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A Comparative of Energy Efficiency of Luminaries for General Lighting for a Residential Building: CFL vs LED

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Abstract

This paper presents comparison study between two types of lighting technologies; the compact fluorescent lighting (CFL) and light emitting diode (LED) luminaries for home general lighting usage. This study includes all parts of the luminaries that include the lamp itself and the housing. An experimental test was done to verify the luminance produced by the two technologies. The generated energy of the two technologies was compared by using DIALUX software under the same lumen flux. Furthermore, the associated cost is also evaluated over the stipulated operational period which shows the most advantages of the LED technology over CFL although the initial capital cost for LED is 22% higher than CFL. However, this increment can be equalized by a short payback period of nearly 18 months for the case. This comparison shows that the LED luminaries have the advantages of a significant reduction in the environmental impact, i.e. reduction of 41-50% of greenhouse gas emission and energy demand, mainly due to lower energy utilization and substantial reduction of 60-78% in electrical consumption.

Keywords: *LED; CFL; DIALUX;* Energy Efficiency

1. Introduction

The sun has been the primary source of light for human for over 200,000 years. The first lamp was invented about 70,000 years ago when hollow rocks or shells were filled with a moss or similar materials that was socked in animal fat then ignited. After that oil lamp began to appear and candles were invented. In 1878 Thomas Edison invented carbon-thread incandescent lamp. In 1970 LED started to take place in world market. Nowadays, there are many types of lighting sources; incandescent and halogen (improvement of standard incandescent) which operate at higher pressure and temperature than standard incandescent lamps. Another type of lighting is fluorescent lamp which is more efficient in producing light compared to standard incandescent or even halogen. There are two types of fluorescent lamps; the linear and compact fluorescent lamps. High intensity discharge lamps (HID) are another lighting source which produces light directly from the arc itself. LED are electronic lighting source. It is a semiconductor device that emits visible light of a citrine color and is different from the mentioned conventional lighting sources. As per (DoE), the lighting energy is forming 10% of total electricity consumption.

Singh et al. [1] studied the design, operation, and showed the advantages and future use of both LED and fluorescent. He also compared the LED system with other systems and estimated the power consumption for each type and concluded that LED provides lower CO_2 emissions, longevity and financial savings despite its higher initial cost. The installation of CFL lamps in school and universities in Lebanon were discussed by Beyah et al [2]. They present a comparative study of four different types of lamps (fluorescent 2x36W), CFL of type Philips, CFL of type Arcluce, LED of type Astra. Different manufacturers of LED and CFL lamps were used in their study suggesting manufacturing materials and component differences. They used “DIALUX” software [3] to calculate lumen flux and concluded that the replacement of fluorescent lamps (2x36W) by LED reduces the total power consumption on the of 48.81 MW (2.16% from total power generated in Lebanon), the saved Energy was 52712.85 MWh/year, saved emission of CO_2 from fuel oil was 35317.71 Ton of CO_2/year, saved fuel consumption from private generators is 36990 liters/day (6,658,200 liters/year), saved cost of maintenance was $ 767,181/year, Reduced Cost of electricity and maintenance was $ 8,955,141/year.

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Studies by McKinsey and Company [4] indicate that switching from CFL to LED products is the best solution to reduce greenhouse gas emissions. McKinsey and Company [5] claimed that LED technology is expected to grow at a rate of 35% from 2010 to 2016, leading to a market share of approximately 40% by 2016, which will lead to reduction in prices. According to the same analysis, the LED market share in the office segment is estimated at 2% and expected to grow to 30% by 2016 and 52% by 2020. Some recent studies introduced LED products in comparison, and demonstrate the potential of this technology in terms of energy efficiency and environmental sustainability [6-10]. In addition to the quantifiable benefits at the present time, a study has shown that the potential of light from LED light source in terms of luminous efficacy and quality of the lighting is significant and prospectively very encouraging (Doe2012a). In this study a compression is made between CFL and LED luminaries of six considered types of luminaries (three LED and three CFL).

Currently, fluorescent lamps are being used in order to illuminate our buildings, these types of lamps are considered by owners to be cheaper compared to other types of lighting such as LED, but the problem with such lamps occurs with the high electrical consumption , maintenance and related costs. In this work, we studied the case of a residential villa in Jordan. Comparison has been made between CFL and LED lamps with same capacity and manufacturer but different power and lumen flux to reach standard lumen per each room and facilities according to international standards. This study is carried out using “DIALUX” software for lighting calculation in all rooms and facilities.

2. Methodology

This study is carried out by analyzing two types of lighting technology using same size and manufacturer by IGUZZINI lighting [11]. The products used in this study are listed in table 1 and their images are shown in Fig. 1. They are a combination of both down lights and ceiling recessed luminaries for general lighting.

Figure 1: Image of sample luminaire (a) LED MV40, (b) CFL M396, (c) LED MB53, (d) CFL M373, (e) LED ME84, (f) M637.

Table 1 Technical specification of luminaries

luminaries	MV40	M693	MB53	M373	ME84	M637
Dimension	ø69x90	ø69x141	ø226x100	ø198x210	600x600x26	ø596x80
Total output [Lm]	1000 lm	832 lm	1000 lm	3300 lm	6100 lm	3025 lm
Total power [W]	5.5W	55W	20W	36W	58W	72W
Color temperature[K]	4000	4000	4000	4000	4000	4000
CRI	54	44	54	54	54	58
LAMP	LED	CFL	LED	CFL	LED	Fluorescent T 16 G5

The units for lighting power are lumen and lux which describe the luminance produced from lighting source. It is a measure of the ability of illuminating system to transform electrical energy into luminous flux. The European Directive and Regulations provides a parameter to describe – energy efficiency during the usage phase expressed in lm/W (luminous efficacy). Literature conducted on lighting systems has selected the luminous flux as the parameter of comparison.The position and characteristics of the room that the standards differs from one room to another depending on the work or actions that will be carried out in the room and estimated number of users for it. To determine the luminance produced from lamps, an experimental analysis for “villa” was conducted in accordance with (EN_12464-1.pdf). All calculations were done using “DIALUX” software (DIALUX website).

The villa consists of two floors; ground and first, which include four rooms; two typical kitchens and two dining rooms, The first floor consist of eight rooms; two typical master rooms, two living rooms, and four bedrooms with dimensions of all these rooms as shown in the table 2, the following figure 2.shows the illumination distribution on the kitchen and figure 3.shows the distribution of luminance on the work plan.

Table 2: the consisting rooms of villa with their dimensions

Level	Room	Dimensions (m)
Ground Floor Level	Kitchen 01	3.6×4×2.8
	Kitchen 02	
	Dining Room 01	4.19×5.25×2.8
	Dining Room 02	4.93×3.88×2.8
First Floor Level	Master Bed Room 01	4×3.88×2.8
	Master Bed Room 02	
	Living Room 01	8×6.2×2.8
	Living Room 02	6.14×9.46×2.8
	Bed Room 01	4.12×3.6×2.8
	Bed Room 02	
	Bed Room 03	3.79×4×2.8
	Bed Room 04	4.12×3.6×2.8

Figure 2: Experimental test-internal view of the kitchen

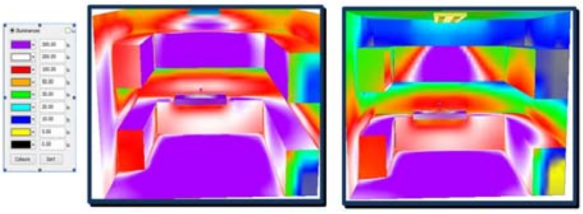

Figure 3: Experrimental test – distribution of luminance on the work plan (left) LED (right) CFL

Table 2: Europ standards of lux for used rooms

Room	Standard lumen flux according to EN12464
Kitchen	500 lux
Dining room	The lighting should be designed to create the appropriate atmosphere.
Reception	300 lux
Office	500 lux
bedroom	200 lux
Living room	200 lux

4. Result and Discussion

The following charts show the comparison between CFL and LED after performing calculations using "DIALUX" software. It considers the area and usage for each room and prices obtained from manufacturers.

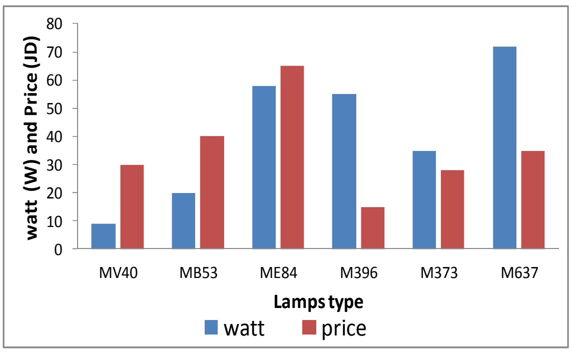

Figure 4: wattage in (W) and prices in (JD) for all used lamps

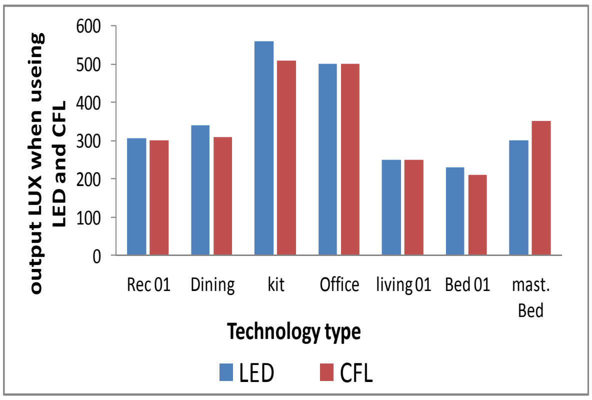

Figure 5: Total lumen flux (LUX) resulted from"DIALUX" calculations when using LED and CFL

Results show that the output lux produced from CFL lamps is lower compared to LED lamps. So we increased number of lamps to reach approximately the same lux which implies higher power requirement for CFL lamps. The total needed watt and price according to the villa requirements and as obtained from the two cases considered above are given in Fig. 5.

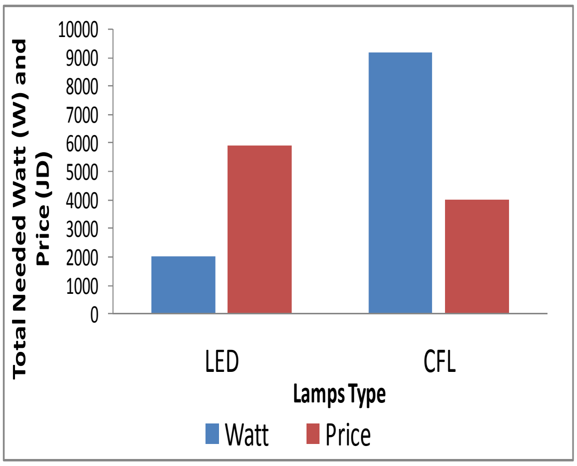

Figure 6: The daily lighting hour for rooms in residential building in Jordan

The Renewable Energy Certificate (RECS) and other survey results show that household characteristics vary by region, which justifies the estimation of lamp usage and energy consumption at regional levels of aggregation, and suggests the need to acquire data for HOU variables which are not in the RECS dataset at ideally the same regional levels. During the analysis of the various datasets identified as candidates for use in this study, it was determined that re-categorizing household characteristic and lighting inventory data was onerous, but possible. Conversely, it was inferred that ensuring end-use metering data from different datasets was of similar accuracy and similar bias was much more difficult, and likely not possible to any degree of certainty. As a result, a strategic decision was made to construct the estimation framework from the fewest, largest sets of available data, and reuse the HOU model developed during the CA RLMS without modification.

The results show that the LED causes lower environmental impact than CFL luminaries, mainly due to lower electricity consumption for their operation. The Lumen efficacy of the luminaries and the lamp is the parameter that dominantly affects the result.

The operating hours for each room is different from region to another and from user to another, according to survey done by Prof. Dr. Al-Ghandour and National Energy Center (NEC) in Jordan the average operating hour for rooms will be as the following chart [12].

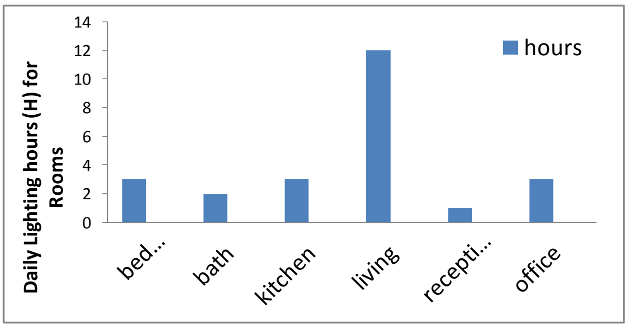

Figure 7: The daily lighting hour for rooms in residential building in jordan

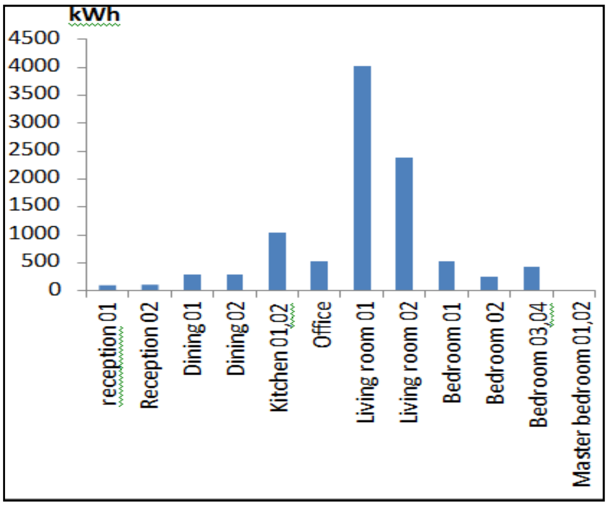

Figure 8: The daily consumed energy in rooms of residential building in kWh for LED

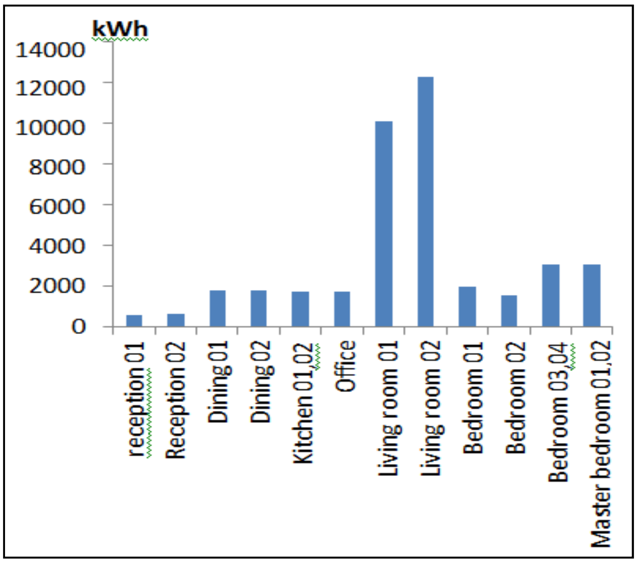

Figure 9: The daily consumed energy in rooms of residential building in kWh for CFL

The feasibility investigation has been carried out, and the payback period has been calculated as shown in the table 3. According to NEPCO (National Electric Power Company) the electricity rates differ according to the energy consumption per month, so for CFL lights the electricity rates is 0.259JD per kWh, and the electricity rate for LED lights is 0.072JD per kWh. The monthly cost for CFL lights is nearly 21.5 JD and the monthly Savings is 291.4 JD. This lead to a Payback Period of 18 months.

Table 3 Payback period parameters

Light Technology	Energy / Day (kWh)	Energy / Month (kWh)	Electricity Rate (JD)	Monthly Cost (JD)
CFL Lights	40.2735	1208.205	0.259	312.9
LED Lights	9.95725	298.7175	0.072	21.5

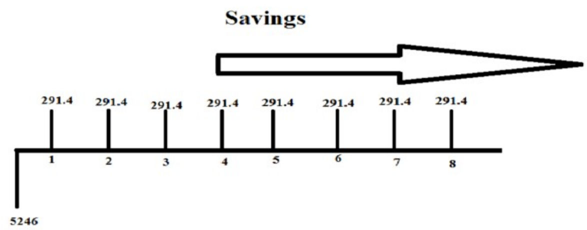

Figure 10: Cash flow diagram

6. Conclusion

This paper presents the evaluation and comparison of two types of luminaries for use as general public household lighting. The luminaries with a LED light source are compared with similar CFL. Results suggest that it is possible to achieve a substantial reduction of 60-78% in electrical consumption. The consumption of the electricity and the way which it is produced are the elements that determine almost all of the impact of this type of product. Based on the data presented in this study, the needed steps to reduce adverse environmental impact are:

- Increase the luminous efficiency of the devices in order to reduce the energy consumption.
- Reduce the decay of luminaries and lighting source.
- Increase the life time of the luminaries in order to reduce replacement and therefore the quantity of waste and new products.

Therefore, using LED lighting will be more efficient despite the high initial capital cost for LED. Initial cost of LED is 22% higher than CFL. However this can be offset by a short payback period of nearly 18 months for the case of a household villa.

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