Simulated economic evaluation of changing from CFLs to LED lighting

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Abstract. Almost world-wide energy inefficient incandescent and CFL lamps are used in great numbers for domestic applications. The desire to reduce electrical loading and electricity bills by using energy efficient lighting has resulted in a high level of interest in replacing conventional incandescent lamp and Compact Fluorescent Lamps (CFLs) with Light Emitting Diodes (LED) lamps. This research will cover all the economic benefits of replacing CFLs and traditional incandescent bulbs with more energy efficient LEDs lightings. The case study was performed on the standard three bed rooms' house design. Most LED bulbs in the market utilise the same light fittings for the traditional CFL bulbs, so replacement is facilitated. The main purpose is to convince and make the community understand how valuable it is to invest in LEDs. Program simulations on the light intensity for the CFLs and LED lighting systems were performed. The energy-saving potentials were also calculated according to the sample of the house under study. LEDs also have a much longer life-span, reducing regular necessary replacements, irritating down-times and inexcusable delays. Calculations results in a simple standard three bed room house saving the total energy of 372.6 kWh, or R530.96 annually as per City of Cape Town domestic electricity tariffs of Block 1 of 142.50 cents per kWh [1].

Keywords: CFL bulbs; LED bulbs; savings; power consumption; electricity bills; RELUX.

1 Introduction

LED lightings feasibilities has been under discussions and debates in recent years as an economically viable alternative for domestic lighting applications. This is because of the financial implications associated with the LED lightings. They provide a significant savings on power consumptions but, their initial cost are very high compare to their counterparts. The other thing that concerns many people is the fact the LEDs light bulbs have been poor in their light diffusion characteristics for many years, hence people may still have that negative perception on LED bulbs. The long-term financial savings and massively long durability have of the LED have not been well understood among the communities in South Africa and other developing countries. The speed at which LED's technology is growing is quite good that; LED bulbs are now available in a variety of forms for numerous applications, their output per lumen has increased, and the overall light output quality and light diffusion standard has largely improved. Their cost prices are also constantly falling. These technological changes

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made many people open their eyes and look into this LEDs versus CFLs matter. The fear that many people have is the speed of the LED's market. They are afraid to by "today" and "tomorrow" the best of the best LED arise again. This brought in a sort of inertia into people's minds to move to LEDs. At first people were much more concerned with the costs involved with changing the fittings and other accessories, which is not a matter of concern anymore because LEDs can make use of the CFLs fittings. This has recently became a major advantage on the cost of implementations and left all the financial implications on the bulbs themselves.

The research will elucidate more on the financial savings that may be attained by substituting the existing CFL bulbs with the appropriate LEDs bulbs, investigated in the standard three bed room house. A standard house was chosen because the majorities of the people in towns lives in standard houses. It was also selected due to that fact that the author believed that the standard three bed room house will set a reference of judgement for both bigger and smaller houses found in towns because it falls between them.

A case study was performed, from which LED's and CFL prices and light output quality were analysed through calculations and software simulations. The financial savings calculations were also done based on the bulbs' ratings (wattage and life-span) specified by the manufacturers. The main objective of this research is to outline how much energy and money could be saved in the long-run in residential areas by increasing the energy efficiency on lightings with the use of LEDs bulbs.

2 Methodology

To analyse and get the viabilities of migrating from CFLs to LEDs lighting systems elucidated, all the economic factors related to light bulbs under investigations have to be analysed in comparison with each other. Few factors that have to be put into considerations when selecting light bulbs were generally explained because of the necessity of knowing at what specifications of the bulb to base the judgement when selecting bulbs and ensure that the area in which these bulbs will be used will be lit according to recommend standards, for this paper IES British interior lighting standard was used. There are five factors to consider when choosing light bulbs for any purpose of lighting:

- **Light efficacy**- how well the bulbs turn electrical energy into light energy. Usually indicated in lumen/watt. LED bulbs are noted to have high efficacy compare to CFLs, of more than 100 lm/W.
- **Durability/lifespan**-this is the estimated functional duration for the light bulbs. Usually given in hours. LED bubs last for up to 50 000 hours while CFLs last for 8 000hours. LEDs are 7 times more durable.
- **Heat emission-heat** this dissipation will have the impact on the internal space temperature. A standard LED emits 3.4 btus per hour while CFL emits 30 btus. This shows that CFL bulbs have more influence on space temperature [7].
- **Environmental impacts**- this has to do with you wanting to conserve nature as encouraged by avoiding the use of toxins lightings. Each CFL bulbs contain 5 grams of mercury which is toxics and dangerous to human being, while LED bulbs are toxic free [7].

- **Initial cost price**-how much money you need to buy you light bulbs of your choice. LED bulbs are up to two times more expensive in relation to CFLs of similar lighting capacity (Table 1).

Table 1: Price / Performance Comparison of Incandescent, CFL and LED Lamps

	Incandescent	CFL	LED
Approximate cost /bulb	$1.00	$2.00	<$8.00
Average Life Span	1,200 hrs	8,000 hrs	25,000 hrs
Watts Used	60W	14W	10W
No of bulbs for 25,000 hrs of use	21 hrs	3	1
Total Purchase Price (over 23 yrs)	$21.00	$6.00	$8.00
Energy Cost (25000 hrs at $0.12 /kWh)	$180.00	$42.00	$30.00
Total operational cost, 23 yrs	$201.00	$48.00	$38.00

These factors describe or contribute to the overall values that people pay for as costs due to lightings and their accessories. Some have a direct effect on the lightings cost and some have indirect effects. Therefore they need to be understood and evaluated well before making decision on which bulb to buy for your planned task.

A case study was performed on all the luminaires as per chosen sample design of a three bed rooms' house. From this sample results and conclusions of larger residential areas are drawn. The case study was separated into two sub-experiments to allow deeper investigations;

- Rating observation and,
- Software simulation

2.1Lightning Inventory

Here calculations of the possible financial savings associated with the implementation of LED lighting systems were worked out plainly using the manufacturer's ratings of light bulbs.
The following types of bulbs were compared as per planned design of the house.

1. Osram CFL 15W 850 lux, 220-240V 50Hz
   The existing bulbs in the initial house plan.
2. Osram LED 7W 650 lux 220-240V 50Hz
   To substitute the existing light bulbs.

Table 2: Lighting Inventory

Place or room	Type of bulb	Quantity
Bed room 1	15 W CFL	2
Bed room 2	15 W CFL	2
Bed room 3	15 W CFL	2
Lounge	15 W CFL	4
Kitchen	15 W CFL	2
Passage	15 W CFL	2
Toilet	15 W CFL	1
Shower	15 W CFL	1
Veranda	15 W CFL	3

Collective data were used to compute the total wattages of all lightings. Then the total energy consumption was calculated by estimating the probable maximum time these bulbs are in use every day for each and every house section separately.

$$Energy = Power \times time(hours)$$

Bed rooms' lights were assumed to be on for five hours a day. The Setting room and passage were assumed to work 10 hours each day because they are the most utilised bulbs in the house due to the functionalities of the location. The electrical bill due to CFL lightings that the house owner will pay according to the City of Cape Town's current tariffs for Block 1 (142.5c/kWh) was calculated per month and later the yearly was found [1]. The same calculations were repeated with the LED bulbs that can replace the existing light bulbs without changing the light intensity in the building. The results were compared and interpreted in accordance with economical savings. Bed rooms' lights were assumed to be on for five hours a day. The Setting room and passage were assumed to work 10 hours each day because they are the most utilised bulbs in the house due to the functionalities of the location. The electrical bill due to CFL lightings that the house owner will pay according to the City of Cape Town's current tariffs for Block 1 (142.5c/kWh) was calculated per month and later the yearly was found [1]. The same calculations were repeated with the LED bulbs that can replace the existing light bulbs without changing the light intensity in the building. The results were compared and interpreted in accordance with economical savings.

2.2 Software simulation

Lastly RELUX was used to simulate the lux outputs produced by LEDs and CFLs separately for the same house in same positions. All walls were made white, to ensure maximum reflection and diffusion of light. Economical calculations were done also and were related to calculation done in A. See Figure 1 below for the sample house that was understudy.

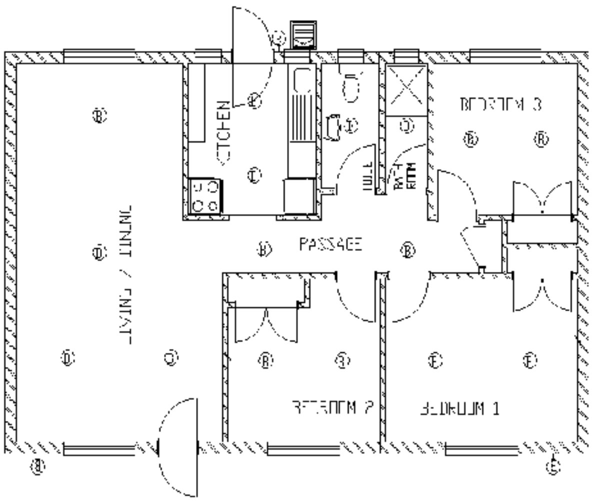

Figure 1: Sample House

2.3 Analysis

2.3.1 Wattage

The results obtained from the ratings observations have come out in the favour of the LED bulbs. The amount of energy consumed per annum by LEDs and CFLs lighting systems were 302.4kwh and 675kwh are respectively. According to ratings' results if 7w LED bulbs substitute the 15W CFL bulbs existing in the plan, 55.2% of the energy used buy fluorescent will be saved annually. This is equivalent to 372.6 kWh or R530.96 savings.

2.3.1 Lifespan and costs

According to Osram light bulbs' ratings, the LED bulbs can last up to 50 000 hours and the CFL last only for 8 000 hours, which they say is equivalent to 5 years and 1 year respectively. The market price was found to be R149.00 per LED bulb and R78.00 per CFL bulb in Eagle Lighting Pty Ltd stores. This creates a big obstacle that deceives many people and surrenders them from buying the "newer" light technology.

2.3.2 Effect on environment and safety hazard analysis

CFLs have more effects on air conditioning systems because they dissipate more heat compare to their counterparts, increasing air conditioning burden.
It was found that compact fluorescent bulbs contains mercury which is highly toxic to human being, and less or no fire hazards are associated LED than CFLs due to less heating-ups and accidental damages.
CFLs dissipate toxic substances that pose human life to danger. If a CFL bulb break, the small pieces of glass have the capability of harming people. They dissipate more heat than LEDs making them burst into fire if they come into contact with water while operating or in a prolonged contact with flammable substances [4-5].

2.3.3 Software simulation results

Results were obtained in 3D, pseudo colours and isolines representation. This depicted to the author how the light was distributed throughout the room, depicting all the level of lighting at every point in the room. All the powers are left to the designer to decide whether or not the light input is sufficient according to case IES British interior lighting standards

2.3.4 Performance Comparisons

According to calculations done in relation to the ratings of 15W CFL and 7W LED light bulbs, the results came out in favour of the LED lights. The overall usage of electricity drop with roughly 55.2%. The graph in figure 2 compares the cost of the energy consumed by CFL and LED system. Savings were also plotted and really they depicted the benefit of paying the reduced electricity bills to the owner of the house, which was the continuously increasing savings. Statistics compiled by Strategic Development Information and GIS Department, City of Cape Town Using 2001 and 2011 Census data from Statistics South Africa revealed that there were approximately 1068572 households in the whole Cape Town. This simply means if one house can save 372.6 kWh annually; all houses together will save an estimated sum of 372.7 GWh. An amount of 152 watts will be reduced from the feeder by each house. Therefore collectively an amount of 152 megawatts will be offloaded from grid. For transformers and feeders that were operating close to their maximum ratings or about to get overloaded due to increasing loads their loads will be reduced with some percentages. This will help to prevent blackouts during peak hours and increase the reliability and continuation of supply.

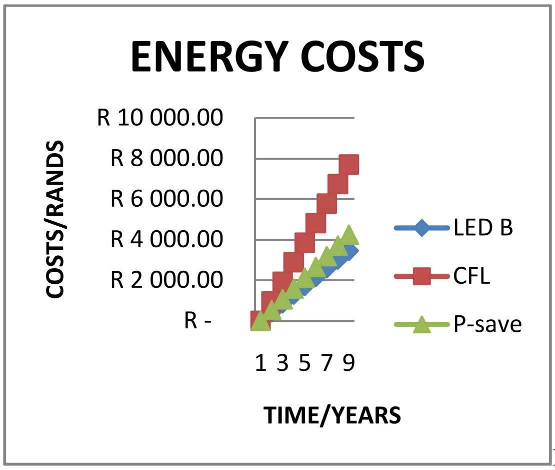

Figure 1: LEDs and CFLs Energy consumption

LED installation will not only favour the customer but utilities also. Since utilities are the one responsible for installations of supplementary transformers whenever electrical demand of a certain place exceeds the power that the existing transformer can provide. They will be saved from paying millions of South African Rands (ZAR) for buying and installing new transformers when the loads get reduced, allowing more space to additional loads in future.There are some regions in South Africa where heating systems are used in winter and cooling systems (air conditioners, heat pumps etc.) are used during the hot summer. There are also places where no heating systems are required in winter but air conditioners, heat pumps, electric fans etc. are widely used to alleviate the heat of the hot summer. CFL bulbs dissipate 30btus per hour and LED bulbs emit 3.4 btus per hour, therefore CFL bulbs dissipate 8.8 times more heat. In these cases, the use of fluorescent lamps increases the load of cooling systems more compare to LED lamps. The thermal energy produced by CFL lamps can amplify the demand for space cooling, as a whole in those regions and will be a net contributor to the overall increase in energy demand. Thus, lighting loads add an extra load to the space cooling systems during peak hours.

2.3.5 Maintenance Costs and overall cost-effictiveness

LED lighting system maintenance cycle are longer compare to one of CFLs, therefore less money will be spend on maintenance with LED system than with CFLs. Figure 3 also shows that, since LED bulbs are having long Life span, the frequency of buying new LED bulbs is roughly 6 times slower than that of CFL bulbs. Figure 4 shows that the total savings from the power consumption and maintenance costs only breakeven after one and half a year.Even though LEDs are expensive compare to CFLs, their durability gave them a merit over their cost. LED lamps last more than six times longer than Compact fluorescent lamps. This gives a clear picture that CFLs are in fact more expensive than LED lamp because one LED lamp's lifespan is equivalent to six CFLs lamps' lifespan added together. Meaning if one LED is twice more expensive than one CFL lamp, then having ten CFLs in one LED lamp denotes that CFLs are three times more expensive than LEDs. The lifespan of bulbs is directly proportional the maintenance cycle of the lighting system. Figure 3 compare CFL and LED maintenance costs over 8 years and hence the savings from maintenance after the initial cost of replacing CFL bulbs. A period of 3 years was taken for the LEDs maintenance costs to pay back for the initial cost and begin to save.

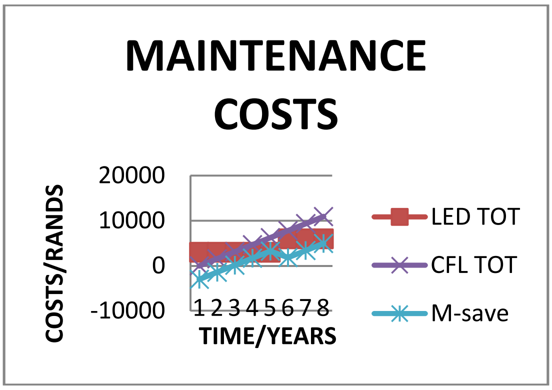

Figure 2: Maintenance Costs

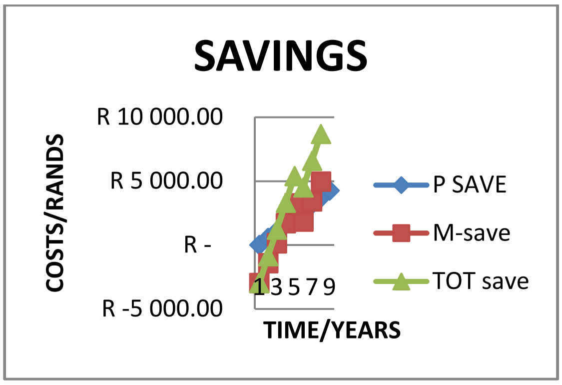

Figure 3: Overall Savings (Energy & Maintenance)

2.3.6 Lighting Effectiveness: Simulations

Luminance intensity results were obtained from Relux as shown in Figure 4, (a) LED output and (b) CFL output. It is well indicated that the lighting level has improved with the when LED bulbs were used in the place of CFL bulbs.

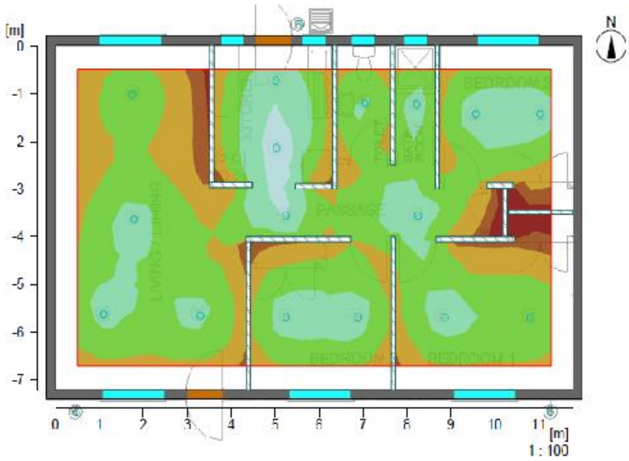

Figure 4a: LED output

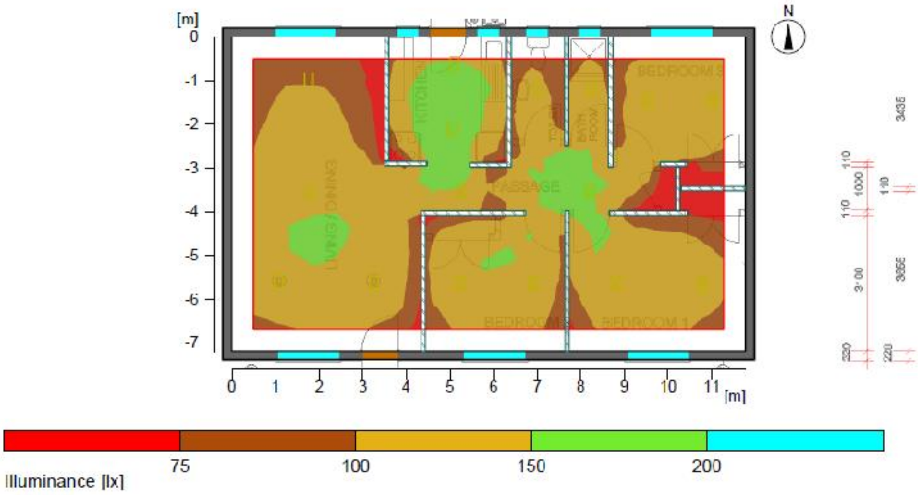

Figure 4b: CFL output

According to case IES British interior lighting standard, the change in lighting system will not violate the light intensities subscribed for domestic use.

3. Conclusions

Even though there are few challenges due to inertia caused by lack of understanding and financial reasons in the process of substituting CFLs with LEDs lighting systems that might elongate and delay the implementation time, it was concluded that LEDs' benefits outweigh CFLs, therefore replacing the existing compact fluorescent lamps with LED lamps in residential areas is economically recommended. The economics of replacing the CFL bulbs from the existing fittings with corresponding LED bulbs in domestic lighting systems has been proven to be 55.2% economically effective through calculations. Many manufacturers are making LED bulbs that can fit into and make use of the existing CFL light fittings. The savings of money are significantly increased with increase in the region of application. It is also suggested that, LED lightings increase efficiency because of the improvement in light output per unit watt, allowing the use of less number of luminaires per square meter.

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