric and overall architectural expression of historic buildings. Interventions can also interfere with inherent building physics systems and this gives rise to structural damage.

Research and experience from the building stock shows that user awareness and behaviour, such as choice of temperature, zone heating and controlled airing, can have a significant effect on energy demand without having any physical impact on the building. User behaviour can, therefore, be important not only to reduce energy demand but also to reduce or avoid the physical impact on historic buildings during the energy efficiency process.

The purpose of this paper is to elucidate the potential of user-driven energy efficiency in historic buildings and to investigate how user behaviour aspects can be integrated in the energy refurbishment process. Based on a review of the existing literature, this paper aims to summarise the present knowledge of user-driven energy efficiency in historic buildings by discussing the following questions:

- in what ways can user behaviour have an effect on energy demand? What is the potential?
- what aspects of user behaviour are particular to historic buildings?
- how can user behaviour aspects be integrated in the energy refurbishment process for historic buildings?

User behaviour related to energy consumption and energy efficiency has recently been given more attention, especially in the social sciences. However, research activities on the topic of user-driven energy efficiency in historic buildings have been limited. This article will draw mainly on the literature of energy user behaviour and on research that deals with energy efficiency and historic buildings. The *user* is here defined as whoever is using the building more or less regularly but, given the focus of this research on domestic households, it particularly refers to residents.

2. The general research agenda: historic buildings and energy efficiency

2.1. Energy targets and historic buildings

To tackle global warming, the EU is committed to reducing its greenhouse gas (GHG) emissions by at least 20% by 2020 [1] and 40% by 2030 [2] compared to 1990. The long-term aim is to reduce GHG emission by 60–80% by 2050 [3]. Part of the challenge lies in refurbishing the existing residential building stock, which is normally ascribed ca. 40% of all GHG emissions. However, there are many different theoretical, technical, and financial barriers that limit the achievement of the full energy saving potential for most buildings.

The cultural heritage of historic buildings can have a considerable effect on the outcome of the process concerns the cultural heritage significance of historic buildings. To address this problem, EU policies today allow for the exemption from certain minimum energy requirements should they unacceptably alter the "character or appearance" of protected historic buildings [1,4]. However, historic buildings do not necessarily require statutory protection per se. Buildings that are not formally listed but still considered as being of heritage interest are also regarded as being worthy of protection and care. Thus, the term *historic building* also encompasses buildings that are not necessarily listed. As stated in the Burra Charter [5], these buildings can possess general heritage values that, with respect to past and future generations, should be maintained. Consideration for these aspects distinguishes working with historic buildings from working with the building stock in general.

Unfortunately, and contrary to general principles of preservation, conclusions about reaching efficient energy performance levels for the historic segment of the building stock are often based on the assumption that it requires dramatic physical improvements with modern standardised measures [6]. Therefore, the goal of development and reaching energy targets is often brought into a supposed conflict with the management of built heritage [7,8]. It has become evident that even small adjustments to buildings and user behaviour may have large and positive impacts on energy saving, provided that the technical condition of the historic building is adequate and that any measure takes into consideration the building's individual characteristics [9]. This however requires a procedural approach to the energy efficiency process.

2.2. A procedural approach to energy efficiency

A systematic approach to facilitate the best decisions when planning energy refurbishment in historic buildings has been developed and published in a European Standard [10]. The standard provides "a normative working procedure for selecting measures to improve energy performance, based on an investigation, analysis and documentation of the building and its heritage significance". It acknowledges the importance of user aspects by stating that "significant energy savings may be achieved through the change of user behaviour without altering the building". The standard further advocates for a "multidisciplinary approach in close cooperation with the owners and users of the building" and suggests that users should be made aware of the impact of their behaviour and how it can influence conservation, energy consumption and associated cost. Thus, while the document on one hand emphasises the importance of user aspects throughout the text, it does not elaborate or specify how to achieve energy savings through user behaviour.

2.3. Behavioural aspects of energy efficiency

Yohanis [11] has defined energy behaviour as actions "taken by householders in their use of energy in their homes". Lopes et al. [12] have in turn argued that energy behaviour represents a significant untapped potential for the increased end-use energy efficiency of buildings. Today, simple measures such as consuming less hot water, adjusting thermostats when leaving for work, lowering the temperature in different rooms, or airing and opening windows in a controlled rather than inattentive manner all represent significant and self-evident energy savings. These common-sense actions are often achieved with low or no capital investment. Although this can seem very simple, the concept of energy behaviour is more complex than that.

From a sociological point of view, it is often proposed that energy demand does not only originate in the individual but is also a social construct wherein institutional and cultural contexts influence energy behaviours and attitudes. Energy behaviour strategies (e.g. social learning, collective actions etc.) must therefore take these perspectives into consideration in order to be effective [12]. For further discussion about the term from a social science perspective, see for instance Owens and Driffill [13], Godbolt [14], Ryghaug et al.

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