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Occupancy-based lighting control in open-plan office spaces: A state-of-the-art review

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ABSTRACT

Lighting accounts for a significant amount of electrical energy consumption in office buildings, up to 45% of the total consumed. This energy consumption can be reduced by as much as 60% through an occupant-dependent lighting control strategy. With particular focus on open-plan offices, where the application of this strategy is more challenging to apply due to differences in individual occupancy patterns, this paper covers (1) to which extent individual occupancy-based lighting control has been tested, (2) developed, and (3) evaluated. Search terms were defined with use of three categories, namely 'occupancy patterns', 'lighting control strategy', and 'office'. Relevant articles were selected by a structured search through key online scientific databases and journals. The 24 studies identified as eligible were evaluated on six criteria: (1) study characteristics, (2) office characteristics, (3) lighting system characteristics, (4) lighting control design, (5) post-occupancy evaluation, and (6) conclusions, and this was used to answer the research questions. It was concluded that the strategy has not been tested yet with field studies in open-plan offices, but that it needs further development before it can be applied in these type of offices. Although lighting currently tends to be controlled at workspace level, many aspects of the strategy can be further developed; there is potential to further increase energy savings on lighting within open-plan office spaces. Individual occupancy-based lighting control requires further validation, focussing on the factors influencing its energy savings, on its cost effectiveness, and on its acceptability for users.

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1. Introduction

Artificial lighting accounts for a significant fraction of global electrical energy consumption. In office buildings in particular, lighting comprises 20–45% of their energy consumption [1]. To promote energy savings on lighting use, aside from the use of more energy efficient luminaries such as LEDs [2], various lighting control strategies have been designed and implemented in office buildings. Examples of such strategies include daylight-linked automatic lighting control, dimming control and occupancy-based lighting control. Linking a light system with occupancy sensors is a cost-effective and easy solution for reducing lighting energy use. Their implementation has been demonstrated successfully in a number of studies, where energy used for lighting has been reduced by between 20% and 60%, depending on the configuration, type of space and type of occupancy sensor used [3–5]. Occupancy-based lighting control has been extensively studied in the private, single user office as this formed the dominant office type for a long time. However, in the 1950s, open-plan offices were designed and adopted by many companies in the 1970s [6]. Due to buildings' average age of 50 years, open-plan office spaces still tend to prevail in commercial office buildings [7]. In these type of office spaces, occupancy-based lighting control still encounters some challenges. Such offices are shared by employees who differ in their occupancy patterns in multiple aspects, from arrival and departure times to the number and duration of breaks during the day [8–10]. These differences are likely to increase even more due to the introduction of flexible working styles that allow employees more flexibility in their working times and working location [11]. In addition, desks no longer belong to one employee, but can be used flexibly by everyone [12]. Consequently, occupancy patterns of workspaces also vary from day to day. As a result, it becomes more challenging to fully align lighting use with the real-time occupancy of the individuals within the open-plan office, or in other words, to establish ‘optimal lighting use’. In these type of offices it is also more difficult to account for the individual lighting preferences of all the occupants, but this falls outside the scope of this paper.

Because occupancy-based lighting control strategies play an important role in the reduction of the energy consumption of offices, their state of art has been reviewed by several studies over the years [13–15]. Haq and colleagues [13], for example, provided an overview of the occupancy detection techniques currently available, the amount of energy they can save on lighting and the factors affecting their performance. Guo and colleagues [14], on the other hand, provide an overview of the energy savings that earlier studies found to result from the implementation of occupancy sensors. Although both studies state that energy can be saved in irregularly occupied spaces, like open-plan offices, they pay only limited attention to the application of occupancy-based lighting control in these type of spaces. They do not distinguish them from private, single user offices, although open-plan offices need a different approach to establish optimal lighting use. Within open-plan offices, three different lay-out types can be distinguished, namely (1) cubicle lay-out with high partitions (1.524 m or higher), (2) cubicle lay-out with low partitions (1.524 m or lower), and (3) open lay-out with no or limited partitions (after Kim and de Dear [16]). In this paper, the term multi-occupant office will be used when referring to all types of open-plan offices and the term open-plan office when