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# A review on lighting control technologies in commercial buildings, their performance and affecting factors

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ABSTRACT

Lighting constitutes a significant portion of building energy consumption. Automatic lighting control systems reduce energy consumption by decreasing operating time of lamps based on various factors like occupancy, time of day, availability of daylight. Various technologies exist that perform lighting control. These technologies differ in their input parameters, their control method, control algorithm, cost of installation, complexity of commissioning, etc. Each of the control schemes has a unique set of factors that affect their performance in terms of energy savings as well as user acceptance. This paper aims to investigate the various control system types, the development of their associated technologies, the savings reported from their application and the factors affecting their performance.



**Contents**



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## 1. Introduction

Energy efficiency is one of the main focuses of research in electrical engineering at the present time. The increased attention and study to identify more efficient and smarter ways to use electrical energy comes directly from the growing need to conserve dwindling global resources, as well as growing concerns over the environmental impact of the conventional energy sources. A decreased use of energy means less to pay for energy bills, reduced load on the grid and less environmental impact. Lighting is the most common and naturally the most constant form of load. It represents a significant portion of the total electricity consumption all building types, and it is more prominent in commercial buildings. For example, according the US Department of Energy, lighting load represents 14% energy consumption in commercial buildings on average [1]. Other studies show that average lighting load can be significantly higher in some cases [2]. A European study shows that in case of medium and large buildings, about 40% of the total electricity is used for interior lighting [3].

Commercial buildings hold great importance when it comes to energy consumption. Out of the total primary energy requirement of the United States, for example, over one-third is consumed by commercial buildings [2]. If office buildings are considered separately, the contribution of lighting energy demand on overall energy consumption can be 25–35% [4]. So, reduction in lighting load in commercial buildings can have significant positive impact in decreasing the electricity demand, which in turn helps reduce carbon footprint [5,6], which is a key focus for energy engineers at the current time. Taking the energy impact of lighting systems into perspective, various governments, international and regional organizations promote specific energy saving guidelines for lighting systems [7,8]. Hence researchers have been continuously thriving to achieve better efficiency in lighting, which means maintaining optimum lighting conditions using as less energy as possible.

Research shows significant savings from various types of lighting control schemes [9]. Manual lighting controls depend mostly on occupant behaviour, occupancy patterns, and general awareness about energy saving [10]. At the user level, lighting installations can be controlled by different types of switching systems. The basic conventional switching systems provide simple on and off options. Dimming regulators provide the users with the option to dim the intensity of the lamps, but in that case the lamps must be controlled by dimmable ballasts. More advanced electronic switches can be programmed to operate in different ways like toggling or changing intensity in steps. Advanced building automation systems provide more flexibility in terms of control by the user, as they offer the ability to implement computer controlled lighting systems. In such cases, the users can control the brightness level and other parameters right from their computer screens. Further, products are now entering the market, which allow to be controlled over internet communication using smartphone apps. These technologies provide new flexible ways to control the lighting scenarios for the user. But when it comes to automation of the switching or dimming process of the lights, there are several different technologies that work beyond the user end. These technologies vary based on the parameters they consider for the control of the lamps. This paper aims to discuss these technologies.

Automatic schemes vary a lot in technology and complexity. In a basic level, the automatic controls can be used to switch on or off the lights, and on a more precise level they can control the level of illumination based on requirement [9]. It needs to be remembered that any control scheme may not be suitable for application for any type of task. Different workspaces have different lighting requirements and widely varying occupant behaviour. Choice of lamps, luminaries and control schemes must be guided according to those requirements to ensure occupant satisfaction and productivity [11]. To successfully select the right lighting technology, the occupant behaviour of every type of room or building based on their type of activity must be surveyed. This occupancy pattern will then provide a picture about how the occupants of the room really use the energy in those spaces [12].

Including the pattern of usage by occupants, there are several other factors that affect the performance of control systems, and these factors may be particular to a certain type of control system. For instance, for occupancy sensors, time delay setting is a key issue which can have an impact on their performance; while for daylight-linked systems, choosing between switching and dimming or between open and closed loop algorithm can be decisive in the success of the implementation. Since each of the control systems uses different parameters in order to control the lighting, the affecting factors of these technologies are also different. Failure of properly understanding these affecting parameters can lead to improper commissioning of the lighting control systems and thus to unsatisfactory energy saving performance and poor user satisfaction. Hence, this literature review aims to investigate the affecting factors for each of these control strategies and review published works of research to determine the impact of changing these factors on the energy saving performance of the lighting control systems. The paper also discusses about current developing trends in lighting control and possible future work that can be achieved in this field.

### 1.1. *Reducing lighting energy consumption*

The factors that affect the overall energy consumption of the lighting system can be understood from the basic equation of electrical energy consumption:

$$W = P*T \text{ Watt hour (W h)} \tag{1}$$

where $P$ is the installed lighting power in Watt (W) and $T$ is the operating time in hours (h). It is obvious that energy consumption W can be reduced by reducing either or both of the factors $P$ and $T$.

Installed lighting power ($P$) can be reduced using more efficient lamps. An efficient lamp produces adequate amount of lighting output (lux) using as less power input as possible. The lux to watt ratio of lamps is called luminous efficacy. The higher the luminous efficacy of the lamp, the more efficient it is in using its input power. By using lamps with higher luminous efficacy, the overall lighting load can be significantly reduced. The lighting load can also be reduced by proper lighting design. Task lighting method in lighting design provides necessary levels of light where the tasks are performed, while maintaining a lower ambient lux level in other areas.