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Occupant behaviour lifestyles and effects on building energy use: Investigation on high and low performing building features

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Abstract

Occupant behaviour is known to be one of the key sources of uncertainty in the prediction of building energy use. Extended literature reviews linked the large performance gaps between residential buildings with same properties and similar climate conditions to the way occupants interact with the building envelope and systems. Furthermore, in the last decades, more stringent energy codes have led to energy efficient design strategies with the aim of reaching the nearly-zero energy target. The success of these strategies is now heavily dependent on how the occupants interact with the building, or rather, on the energy-related lifestyles they assume. In line with this, the present study employs building simulations to demonstrate the potential impact of different occupant behaviour lifestyles on the energy use of a Mediterranean (i) residential nearly-zero energy building (nZEB) under-construction and a (ii) Reference Building (RB) whose envelope-driven loads dominate the consumption profile.

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1. Introduction

Energy-related occupant behaviour in buildings is a key aspect for building design optimization, energy diagnosis, performance evaluation, and building energy simulation due to its significant impact on real energy use and indoor environmental quality in buildings [1]. Human actions affect the real building energy use directly and indirectly by

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regulating the heating and cooling set-point, the ventilation rate, the window blind position, turning on/off or dimming lights, turning on/off equipment, and setting indoor thermal, acoustic, and visual comfort criteria. A variety of internal and external factors drives the human to interact in a certain way with the building and its systems [2]. Various field studies measured the impact of occupant-driven parameters on energy consumptions in residential buildings means to data gathering setups and monitoring campaigns [3,4]. The outcomes showed large discrepancies in the effect of occupant behaviour among houses in a community and across communities, with corresponding large impacts on energy use. In detail, some studies have shown that the behaviour of the household members may lead to differences in energy consumptions of over 300% [5,6]. Therefore, the consideration of occupant behaviour becomes a crucial aspect and should be addressed accurately as standard practice in low-energy design and post-occupancy behavioural change programs.

Promoting and achieving energy-conscious behaviour among households is indeed a key issue for reducing energy consumptions in the residential sector [7]. Outcomes from domestic behavioural change programs at national level [8] and worldwide [9] showed an energy saving potential around 15 to 18% by raising the awareness of the building occupants in homes.

Furthermore, in the past 20 years, more stringent energy codes and environmental standards have led to energy efficient design strategies in the building sector in order to reach the nearly zero energy target. Indeed, the technological solutions for the building envelope and the efficiency of the building systems were optimized and now the success of these high performing buildings are heavily depend on how the occupants interact with them [10]. In this context, the unpredictable loads generated by the users gain greater influence than in buildings whose envelope-driven loads dominate the consumption profile [11] and stakeholders of energy behavioural change programs might have to focus on different key aspects depending on the energy performance levels of the building.

In line with this, this paper aims to stress the urgent need of more solid occupant behaviour reference models and to show how the impact of human-related factors on the building energy use might change by assuming different levels of building energy performance. In particular, three occupant behaviour lifestyles were assumed: low consumer (LC), standard consumer (SC), and high consumer (HC). These lifestyles were established by considering six different types of occupants' interaction with the building system regarding the (a) regulation of heating and cooling set-points, (b) energy use for equipment, lighting and domestic hot water (DHW), (c) ventilation rates, and (d) regulation of window blinds. This study wants to highlight the behavioural patterns that mostly influence the energy use with regard to the energy performance levels of the building and consequently to identify key variables that should be mainly addressed by decision-makers of behavioural change programs in low and high performing buildings.

2. Methodology

This study deploys EnergyPlus (version 8.4) simulations [12] for describing the effect of the occupant-driven variables on the building energy performance of a (i) residential nearly-zero energy building (nZEB) under-construction and a (ii) "traditional" Reference Building (RB) whose envelope-driven loads dominate the consumption profile. In detail, the characteristics of the RB are established by using the same geometrical model of the nZEB, but considering different performance levels of the building envelope and the HVAC systems.

The weather conditions of Turin are considered, based on the Italian Climatic data collection Gianni De Giorgio (IGDG) Weather for Energy Calculation database of climatic data [13].

2.1. Case study

The case study (Figure 1) represents an Italian significant design experience of a residential 147-m^2 nZEB [14], the so-called CorTau House, in which the architectural quality in the refurbishment of a traditional rural building is combined with high-performing energy solutions [15]. The design is based on bioclimatic principles and the strategies adopted consist of a strongly insulated building envelope characterized by an exterior layer made of high density rock-wool panels (λ =0.037 W/mK; ρ = 150 kg/m^3). Windows are composed by aluminium frame with thermal break with low-e triple-pane glass with argon. With regard to the building primary system, a controlled mechanical ventilation (CMV) system with heat recovery and dehumidifier is combined with radiant floors for space heating and cooling in all rooms. Space heating and cooling is provided by a water-to-water heat pump, which also supplies DHW production.