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How peers' personal attitudes affect indoor microclimate and energy need in an institutional building: Results from a continuous monitoring campaign in summer and winter conditions

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ABSTRACT

Occupants' behavior can significantly affect building performance, in particular in massive institutional buildings occupied by a wide variety of users. This work aims at highlighting the importance of peers' personal attitudes in determining building thermal-energy, lighting performance, and openings' schedule. A university building located in central Italy was selected. Different rooms with equivalent end-use, geometry, exposure, construction characteristics, occupancy, and appliances were considered. Occupants could be considered as peers, since they carry out the same job and schedule and have the same education and age. Nevertheless, they presented different attitudes and thermal perception, therefore producing different energy need. In order to assess peers' behavior, office rooms were continuously monitored in terms of indoor visual-thermal comfort parameters, electricity consumption, and door/window opening rate in spring, summer, and winter conditions. Occupants' attitudes were compared by considering also the outdoor climate conditions. Results demonstrated that occupants' individual behavior represented a key variable affecting building management of large buildings even if the occupants can be theoretically assumed to be "peers". Significant discrepancies were found between the monitored rooms, demonstrating that typical peers do not behave the same at all, but require differential energy needs that should be considered while predicting thermal-energy and lighting behavior of massive institutional buildings.

1. Introduction

In recent years, the global world energy use has rapidly increased, taking building energy consumption to the levels of transport and industry and even more [1]. The main reasons for this deep change lives in the broad population growth, the increase of building services and comfort levels, and obviously, the rise of time spent indoor. In particular, commercial and institutional buildings, which include a wide variety of energy appliances and uses, have expanded their energy consumption from 11% to 18% from the 1950s in the USA, while the European average, accounted for around 11% of all final energy use in 2004 [1]. Therefore, the environmental effects of the building stock could be significantly improved by increasing the energy efficiency of functional buildings, i.e. using less energy for heating, cooling, lighting, and other appliances, without affecting human health and comfort conditions [2]. The spread of building energy efficiency truly is a key issue in the European strategy for smart and sustainable growth [3], in fact, the European Directive 2010/31/EU (EPBD) requires the energy refurbishment of existing building stock and the construction of all new buildings to be Nearly Zero Energy by 2020 [4]. When public buildings are considered, the above-mentioned deadline is moved up to the end of 2018, confirming the strategic role played by these buildings in the European energy context. Institutional buildings are asked to be a model of good practice in the context of sustainable building development. Moreover, in educational and research buildings occupants spend the most of their daytime doing sedentary intellectual activities that require specific indoor comfort conditions [5]. Given these considerations, a large amount of literature faces the improvement of the energy efficiency of commercial and institutional buildings, and usually focuses on technical approaches. Lin and Hong [6], for example, investigated the impact of factors such as indoor temperature set

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Fig. 1. (a) Picture and (b) plan view of the monitored institutional building in Perugia, Italy.

Fig. 2. Typical indoors of a monitored office room.

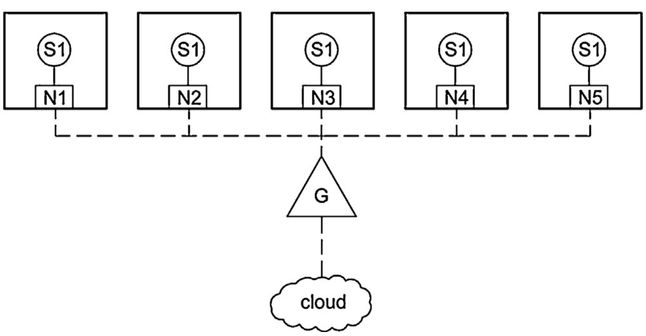

Fig. 3. Scheme of the positioning of the Wireless Sensor Network inside the 5 monitored offices (N = nodes, S = sensors, G = gateway, 1–5 = monitored rooms).

point, air infiltration, building type, and climate on the variation of space-heating energy use in office buildings. Furthermore, a large number of researches develop active and passive methods for reducing the energy demand of HVAC systems. Passive methods generally concern heat loss reductions through improved insulation of the building envelope [7,8]. Active methods tend to improve or upgrade the building components, e.g. by means of energy and emission analysis of institutional building chillers [9,10].

A thermal-energy efficient and sustainable design of institutional buildings, however, can only be obtained by factoring several parameters, such as the interaction between indoor and outdoor environment and building end-use and operational processes. Among the parameters to be taken into account, occupants' behavior is a key factor influencing its thermal-energy performance. In fact, human attitudes and habits in interacting with system controls and building envelope are widely recognized parameters affecting building indoor microclimate and energy needs [11–14]. They can also significantly alter the effectiveness of well-acknowledged energy efficient retrofit solutions [15,16]. Therefore, both technical and human based parameters have to be taken into account in the achievement of building energy efficiency. In this view, Chen et al. [17] carried out a statistical survey and a one-year monitoring in residential buildings in order to define three-levels of systematic definitions of occupant behaviors. Similarly, Hong et al. elaborated a framework of Drivers, Needs, Actions, and Systems (DNAS) to standardize energy-related occupant behaviors in buildings [18] and developed a schema to be used for the implementation of such DNAS framework into building simulation tools [19].

Accordingly, predictive tools for studying thermal-energy performance of buildings should take into account even the personal variation of behavioral attitudes, together with classic occupancy schedules [20,21]. In order to overcome occupant behavior modeling uncertainty, O'Brien and Gunay [22] proposed a robust design method to model people's adaptive actions on daylighting and solar shading in building performance simulation. Fabi et al. [23], instead, collected numerous data from an experimental campaign to verify the predictive accuracy of different existing models of window opening in buildings. Still considering occupants' manual control of solar shades, Yao et al. [24] elaborated a stochastic model to be coupled with EnergyPlus dynamic simulation software for co-simulation purpose. The obtained results showed that infrequent and unappropriated use of solar shadings in office buildings was found to contribute to the decrease in indoor thermal comfort.

On the other hand, aware and green occupants' attitudes can be considered as possible energy retrofits, especially in those buildings where other invasive and expensive energy retrofits are unachievable [25,26]. Therefore, people should be educated to sustainable behavior in order to achieve overall energy efficient buildings. To this aim, eco-feedback is a widely diffuse practice based on providing to individuals or groups of users' feedbacks on their energy behaviors and possible negative consequences aiming at increasing their environmental impact awareness [27]. A novel eco-feedback system was investigated by Gulbinas and Taylor [28] who showed the influence of organizational network dynamics in energy conservation among commercial office building occupants. Moreover, they demonstrated the diverse impact of eco-feedback in office buildings compared to residential buildings. Assessing various feedback types, Kamilaris et al. [29] analyzed the response of different office employees in a university building to individual feedback on energy use at the work-desk finding aware use of appliances and energy reduction until 13 weeks after the feedback removal. Nevertheless, simply informing people on their consump-