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Economic feasibility of maximising daylighting of a standard office building with efficient electric lighting

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ABSTRACT

This paper investigates the cost of developing various daylighting strategies for a standard office building in relation to their ability to reduce electric lighting consumption. The reference building design for this study corresponds to a typical configuration that minimises the construction costs and is typical of the French market. We have compared scenarios that entail moving service spaces to the periphery, increasing ceiling height and adding light wells of various shapes. These special features increased the proportion of the indoor area with sufficient daylight by up to 40%, with an increase of construction costs ranging between 1.3% and 15.5% of the cost of the building. The extra cost of adding light wells was estimated at an average of €344 per work place, or €34 m^{-2} for a standard building with a distance between facades of 18 m. This value has to be compared with typical construction costs of €1500 m^{-2}. Payback time on investment based only on savings on lighting electricity appeared to be far too long (from 41 years to 540 years depending on the configuration tested) for this alone to justify the investment. However, benefits should be assessed in relation to the occupants' well-being, safety in case of an electrical black-out, and rental and resell value.

1. Introduction

When approaching the issue of financial benefits of daylighting techniques, the first dilemma facing us is that the investment in lighting competes with electric lighting installations that require less and less electricity due to the improved efficiency of lamps and luminaires. This reduces the margin of the gains of daylighting solutions if we consider the savings on lighting electricity.

1.1. Trends in consumption for lighting in relation to French regulation

In France, each new energy regulation tends to reduce the maximum electrical power density for lighting that can be installed. A survey of the existing stock of office buildings shows that lighting accounts for 14% of the primary energy required by office buildings [1]. In the French energy regulation from 2000, maximum electrical power density for lighting was set to 16 W/m^2 [2]. The 2005 energy regulation introduced a drastic reduction of global energy requirements, which led to a maximum electrical power density of about 12 W/m^2 [3]. The consequence is that the relative proportion of primary energy requirements associated with lighting was increased to 47% as seen in Fig. 1. Using the 2012 regulation this proportion stabilises between 40% and 50% of primary energy requirements [4]. Thus, since lighting represents the largest part of electricity consumption, it is potentially a relevant field for energy savings.

Once electrical power density for lighting is minimised, the only way to save on electricity used for lighting is by turning off or dimming lights when

(1) Daylight supplies sufficient illuminance levels at location of use.
(2) Occupants are not using the space.

The 2011 edition of the European standard concerning lighting requirements at work places specifies minimum illuminance levels for tasks, the immediate surroundings and the background

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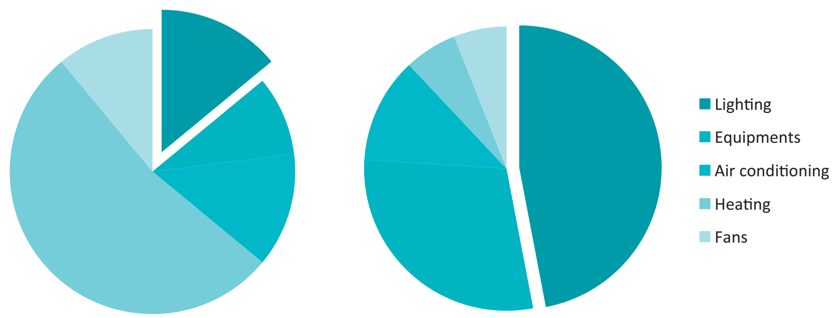

Fig. 1. Proportion of primary energy required for electric lighting, HVAC, equipments in an office building, when global energy performance is improved due to regulations. Existing stock of office buildings and office buildings that comply with the French energy regulation from 2005 [3].

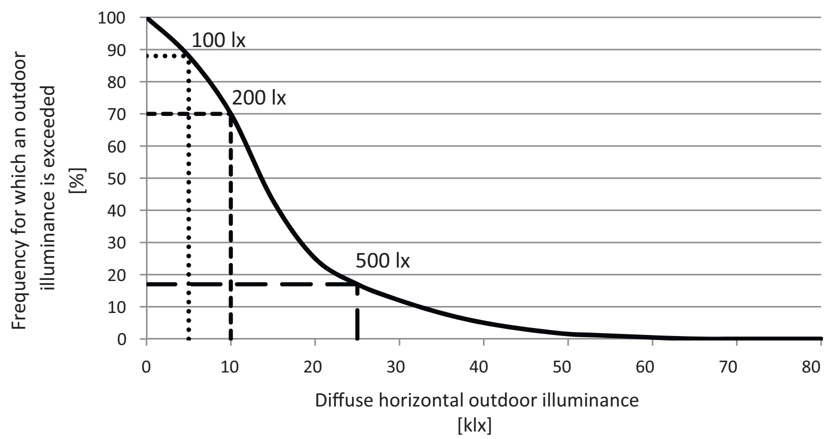

Fig. 2. Graph showing the increase of the threshold frequency for which an outdoor illuminance is exceeded when required horizontal indoor illuminances are decreased from 500 lx to 200 lx and 100 lx at a point where DF is 2%. 8:00–18:00 legal time, Lyon, France [12].

with values equal to 500, 300 and 100 lx, respectively [5]. Obtaining 500 lx with daylight on a surface a few metres from the facade is much less frequent than obtaining 100 lx as seen in Fig. 2. This means that reducing the minimum illuminance requirements on a given surface with a given daylight factor has a direct positive effect on the number of hours per year when the values are exceeded from daylight only. Therefore, the potential of daylight to contribute significantly to providing ambient light (100–200 lx) is much greater than the potential for providing task light (500 lx).

In a former publication, the energy saving potential of task and ambient lighting was identified as one of the solutions leading to lowest lighting electricity consumption [6]. Since the illuminance requirements for ambient lighting are lower than the illuminance requirements for task lighting, use of task/ambient lighting in open-space office should also make the best use of daylight coming from the two facades, since task lamps will satisfy visual needs at task. This approach appears attractive for one who looks for the lowest possible annual lighting consumption.

1.2. Benchmarking of electricity consumption

As a rule of thumb, if one expects to use low electric power for lighting, 2/3 of lighting electricity is used for ambient lighting and 1/3 for task lighting. The share of ambient light may increase in the case of brighter ambient lighting schemes. This suggests that daylighting strategies should focus mainly on the supply of ambient light, since 2/3 of the installed electrical power is used for ambient lighting only, and it is easy to provide low illuminance with daylight. Here is a worked example:

For a work space of 10 m^2 with a single occupant, ambient lighting providing 100 lx on floor and on walls at eye level, requires at least 4000 lm from ceiling luminaries (minimum 40 W), which contributes to 4 W/m^2 over the 10 m^2 office. The task light (500 lx on task, /300 lx on desk), following [5], requires the addition of about 1200 lm on top of ambient lighting, over 3 m^2, requiring the production of at least 2000 lm from the light source (minimum 20 W with LED or fluorescent sources), which corresponds to 2 W/m^2 over the 10 m^2 office.

The above values can be used to estimate annual electricity consumption for lighting. Without taking daylight into account, and presupposing an occupation of the space for 1500 h per year for task lighting and 2550 h per year for ambient lighting (the latter including the lighting requirements outside office hours for cleaning, for instance), we observe that the cost of electricity for lighting is below €2 m^{-2} year for a building located in Lyon, France (see Table 1). The consequence of this low cost is a restricted capacity of return on investment through daylighting strategies.

Table 1
Annual cost of electricity for task lighting (1500 h/year) and ambient lighting (2550 h/year) with no daylight control.

For office space, excluding circulation	Electrical power density [W/m^2]	Annual consumption [kWh$_e$/m^2]
Task light (1500 h/year)	2	3.0
Ambient light (2550 h/year)	4	10.2
Total	6	13.2
Cost estimate (0.15 €/kWh$_e$)		1.98 €/m^2 year