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Energy Procedia 61 (2014) 928 – 932

Energy Procedia

The 6th International Conference on Applied Energy – ICAE2014

# Analysis of the effect of artificial lighting on heating and cooling energy in commercial buildings

Byung-Lip Ahn[a,b], Cheol-Yong Jang[a], Seung-Bok Leigh[b], Hakgeun Jeong[a]*

[a]*Energy Saving Laboratory, Korea Institute of Energy Research, 152 Gajeong-ro Yuseong-gu, Daejeon 305-343, Republic of Korea*
[b]*Dept. of Architectural Engineering, Yonsei University, 50 yonsei-ro, Seodaemun-gu, Seoul 120-749, Republic of Korea*

**Abstract**

In relation to recent attention focused on the use of energy by lighting, there is a large potential for commercial buildings to save energy in this respect. The use of energy-saving bulbs or dimming controls triggered by daylight, not only enables lighting energy saving, but delivers cooling energy through a reduction in indoor heat production. In this study, we examine the energy use in commercial buildings by evaluating lighting energy saving methods and the effect of using dimmer controls with a heat control method, which can both maximize the cooling load reduction during summer and save energy. Results show that the total energy from the reference commercial building was reduced by 20.9% by replacing LFL T12 bulbs with LEDs, together with an additional saving of 19.9% in cooling energy by using the lighting heat & dimming control method.

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*Keywords:* Building energy, Heating and cooling loads, Lighting energy, LED lamp, Lighting heat, Luminance efficiency

## 1. Introduction

The consumption of energy by buildings in developed countries comprises 20–40% of a country's total energy used, and there is an average annual growth of commercial buildings of 2.4%.[1] The source of primary energy use various between commercial buildings depending on the year of their construction.[2] Although heating energy consumes over half the total energy used in vintage buildings (due to poor insulation envelopes and HVAC utilities), there has been an increasing trend in the amount of lighting and cooling energy used in modern buildings constructed in the 2000's, and a decreasing trend in the amount of heating energy used. This is related to the high energy efficiency of the building design, and to the use of thermal materials and efficient HVAC utilities, which are progressively being introduced to the market to

* Corresponding author. Tel.: +82-42-860-3127; fax: +82-42-860-3202.
*E-mail address:* hgjeong@kier.re.kr.

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Peer-review under responsibility of the Organizing Committee of ICAE2014
doi:10.1016/j.egypro.2014.11.997

inspire energy savings to combat increasing fuel prices and climate change issues.[3] This indicates therefore, that there is a large potential to save energy in relation to lighting in modern commercial buildings, as even though high-luminance lamps have been developed, lighting energy represents the largest amount of energy used in this setting.

In this study therefore, we compared lighting energy saving methods and the effects of these methods on the amount of energy used by buildings for various climate zones. In addition, we compared the effect of the lighting heat control method which can maximize the heating and cooling load reduction with other lighting control methods.

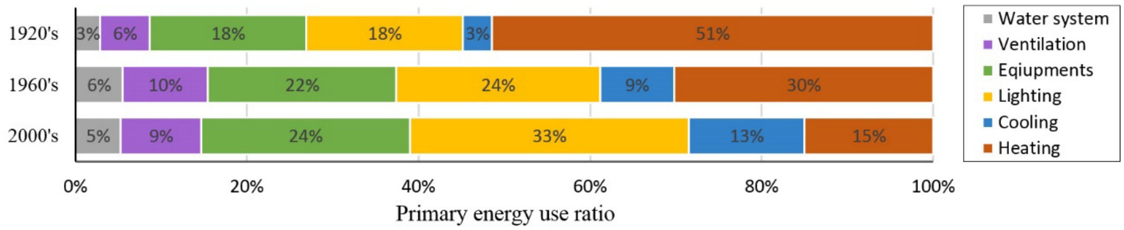


Fig. 1. Ratio of the primary energy use of commercial buildings according to the year of construction

## 2. Methodology

### *2.1. Overview of lighting energy saving methods*

The general method used to effect lighting energy saving is via bulb replacement with high-luminance lamps, such as linear fluorescent (LFL), or light-emitting diode (LED) lamps. The efficiency of LFLs is reported to be 5 times greater than that of traditional lamps, including incandescent and halogen lamps, and the replacement of existing lamps with LFLs with an efficacy of 80 lm/W would therefore reduce the total energy requirements for lighting by up to 35%[4]. However, current predictions are for LEDs to predominate by 2035. The light efficacy of LEDs is increasing very quickly, and white LEDs with a light efficacy of 110lm/W will be available by 2015.[5] Furthermore, since LED lamps emit 25% visible light from an LED-chip, and 75% in convective heat from the heat sink (thereby increasing indoor heat gain), the use of lighting heat control methods could reduce the additional indoor cooling loads.[6].

A light dimming control using the presence of daylight, or an on/off switch when the building is occupied, could therefore reduce the amount of lighting energy used, and recent research has shown that daylight-linked lighting control systems have the potential to reduce the electrical energy consumption in office buildings by as much as 30–60%.[7]

### *2.2. Energy simulation of reference building*

To analyze the impact of lighting energy saving methods on the heating, cooling, and lighting energy consumption of commercial buildings, our study was applied to the Commercial Reference Building Model, which consists of a core zone with four perimeter zones on each floor (as provided by the U.S. Department of Energy) using the simulation program, EnergyPlus.[8] To compare the effect on buildings with various patterns of energy consumption, we assumed that the reference building was located in three climate zones: Hot & Humid (Huston), Mixed & Humid (Baltimore), and Cold & Dry (Minneapolis). As a baseline case, to evaluate the energy saving effects of replacing the LFL T12 with new lamps, we applied the lighting fixtures LFL T8, T5, and LED lamps, with a light power density (LPD) ranging from 8.0 to 13.3 W/m$^2$. The effects of using daylight as a dimming control in perimeter zones, was also computed with the LED light heat control method.

Table 1. Input parameters for reference commercial building

| Climate zone | Construction (W/ m²K) | | | | Window-wall ratio | Conditioned area (m²) | Thermostat | |
|---|---|---|---|---|---|---|---|---|
| | Wall | Roof | Floor | Window | | | Heating | Cooling |
| Hot & Humid | 0.70 | 0.36 | 1.86 | 5.84 | 0.33 | 4,982 m² | 21ºC | 24 ºC |
| Mixed & Humid | 0.70 | 0.36 | 1.86 | 3.24 | | | | |
| Cold & Dry | 0.48 | 0.36 | 1.86 | 3.24 | | | | |
| | Lighting fixtures | | | | Illuminance level for dimming control | | Equipment (W/ m²) | Occupancy (m²/ per) |
| | LFL T12 | LFL T8 | LFL T5 | LED | | | | |
| Efficiency (lm/ W) | 60 | 80 | 108 | 110 | 500 lx at 0.8m height | | 10.76 | 10.58 |
| LPD (W/ m²) | 13.3 | 10.0 | 8.0 | 8.0 | | | | |

## 3. Results & Discussion

Table 2 shows the simulation results of heating, cooling, and light energy use in the reference building using lighting energy saving methods (such as replacing old bulbs and using a dimming & heat control). When replacing the LFL T12 with new bulbs, the LPD lowered because the efficiency of the lighting source was higher; thereby causing a reduction in indoor heat gain, and decreasing the lighting and cooling energy use, but increasing the use of heating energy. It is evident, therefore, that in hot & humid region that require a high cooling energy rate, there was a greater effect of total energy saving than in other regions, and the total energy use was reduced by 20.9% as a result of a reduction in the cooling and lighting energy use by 8.4% and 40.0%, respectively. This was achieved solely by replacing the LFL T12 bulbs with LED lamp. However, in the cold & dry region, which requires a higher heating energy rate, the total energy use was reduced by 11.7%, (the lowest saving effect), because the low LPD increases the heating load by 10.0%, even though the lighting energy was reduced by 40.0%.

For the dimming control cases, because fluorescent lamps need at least 50% of the input power constantly for dimming, the LED dimming control case shows a higher saving effect than that of the LFL T5 case, in spite of the similar efficiency of both lamps. For the LED dimming control case in all regions, the lighting energy use was reduced by 19.0% more than in the LFL T5 dimming control case, and the total energy use decreased by 31.6% more than baseline case in hot & humid region.

In addition, the LED dimming & heat control method delivers the highest saving effect of all methods, since the additional cooling energy can be reduced owing to the convective heat from the heat sink of LED lamps being transported outdoors. This saving was particularly apparent in the hot & humid region, where the total energy use decreased by 33.9% more than the baseline case, as a result of the cooling and lighting energy use being reduced by 19.9% and 59.8%, respectively.

Table 2. Simulation results for reference building using lighting energy saving methods

(a) Simulation results of replacement with high-efficiency lighting (kWh/m²·yr)

| **Climate Zone** | **LFL T12 (baseline)** | | | | **LFL T8** | | | | **LFL T5** | | | | **LED** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | H | C | L | **T** | H | C | L | **T** | H | C | L | **T** | H | C | L | **T** |
| Hot & humid | 9.7 | 40.3 | 41.8 | **91.8** | 10.4 | 38.0 | 31.4 | **79.8** | 10.9 | 36.5 | 25.1 | **72.5** | 10.6 | 36.9 | 25.1 | **72.6** |
| Mixed & humid | 24.7 | 22.7 | 41.8 | **89.2** | 26.9 | 21.0 | 31.4 | **79.3** | 28.4 | 19.9 | 25.1 | **73.4** | 27.9 | 20.2 | 25.1 | **73.2** |
| Cold & dry | 53.2 | 13.6 | 41.8 | **108.6** | 56.9 | 12.7 | 31.4 | **101.0** | 59.2 | 12.1 | 25.1 | **96.4** | 58.5 | 12.3 | 25.1 | **95.9** |

(b) Simulation results of dimming & heat control methods (kWh/m²·yr)

| Climate Zone | T8 dimming ctrl. | | | | T5 dimming ctrl. | | | | LED dimming ctrl. | | | | LED dimming & heat ctrl. | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | H | C | L | **T** | H | C | L | **T** | H | C | L | **T** | H | C | L | **T** |
| Hot & humid | 10.8 | 36.7 | 26.2 | **73.7** | 11.2 | 35.5 | 20.9 | **67.6** | 11.3 | 34.7 | 16.8 | **62.8** | 11.5 | 32.3 | 16.8 | **60.6** |
| Mixed & humid | 28.0 | 20.1 | 26.3 | **74.4** | 29.4 | 19.2 | 21.0 | **69.6** | 30.0 | 18.7 | 17.0 | **65.7** | 29.8 | 17.2 | 17.0 | **64.0** |
| Cold & dry | 58.6 | 12.2 | 26.3 | **97.1** | 60.6 | 11.7 | 21.0 | **93.3** | 61.6 | 11.4 | 17.0 | **90.0** | 61.3 | 10.4 | 17.0 | **88.7** |

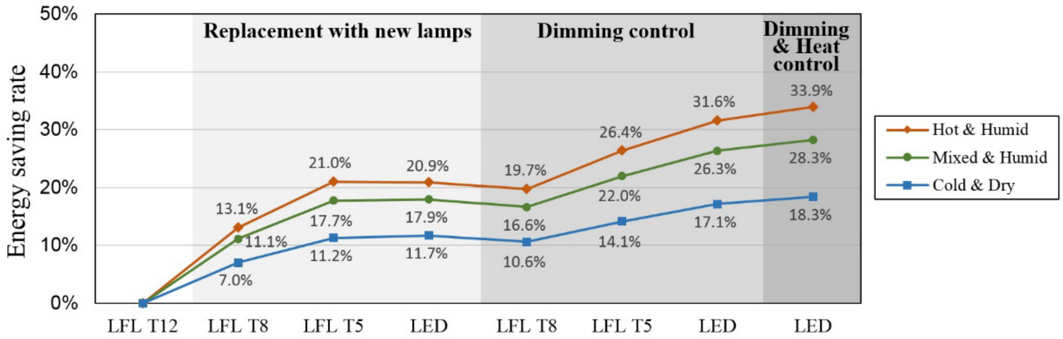


Fig. 2. Energy saving rates compared with baseline (LFL T12) case

## 4. Conclusions

There is a large potential to save lighting energy in commercial buildings, as even though various lihgting energy saving methods have been developed. Lighting energy saving methods affect the amount of cooling and heating energy used, as well as that of lighting energy. In the cold & dry climate zone, which has a high heating energy demand, there was a lower saving effect than in the other climate zones, due to an increase in the requirement for heating. However, in the hot & humid region, which has a high cooling energy rate, the effect of energy saving is higher than in the other regions because there is a simultaneous reduction in energy use for both lighting and cooling. In addition, if the lighting heat control method is used in combination with replacing bulbs and dimming control method, the effect of energy saving would be even higher.

## Acknowledgements

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP) (No.2011-0028075), and conducted under the framework of Research and Development Program of the Korea Institute of Energy Research (KIER)

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**Biography**

Byung-Lip Ahn is currently working for Korea Institute of Energy and doing Ph.D course in Yonsei University in South Korea. He has researched on energy efficiency of buildings, especially, his previous research was about lighting heat control method to reduce cooling and heating loads in buildings.