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An approach for estimating the carbon emissions associated with office lighting with a daylight contribution

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Abstract

A method is proposed for estimating the electricity consumption (and associated carbon emissions) of a defined electrical-lighting configuration in an office building, accounting for the daylight contribution from windows and rooflights. Heat gains due to lighting for an average day in each month may be used to aid assessments of the effect of lighting systems on the cooling load, known to be high for office environments. For a typical 6-storey office building, annual energy savings for lighting of 56–62% and a reduction in CO_2 emissions of nearly 3 tonnes are predicted by changing the lighting and daylighting specifications for a defined "2005" scenario to those of a low-carbon "2030" scenario. The associated reduction in peak lighting-load, and hence heat gain due to lighting, is 3 W/m^2.

Keywords: Lighting; Office; Daylight; Energy; Carbon

1. Introduction

The energy consumption of lighting in buildings is a major contributor to carbon emissions, often estimated as 20–40% of the total building energy consumption [1,2]. Furthermore, the heat gains produced from such lighting have an important influence upon heating and cooling loads. In this context, the Carbon Vision TARBASE programme [3] is investigating the carbon emissions of UK buildings, with the aim of identifying

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Nomenclature

A_g	area of glazing (m^2)
A_s	area of horizontal surface to be illuminated (m^2)
A_T	total area of room surfaces (m^2)
BF	ballast factor of lighting $0 \leqslant BF \leqslant 1$
C	correction factor for glazing due to dust, poor maintenance, etc (see Table 1)
DF	daylight factor, ratio of average internal illuminance to external illuminance (%)
E_e	external illuminance (lux)
E_i	internal illuminance (lux)
H	height of room (m)
L	length of building or room (m)
LED	light-emitting diode
MF	maintenance factor of lighting, $0 \leqslant MF \leqslant 1$
O	orientation factor for glazing (see Table 2)
P	power of lighting (W)
R	average reflectance of all room-surfaces, $0 \leqslant R \leqslant 1$
UF	utilisation factor of lighting, $0 \leqslant UF \leqslant 1$
W	width of building or room (m)
ε	lighting efficacy (lm/W)
θ	vertical angle of visible sky from horizon (degrees)
τ	transmittance of glazing, $0 \leqslant \tau \leqslant 1$
ϕ	luminous flux (lumens)

how technological interventions might reduce emissions by 50% by the year 2030. To define this 2030 scenario, estimations are made with respect to technological and building improvements that, although not necessarily readily available now, should be obtainable within 25 years. The project investigates several building categories such as domestic, office and retail. Within each category, several different types of building are defined that are indicative of that category. For the eight categories of building under investigation, electrical lighting accounts for a substantial proportion of carbon emissions (e.g. offices). Lighting technology interventions have thus been reviewed to identify plausible lighting arrangements for 2030. This paper will concentrate on the interventions for office variants.

As part of the TARBASE building assessment, a technique for estimating the carbon-dioxide savings associated with changing the lighting specifications of a building was required. This has to account for any changes in glazing and in the efficacy of the lighting technology. Using controls for demonstrating the optimised configuration for daylight-supplemented electrical lights is well-documented [4–6], with particular interest on the effect of thermal loads [7], as discussed in Section 5. However, the more advanced, and material-based, solutions [8–10] for optimising daylight are not applicable to the methodology described here. They do, however, provide innovative solutions for reducing lighting-energy consumptions.

With the project considering a large number of buildings, it is important that the approach should be as efficient as possible with regards to the available time [11]. While