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Investigation of LED Alternatives in Retail Lighting

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Abstract
The recent 2010 Energy Performance of Buildings Directive (EPBD) and the existing UK benchmarks place a high demand on building professionals towards the design of nearly zero energy buildings. The energy consumption for lighting in retail buildings accounts for 40% of the overall energy consumption. Thus, the energy use of the lighting system is one area where significant energy savings are possible.

This paper investigates the effectiveness of using LEDs for general lighting in a typical retail application and is a project conducted under the auspices of the BRE (British Research Establishment). The proposed LED lighting system is designed and simulated in Dialux so as to satisfy the required illuminance levels according to the regulations and at the same time to offer a more energy efficient and cost effective lighting solution. To take this a step further, the integration of a photovoltaic panels system to supply the lighting system is assessed and RETScreen software is used.

Keywords: Lighting, LED, photovoltaic, Dialux, RETScreen

Introduction

Lighting Design is a very important aspect of a building's operation and energy performance. Its main aim is to create the suitable illuminated environment for the task performance in a space by combining artificial lighting with daylight. Therefore, the main target of a light designer is to satisfy the visual needs of the occupants in relation always to safety.

Retail lighting is a combination of three types of lighting: General lighting, Display lighting and Accent lighting. The lighting systems that are usually used today consist mainly of linear fluorescent lamps followed by high intensity discharge lamps and then compact fluorescent lamps (CFL).The energy consumption for lighting in retail buildings accounts for a major percentage of the overall energy use (The Society of Light and Lighting, 2009, pp. 191-197). Therefore, retailers seek to maximize the returns on their investments, since designing, building and maintaining a shop is extremely costly.

This project investigates the effectiveness of using LEDs for general lighting in a typical retail services application. The existing lighting system of the building is assessed and the illuminance levels and energy consumption are defined. These are compared to the current regulation benchmarks and as a result the system is suggested to be replaced by a more efficient LED system. The proposed lighting system is designed so as the delivered illuminance and consequently the interior environment is upgraded. The energy requirements of the LED system are also assessed. The conclusion is that the suggested lighting system is more efficient and better performing, since the visual aspect is improved and the energy consumption and electricity cost of the lighting system can be reduced by more than 50 %.

What should be highlighted is that a photovoltaic panel system installation is also examined, that is meant to satisfy approximately all the energy needs of the lighting system.

The proposed LED lighting system was simulated in Dialux software and a RETScreen study was conducted in order for the photovoltaic panels system to be assessed and sized and for the investment to be financially evaluated. The results are very encouraging concerning the performance of the LEDs and moreover show that almost 85% of the lighting system's consumption can be covered directly by renewable energy.

LED Technology

An LED is a complicate construction with the main component being the diode that is contained in a package (Mohan, Undeland, & Robbins, 2003).For a Light Emitting Diode, depending on the semiconductor material the wavelength of the emitted light and therefore its color varies. Thus, LEDs can emit light of an intended colour without using colour filters (Philips, 2012). In general lighting applications what is the main concern is the generation of white light for the LEDs, which is done by converting the LED emitted spectrum into white light or by mixing two or more discrete emissions. Three procedures can be followed in order for this to be achieved: Phosphor conversion, Discrete colour mixing, Hybrid method (DEFRA, 2009).

LED in Retail Lighting

In the case of retail services LEDs are an ideal choice for the lighting design thanks to the wide variety of characteristics they offer that cover the demands of such a specific design. First and foremost, what is the most significant factor in merchandise is the color appearance of the products. Shoppers should be able to determine the exact color of the merchandise they buy, be it clothes or any other product, and the factor that determines color appearance in lighting is the Color Rendering Index (CRI) and the Color Temperature. The closest the CRI is to 100 the more natural and vivid the colors will appear. The LED lamps offer a great variety of different light temperature lamps with CRIs that are very satisfactory. They present a series of advantages that stimulated their dominance over other light sources.

- They have high levels of brightness and intensity
- High efficiency with low voltage and current requirements
- Low radiated heat
- No Ultraviolet radiation
- Long life and great reliability and endurance
- They can easily be controlled (i.e. dimmed) (Philips, 2012)

LED systems provide much better efficacies than other lighting systems. In retail services stores the 35% of the total energy consumed goes to the lighting system (Department of Energy and Climate Change, 2012) . Thus, they can highly contribute to the decrease of the power consumption.

All in all, they significantly contribute to a successful and efficient lighting design of retail stores by providing the following:

- A uniform and comfortable lighted internal environment that is welcoming
- A good quality lighting system
- An energy efficient lighting system

Methodology
This project is divided into two major parts as far as the calculation process is concerned,

- Current lighting design assessment
- Suggested lighting design assessment

The main target is to model the operation of the current lighting system as well as the operation of the suggested, more efficient LED lighting system. To achieve this, the specialised lighting design software “Dialux” was used, which is a professional lighting design software and is used by most planners and manufacturers in the world (Dialux, 2012).

The current lighting system consists of Linear Fluorescent, Compact Fluorescent and Metal Halide lamps. It is simulated so as to represent the reality and provide the data related to the current illuminance levels and power consumption.

The second part of the design targets to an upgrade of the whole lighting system. This will be achieved by satisfying the requirements set by the lighting regulations and at the same time optimizing the energy efficiency and cost-effectiveness of the system. The first step of this process is to classify the necessary illuminance levels for the parts of the building according to their use. The second step is to conduct a research so as the most adequate luminaires to be selected, whose combination provides the desired light quality (Energy Star, 2012). The chosen luminaires are LED type and a thorough research was conducted so that the proper fittings for each space and space requirements were selected. They were chosen with the basic criterion to satisfy the illuminance standards as set by the regulations and to provide a warm white light that is necessary for retail premises (Holophane, 2004). The luminaires are placed in positions that do not affect the architectural internal design of the space. More specifically, the whole design process has to be very carefully planned. Any extra changes in the tracks that support the luminaires or in the electrical installation, will act additively to the capital cost which is not desirable. In addition to this, the created waste from any renovation or constructional process can cause harm to the environment and also affect the local society.

Results
The total installed power in the shop can be seen in the following table:

Table 1, Installed Power of the Current Lighting System in the main areas of the shop

Area	Installed Power in Sales Area [W]	Installed Power in Fitting Rooms [W]
Ground Floor	9253	1428
First Floor	7779	581

Table 2, Power Density of the Current Lighting System in the main areas of the shop

	Power Density in Sales Area [W/m2]	Power Density in Fitting Rooms [W/m2]
Ground Floor	30.29	41.21
First Floor	35.78	43.68

According to the Code of Lighting suggestions, the illuminance targets and the target for the power density of lighting systems in retail premises so as to be characterised as “good practice” are the following:

Table 3, Targets of average power density for commercial application with particular maintained task illuminances, based on current good practice, source: (Code for Lighting , 2006)

Lamp type	Task Illuminance (lux)	Average Installed Power Density (W/m^2)
Fluorescent	300	7
	500	11
Compact fluorescent	300	8
	500	14
Metal halide	300	11
	500	18

It is thus obvious that the current lighting system is not satisfactory in terms of achieving the power density benchmarks, and this has a negative effect on the building's energy performance.

An average general illuminance of 300 lux and display illuminance of at least 500 lux is necessary so that the merchandise can be properly displayed and the shopper guided through the shop (The Society of Light and Lighting, 2009, p. 191). From the simulation results that are demonstrated in table 4, it can be understood that the current lighting system does not satisfy the illuminance needs of the shop. The areas of main interest are the Sales Areas, where the display and general lighting levels are of great importance and should be provided adequately.

Table 4, Comparison of illuminance levels to benchmarks

Area	E_{av} on the work plane (lux)	Percentage above the 500 lux
Sales Area - First Floor	161	-67.8
Sales Area -Ground Floor	576	15.2

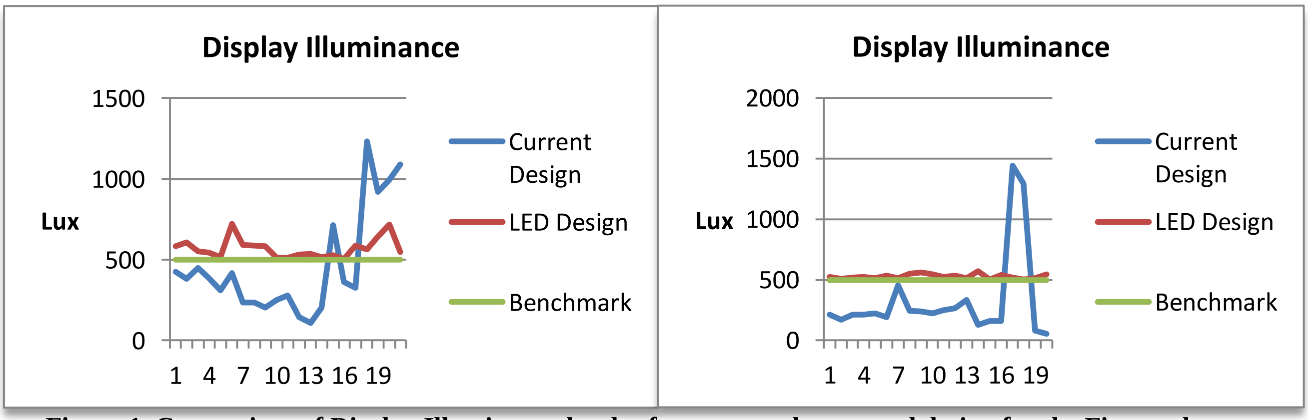


Figure 1, Comparison of Display Illuminance levels of current and suggested design for the First and Ground Floor Sales Areas

It is obvious from the figure 1 that the LED lighting system complies amazingly well with the regulations, and the illuminance results are improved in comparison to the current design. The selected LED fittings were carefully chosen according to their lumen output and their beam form. Wide beam LEDs are preferable to satisfy the general lighting needs, whereas medium or narrow beam LEDs are used in order to satisfy the display lighting needs. The design focused on satisfying the general illuminance requirements in the sales areas and after this was achieved, and an average of 300 lux could be found everywhere, was the turn of the display lighting needs. The strategy that was followed was placing a few extra narrow and medium beam LED fittings and orientating them properly to face the target areas. By positioning them at the adequate tilt the display illuminance of minimum 500 lux was managed and also the smallest possible number of fittings was used.

In figure 4 a comparison between the average illuminance levels of the current and the suggested lighting system for the the Staffroom and the Office areas is demonstrated. In the Staffrooms the merchandise is kept the staff circulates most after the Sales Areas. Therefore, the adequate illumination of the space is of high importance so that the employees can perform their tasks safely. The benchmark illuminance is 300 lux. In the case of the the Office great deviations in the illuminance levels are observed. The current system provides very high light levels in the Staffroom, without that being necessary, and causing excess electricity consumption and dissatisfaction.

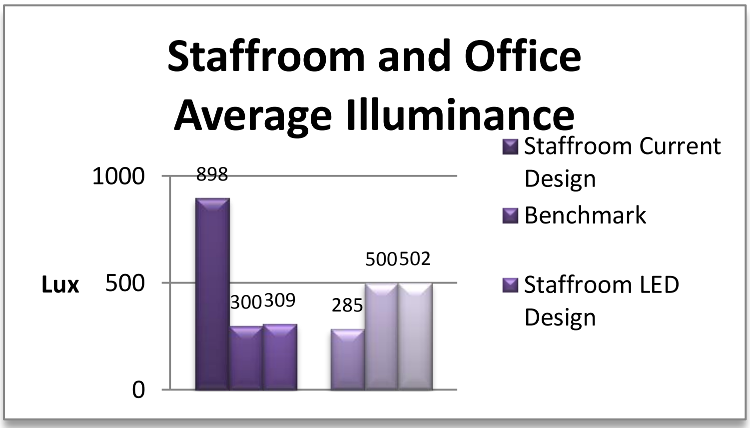


Figure 2, Comparison of the Average Illuminance in the Staffroom and Office

Even though the LED system design suggests more fittings than before, the electricity consumption and costs are expected to be radically reduced

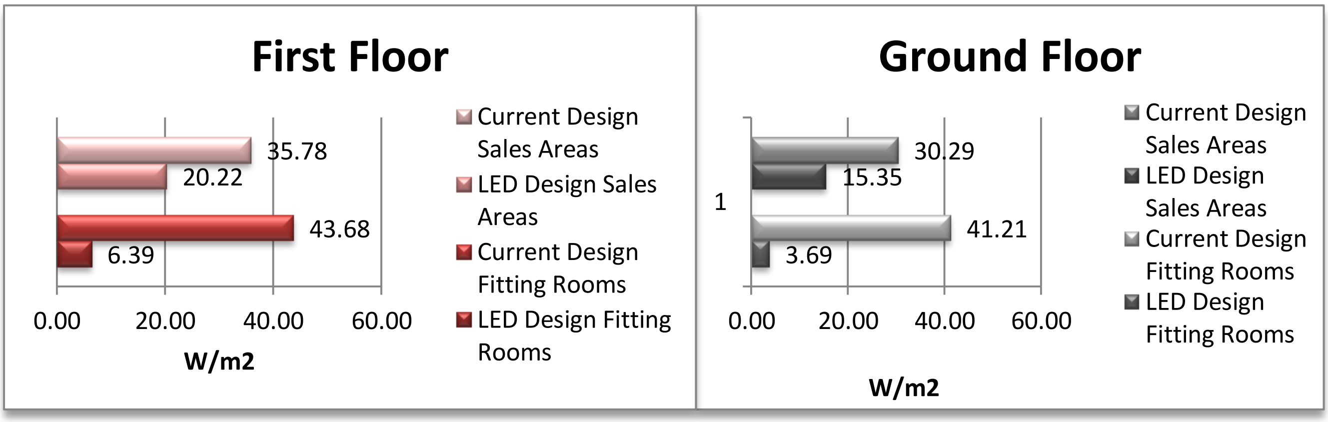
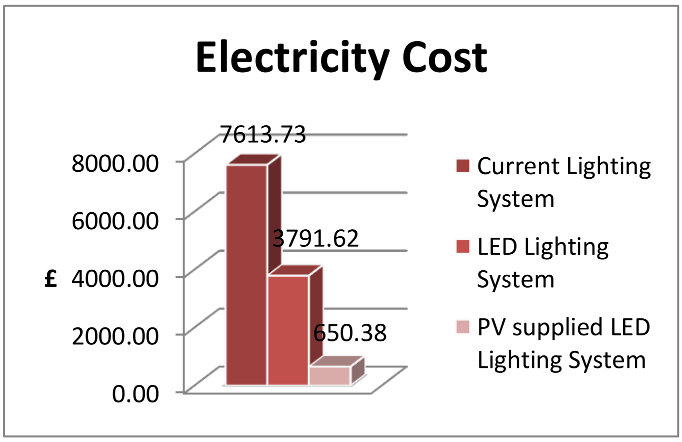


Figure 3, Comparison of the Power Density of the Lighting Systems



In practice, as can be seen in the figure number 4 this corresponds to a decrease of 58.17 %, that is £ 4470.5. In addition to this the LED lights will not need to be replaced until after at least 10 years pass. This fact adds more to the cost effectiveness of the system.

Figure 4, Comparison of the cost of electricity

Some savings will also be achieved from the fact that the LEDs generate little heat (Graves & Ticleanu, 2011). Therefore, the A/C system can operate less. The sustainable aspect of the LED lighting system can be promoted furthermore by installing a stand-alone system on the roof of the building that covers the lighting needs of the sales areas of the building that represent almost 83% of the energy requirements of the whole lighting system. The analysis of the sizing, design and performance of the photovoltaic panels system is done by the help of RETScreen software (RETScreen, 2012).

Conclusions

The results of the Dialux simulation proved that the illuminance levels that the current lighting system delivers are insufficient. The new LED lighting system that is proposed to be installed is more efficient and well performing. What is remarkable and should be highlighted, the fact that the LEDs achieve huge energy savings in the lighting system

Table 5, Energy savings in the lighting system

Percentage Reduction	Sales	Fitting Rooms
Ground Floor	49.34%	91.04%
First Floor	43.48%	85.37%

In addition to this the installation of a photovoltaic panel system that covers a big part (83%) of the needs of the LED lighting system contributes even further to the energy efficiency and the emissions reductions. Thanks to the government's support towards the renewable energy sources, the payback period of 10.3 years is very reasonable and the investment is considered to be feasible.

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