

Chapter 2

Importance of Energy Prevision Accuracy for Zero-Energy Buildings

Abstract The energy-related attitude of occupants can cause big variations between real and predicted building energy consumptions. Such discrepancies have been found especially high in nZEBs and energy-efficient buildings. Considering that actual regulations impose the nZEB target and that in such optimised contexts users' actions have a considerable impact, a comprehensive knowledge of occupants' behaviours should be the main goal of the building sector to effectively reach the expected performance. In this perspective, this chapter firstly analyses the human-building interactions in nZEBs, by focusing on the energy implications of their attitudes. Then, nZEBs' performances are investigated and reasons for the operation gaps are highlighted. Finally, literature results from energy simulations are reviewed to evaluate the influence of different users' energy attitudes.

2.1 Introduction

Users' presence and behaviours have considerable consequences on building energy performance [1]. In fact, the actions and the management the occupants take are the main reasons for energy consumptions [2–4]. In low-energy buildings and, in particular, in nZEBs the strategies applied to the envelope and the systems in order to optimise the energy use, produce a delicate balance. In such contexts, people's direct (e.g. devices' adjustments) and indirect (e.g. thermal loads) influence assumes an increasing influence [5] and the prediction of their behaviours is even more complex [6].

Accurate forecasts of building performances are of primary importance since the building sector is unavoidably moving towards nZEB constructions in relation to both public and private buildings.

The EPBD, 2010/31/EC [7], which regulates the imminent diffusion of nZEBs, also reports the unique standardised definition of these buildings. The directive describes such construction typology as the one concerning buildings with very high energy performance, where the nearly zero or very low amount of energy required should be extensively covered by renewable sources produced on-site or

nearby. Despite this definition, the EPBD neither prescribes a common approach to implementing nZEB nor describes the assessment categories in detail. For these reasons, each country has established different parameters in their own definition.

In most countries, the nZEB definition refers to maximum primary energy as one of the main indicators. In a few cases (e.g. the Netherlands), the primary energy use of the building is assessed through a non-dimensional coefficient, comparing the building's primary energy use with a "reference" building with similar characteristics. In several countries (e.g. the UK and Spain) carbon emissions are used as the main indicator, while in others (e.g. Austria) carbon emissions are used as a complementary indicator to primary energy use.

The nZEBs offer as a further step in comparison to green buildings since they are usually characterised by high-performance envelopes, ad-hoc designed systems and on-site energy production and recovery, targeting at a considerable reduction of energy consumptions.

All these features make that the human component has a greater weight in such buildings than in standard ones and, as a consequence, it usually causes larger discrepancies in the predicted error for energy consumptions [8]. While the average error in standard buildings is roughly 30% [9], studies have found differences up to 50% between design evaluations and measurements in nZEBs [10].

The following sub-sections report findings from previous studies that highlight the importance of the human factor in the specific case of nZEBs. Starting from a discussion on the interactions between the users and the building (Sect. 2.2), it is underlined how people affect building's performance referencing to results from both surveys (Sect. 2.3) and simulations reported in the literature (Sect. 2.4).

2.2 User-Building Interaction

People's reactions to discomfort can lead to opposite consequences in buildings performances. Wise and conscious users' behaviours can aid the building to perform as well as possible, conversely, wasteful actions can cause relevant energy increases.

In fact, when people feel discomfort, they can operate three different types of adaptations: environmental, personal and psychological [11]. The first one is the most tangible and it concretely influences the indoor environment since it concerns the modification of the devices' status (e.g. windows, fans). The general impact of the second type of adaptation is more limited because it strictly regards the single person (e.g. modify the clothing level). Finally, psychological adjustments are the less effective because they are related to the management of emotions, forcing an adaptation to the existing problems (e.g. ignore the problem) [12].

Among these strategies, only environmental modifications have a direct energy impact. However, some of them can quickly restore users' comfort but can be extremely inefficient in the energy perspective, dramatically affecting the energy consumptions. Researchers recorded many and frequent wasteful building

operations that led to energy wastes by the heating, mechanical and electric system [13]. For example, Lindén et al. [4], reporting results from a survey of 600 households, discovered that only 17% of the subjects turn off lights when leaving a room and 40% air daily during wintertime.

However, in energy efficient buildings, users seem to pay more attention to their behaviours. In fact, researchers [11] found that occupants of such buildings are used to make less environmental and more personal adjustments to restore their comfort in comparison to their counterparts in standard buildings. It has been suggested that these greener actions could be a consequence of knowing to be in a certified and low-energy building [14].

2.3 Surveys on NZEB Performance

Since the expectations in relation to nZEBs' performances are extremely high both in the designers and the final users' perspectives, many researchers evaluated whether the design promises have been maintained.

Unfortunately, there is not a homogeneous response. In fact, some studies [10, 15] observed very good performance of low energy buildings since they have satisfactory indoor environments (e.g. ventilation requirements and temperature levels), use low energy and make users in a positive mood. On the contrary, other researchers [16, 17] underlined that to have an energy certification or to match the design requirements of nZEB are not always synonyms of good performance and excellent environment. Thermal conditions, in particular winter air temperature, have been advised as problematic issues [18]. Inadequate IAQ has been observed too [19]. In fact, the envelopes' tightening, drastically reducing the infiltrations, lead to a decrease in air quality whether the ventilation system does not correctly perform. Such problems are also a consequence of the lack of precise regulations to guarantee healthy environments.

Such divergences among the studies highlighted that the design evaluations often do not match the real ones, both in terms of IEQ and energy use. Researchers [10, 15, 20] that tried to understand the reasons that contribute to increasing the discrepancies between the design and the real assessments in nZEBs, suggested that the gap could be due to:

- Wrong assumptions during the design phase;
- Initial problems due to advanced energy-efficient technology;
- Peculiar users' interaction with building components;
- Uncertainty of building simulations in relation to input data and occupants' behaviours;
- High variability of users' behaviours due to psychological component.

All of the above-mentioned reasons provide to broaden the performance gap [17] but those connected to incorrect assumptions on users' personal and environmental

adjustments have the greatest impact on the design, the simulation as well as the building operational phases. For this reasons, it is really important to estimate, in particular, the weight of the human component to improve energy and environmental performances. In recent years the international attention moved in this direction, promoting several projects concerning occupants' behaviours in the built environment [21, 22].

2.4 Simulations' Results

Simulations have been widely used to evaluate the building performances and also to estimate the impact of occupants' behaviours.

Discrepancies between real and predicted energy consumptions have been assessed along different building uses, locations and typologies [23, 24]. However, the identification of the energy performance gap in high performance buildings is even more relevant for the target these buildings should reach and for the clients' economic investments [25].

Large deviations between real and simulated results have been identified by several researchers. A mean discrepancy of about 20% has been assessed through the comparison between actual and simulated energy uses of a representative stocks of LEED-certified buildings (i.e. 11 samples) [26]. Evaluations on a wider sample (i.e. 21 buildings) [27] highlighted a very small difference between actual and simulated performances among the buildings. However, a very high standard deviation (i.e. 46%) along the sample has been recognised: such variability is the sign of a big divergence in the performances of buildings with the same level of certification.

Further studies focused also on the effects of different users' attitudes on the building performance. It has been demonstrated that users' behaviours and management can significantly deteriorate the building performance and the energy generation [28]. Similarly, evaluations of the impact of different occupants' lifestyles in the nZEB context, showed that people are the key point of nZEBs' success [29]. In fact, if their management is wasteful, it is impossible to reach the nZEB target even if the building is of high performances.

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