Energy for Sustainability 2013
Sustainable Cities: Designing for People and the Planet
Coimbra, 8 to 10 September 2013

EFFICIENT LIGHTING DESIGN FOR A MUSEUM EXHIBITION ROOM

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Keywords: Energy efficiency in buildings, Efficient lighting, Museum buildings

Abstract *Buildings are responsible for about 40% of Europe's total energy consumption. Therefore, reducing energy consumption in the building sector offers a great potential of reduction of the European Union's energy dependence and greenhouse gas emissions. In museum buildings several energy efficiency measures can be adopted to reduce its energy consumption and improve the comfort conditions. In this context, the lighting design in museum buildings is a critical issue. The lighting solution implemented in a museum has to assure an excellent visual performance but at the same time has to avoid the deterioration of its exhibitions. This paper presents the main results obtained from a lighting efficiency project implemented in the main exhibition room of the museum installed at Casa Rural Quinhentista, located in Pampilhosa do Botão, Portugal. The luminotechnical studies considered to evaluate the different design possibilities have been conducted with the help of Dialux and POV-Ray software. The impact of the proposed efficient lighting systems on energy consumption and CO_2 emissions has been evaluated and economic efficiency was examined by assessing not only the simple payback period but also the Net Present Value of the lighting systems herein considered.*

1. INTRODUCTION

Reducing energy consumption in the building sector is a fundamental measure in order to reduce the EU energy dependence and greenhouse gas emissions. The Energy Performance of Buildings Directive (EPBD) [1] and its recast [2] are the main legislative instruments in the EU for promoting high energy performances in buildings. The recast of EPBD has established more ambitious goals such as the obligation that all new buildings must be nearly zero-energy by the end of 2020. More recently, the Energy Efficiency Plan (EEP) [3] also states that the building sector offers greatest energy saving´s potential.

Although museum buildings present specific characteristics for its operation and maintenance systems, several energy efficiency measures can be adopted and implemented to reduce energy consumption and improve the comfort conditions of the building [4]. [5], based on the results from the study of energy efficiency of the main building of the Caramulo Museum concluded that it is possible to plan an energy efficient museum building according to its location. However, special attention must be given to the lighting systems in museum buildings, since it has to assure an excellent visual performance, avoiding at the same time the deterioration of the objects used in the exhibitions. According to [4], there are three tasks for the lighting in museums, visibility of objects, conservation of objects, and illumination of rooms, which can be realized by daylight and/or artificial light. A good visibility of objects needs a minimum brightness, good contrasts without cast shadows, good colour reproduction, and avoidance of glare. Few studies of specific lighting projects in museums are reported in the literature. [6] reviews the design principles for lighting in museum design and considers the lighting solutions developed during the MUSEUMS projects included in the EC-supported museums demonstration project. The work presented in [7] deals with the energy performance of eight new and existing museum buildings located around Europe and includes the analysis of efficiency for heating, cooling, lighting and other electrical devices. [8] presents the results obtained from the architectural and energy retrofitting carried out in the Historical Bardini Museum in Florence applying appropriate and strategic low-energy and sustainable techniques.

In this context, a project design for an efficient lighting system for the main exhibition room of a rural museum has been performed. The first phase was carried out aiming at the energy characterization of the whole building, useful for identifying energy efficiency opportunities and to obtain the referential energy consumption for the evaluation of the impact of the proposed measures. The project has been developed taking into account the building´s characteristics, the nature of exhibitions and both electrical and photometric characteristics of the luminaires. The simulation studies have been conducted with the help of Dialux and POV-Ray software. Main results are presented and discussed.

2. LIGHTING PROJECT

During 2005, a project for the reconstruction of the damaged areas of the Casa Rural Quinhentista (see left side of Figure 1) has been performed. Following this intervention, one of the buildings of the Casa Rural Quinhentista has been converted into a museum.

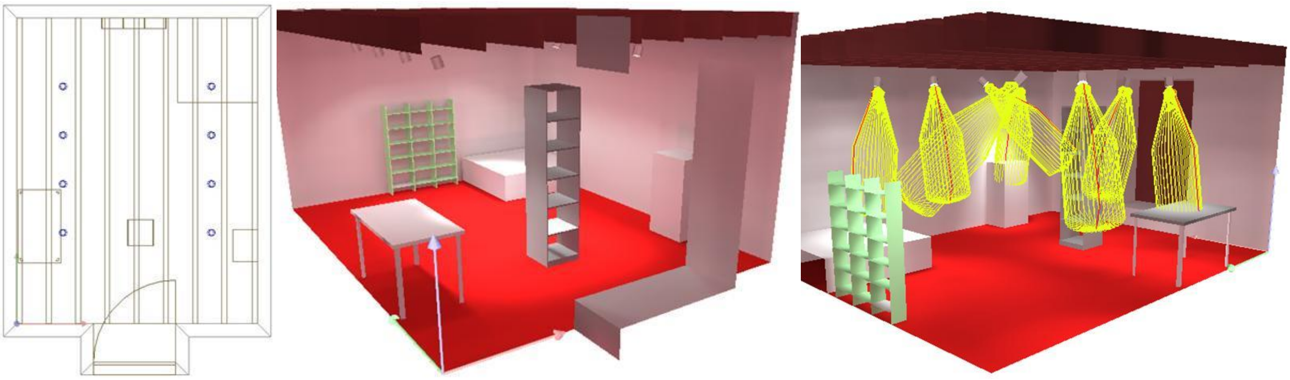
In the museum building the artificial lighting is mainly provided by incandescent halogen lamps and fluorescent lamps. To improve the energy efficiency of the building and to reduce energy bills and correspondent greenhouse gas emissions, an efficient lighting project for the main exhibition room has been performed in response to a request from the museum administration. In the exhibition room there is no daylight and the artificial lighting is provided by two luminaires with four 35 W halogen spot lamps each (see right side hand of Figure 1).

Casa Rural Quinhentista – main entrance | The exhibition room

Figure 1. Museum building and exhibition room.

2.1. Simulations performed with halogen and LED lamps

Different simulations have been performed using the software Dialux and POV-Ray. Some results obtained are presented here. Figure 2 depicts the simulation of the exhibition room performed with Dialux.



Plant | 3D view | Lighting directions defined

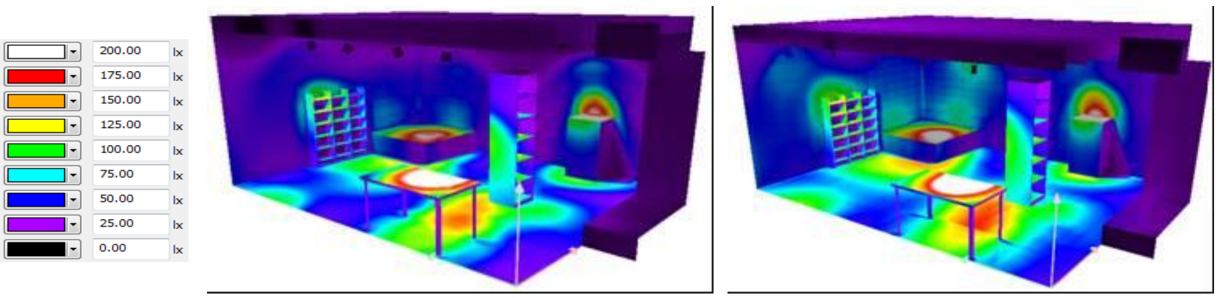
Figure 2. Simulation of the exhibition room with Dialux.

The main technical data of the two lamps considered in the simulation study are presented in Table 1.

	GE ConstantColor® Precise™ MR16 (20 W)	MEGAMAN - MR16 6W GU5.3 36D 4000K
Bulb	MR16	MR16
Base	GU5.3	GU5.3
Power	20 W	6 W
Voltage	12 V	12 V AC/DC
Lúmen	225 lm	240 lm
Colour Temperature	2900 K	4000 K
CRI	100	85
Beam Angle	40º	36º
Lifetime	5000 h	50000 h

Table 1. Halogen and LED lamps technical data.

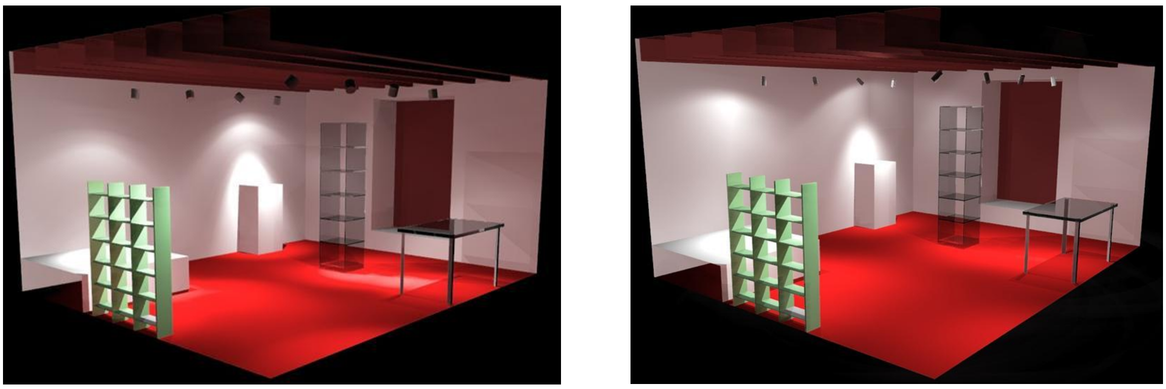
The false colour images obtained for each simulation are presented in Figure 3. The results obtained are very similar and the illuminance levels at the objects area do not exceed 200 lux. This value is very important in order to prevent the objects' degradation.



Colour scale 20W halogen lamps 6W LED lamps

Figure 3. False colour image representation for the halogen and LED lamps with Dialux.

Figure 4 depicts the simulation of the exhibition room performed with *POV-Ray*, using the



20 W halogen lamps 6 W LED lamps

Figure 4. Simulation of the exhibition room with POV-Ray (RayTrace technique).

Ray Trace, a technique for generating an image through the lighting path, by creating virtual images with a reasonable degree of realism. The results obtained are very similar, showing that the two lamps are creating the same lighting environment. Although the exhibition area is being well-lighted (see Figure 4), the illuminance levels are less than the recommended levels to preserve the collection.
Table 2 summarizes the input data, computed on an annual basis, regarding costs, energy and CO_2 emissions for the existing 35 W halogen lamps and the lighting projects proposed, in particular 20 W halogen lamps and 6 W LED lamps, considering a daily operation of 7 hours during 260 days.

	35 W Hal	**20 W Hal**	**6 W LED**
Investment cost	37.36	37.36	145.12
Annual energy consumption (kWh)	509.6	291.2	87.36
Annual energy costs (€)	86.63	49.50	14.85
Annual maintenance costs (€)	13.60	13.60	5.28
Annual CO_2 emissions (kg)	188.04	107.45	32.24

Table 2. Halogen and LED lamps technical data.

The analysis of the simple payback period allows us to conclude that the lighting project with 20 W halogen lamps is better from this point of view than the one with 6 W LED lamps, attaining, respectively, 1.01 and 1.81 years. However, the payback period only looks to a certain point on its horizon having no concern about what lies beyond. Therefore, the option with the better payback is not necessarily the best option, namely when long-term benefits are at stake. In this context, the Net Present Value (NPV) is a better performance indicator which reflects the benefits of long life benefits. Thus, from this standpoint and considering a 10 year time span and a 7% discount rate with an energy cost escalation rate of 3%, the NPV achieves the highest value for the LED lighting project with a value of 561.79 € against 306.62 € for the halogen project. If we consider the useful life of LED lamps, the NPV doubles when compared to the one obtained by the halogen project.

3. DISCUSSION AND CONCLUSIONS

This study presents the main results obtained from the consideration of two alternative efficient lighting projects for an exhibition room of a rural museum building. The projects herein considered took into account the specific characteristics of the room and the nature of the exhibitions ensuring its preservation. This technical analysis was combined with an economic assessment based on two indicators: the simple payback period and NPV. We have concluded that for this kind of investments long-term benefits are not reflected in lower paybacks. In fact, in cost-justifying LED benefits better decisions are accomplished when NPV is considered. This conclusion may be reinforced if the computation NPV and payback period accounts for the cooling demand required when halogen lamps are used. Future work is currently under way in order to explore other lamps technologies in the market, such as those that integrate with control systems and to apply this techno-economic analysis to the remaining exhibition rooms of the museum under study and Although the museum under study has specific features, as it is a rural museum, the authors would like to compare this case study with others already published in the literature, namely those referred in [6] and [7].

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