Available online www.jsaer.com

***Journal of Scientific and Engineering Research*, 2018, 5(11):197-203**

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Comparative Study of Light Emitting Diode (LED), Compact Fluorescent (CF) and Incandescent Lamps

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Abstract This work focused on the comparison of incandescent lamps, compact fluorescent lamps (CFLs), and light emitting diode (LED) lamps, which intrinsically analysed the energy consumptions, energy consumption costs and relatively the savings that would be derived when the incandescent lamp is replaced equivalently with the energy efficient lamps. Furthermore, a thermal characteristics in terms of the average temperature, pragmatically estimated and recorded as a result of heat dissipation emanating from the various lamps for the purposes of making the best choice in lamp usage where also studied. Results showed that, incandescent lamp consume more energy which variably can make the consumer to pay high in electricity bill as compared to CFLs and LED lamps. Furthermore, results showed that, using energy efficient lamps, save costs and heat that would have being dissipated into the system as a result of the traditional lamps. It showed that, the estimated savings derived are as follows; ₦37555 on using 3W LED lamp, ₦31114 on using 9W CFL, ₦53679 using 5W LED lamp, ₦47138 using 11W CFL, ₦87035 using 8W LED lamp, ₦75252 using 20W CFL, ₦161814 using 24W LED lamp, and ₦147504 using 40W CFL when replaced with its equivalents incandescent lamps over 30,000 hours. Again, on one hours operation per day, it detailed that a consumer will pay ₦36.28, ₦90.69, and ₦181.38 for using 40W, 60W 100W, and 200W incandescent lamp respectively. ₦8.16, ₦9.98, ₦18.14, and ₦36.28 using 9W, 11W, 20W, and 40W CFL respectively. ₦2.72 on using 3W LED lamp, ₦4.53 on using 5W LED lamp, ₦7.26 on using 8W LED lamp, and ₦21.77 using 24W LED lamp every month. On the thermal characteristics, it also showed that 40W, 60W, 100W, and 200W incandescent lamps dissipate average temperature of 7.7^{O}C, 17.7^{O}C, 24.2^{O}C, and 41.2^{O}C respectively. 9W, 11W, 20W, and 40W CFL dissipate 2^{O}C, 3.5^{O}C, 4^{O}C, and 8.4^{O}C respectively. 3W, 5W, 8W, and 24W LED lamps dissipate 1.1^{O}C, 1.7^{O}C, 2.1^{O}C, and 7.2^{O}C respectively.

Keywords Incandescent Lamp, Compact Fluorescent Lamp, LED Lamp, Temperature, Energy

1. Introduction

It has become worrisome that most people do not know how to reduce the cost of their electricity bills nor avert increase in average temperature experience as a result of using incandescent lamps. People are paying unnecessarily high electricity bills while others are temporally being disconnected because of inability to pay. A wealthy person is not only when that person is earning high, either through the company he/she works or business embarked on, but the manners of spending money in the case of subscribing for electricity bills, is also a matter to consider. "All over the world, energy inefficient incandescent lamps are used in great numbers. Replacement of these lamps can save energy and reduce energy bills for the consumers" [1].

There are so many traditional lamps that do not have the possibilities to equivalently match with or neither to exceed the modern lamp usage such as light emitting diode (LED) lamp in terms of costs of electricity energy usage billing, temperature heat of dissipation into the environment, life span and energy efficiency. It has been

estimated that the light emitting diode (LED) lighting system will distinctly replace 46 percent of general illumination lumen-hour sales by 2030, which will result to yearly primary energy savings of 3.4 quads [2].

2. Materials and Methods

A box was constructed for the experiment. Lamp holder with wire was attached at the center side of the insulating box. An experimental insulating box of dimensions of height 27cm, length 37cm,and breadth26cm was constructed with a volume of 25974cm^3, and used so that there will be high sensitivity for the meter to read the heat of dissipation from the lamps in the shortest period of time. Admittedly, the larger the confined space, the lower the average temperature heat of dissipation being able to sense by the meter in relation to time. Also used, are different kinds of lamps with its respective wattages. The lamps used in this experiment are classified as Incandescent, Compact Fluorescent (CF), and Light Emitting Diode (LED) Lamps. The wattages of these lamps used during this task are according to the availability in the market system in Nigeria. The wattages used were between 3-200 watts. More details about these lamps and their wattages are detailed in Table 1.

Table 1: Equivalent Wattage of Lamps

Incandescent lamp (W)	CFL (W)	LED Lamp (W)
40	9	3
60	11	5
100	20	8
200	40	24

The methods used involved both the experimental part and theoretical part. In the experimental part, average temperature of heat dissipation was determined and compared among the lamps, whereas, the theoretical part involved calculations of energy consumption, cost of energy consumption, energy savings and cost savings of the lamps was also estimated and result compared. In the experimental study, a temperature meter was used to measure the amount of heat emanating out from the various lamps. This heat measuring meter called Hampton temperature and humidity meter, also measure the humidity of a confined space in relation to that of the heat of the surrounding or room. It measured heat of dissipation in degree centigrade (^{O}C). It also has clock, reading the time duration according to heat of dissipation (heat energy).

2.1. Experimental Basis

The wattages of LED lamps were considered first during the experiment before CFLs and incandescent lamps. The reason for that was to sort for accuracy. Before embarking on the experiment, I believed that energy efficient lamps dissipate lesser heat than energy inefficient lamps of the same equivalents, taking review from various literatures. According to [3] when a 60 watt external ballasted mercury vapor lamp and a 60 watt halogen lamp are placed in two separate insulated boxes with a thermometer inside, these two lamps should have effectively raised the temperature in both boxes to the same degree, but rather, after 30 minutes, the thermometer in the container with the halogen lamp gave a reading 20°F higher than the other box, (135°F vs 115 °F).

2.2. Theoretical Basis

The energy consumption, cost of energy consumption, energy consumption savings, and energy consumption cost savings of these lamps were estimated based according to [4] equations below:

$$\text{Energy consumption} = \frac{\text{Power rating x hour of usage}}{1000} \quad (1)$$

$$\text{Energy consumption cost} = \frac{\text{Power rating x hour of usage x utility rate per kWh}}{1000} \quad (2)$$

$$\text{Energy saving} = \text{energy consumption of lamp B} - \text{energy consumption of lamp A} \quad (3)$$

$$\text{Energy cost saving} = \text{energy cost of lamp B} - \text{energy cost of lamp A} \quad (4)[4]$$

3. Results

Table 2: Comparative Cost and energy savings over 30, 000 Hours

Lamps (W)	Watts	Energy Saved (kWh)	Money Saved (₦)
Incandescent Lamp	40		
	60		
	100		
	200		
Compact Fluorescent	9	930	31,114
Lamp (CFL)	11	1470	47,138
	20	2400	75,252
	40	4800	14,7504
LED Lamp	3	1110	37,555
	5	1650	53,679
	8	2760	87,035
	24	5280	161814

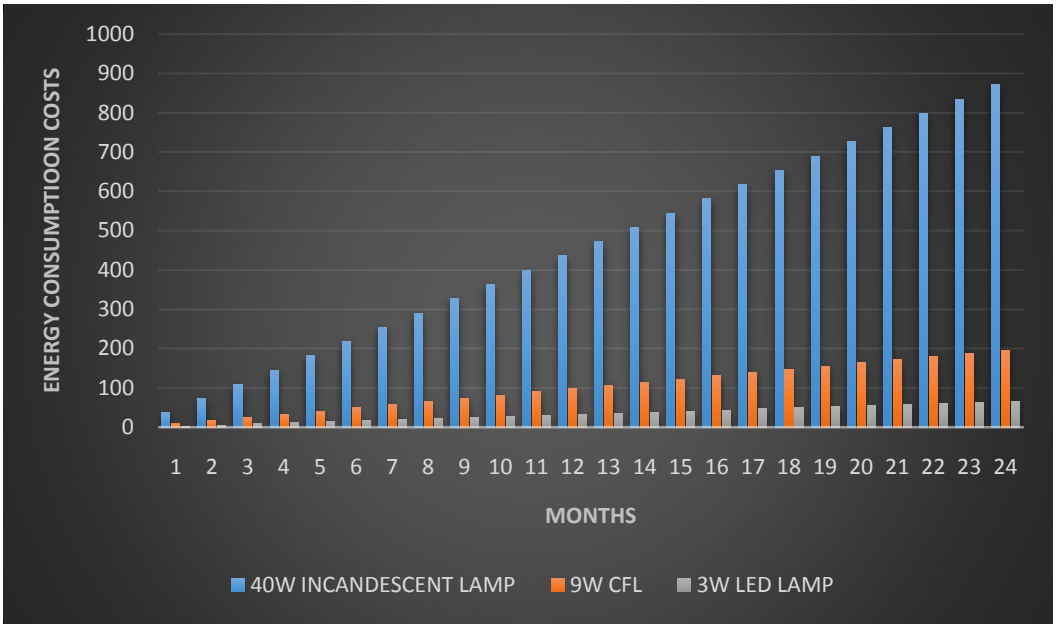

Figure 1: Energy Consumption Cost Chart of 40W Incandescent Lamp, 9W CFL, and 3W LED Lamp

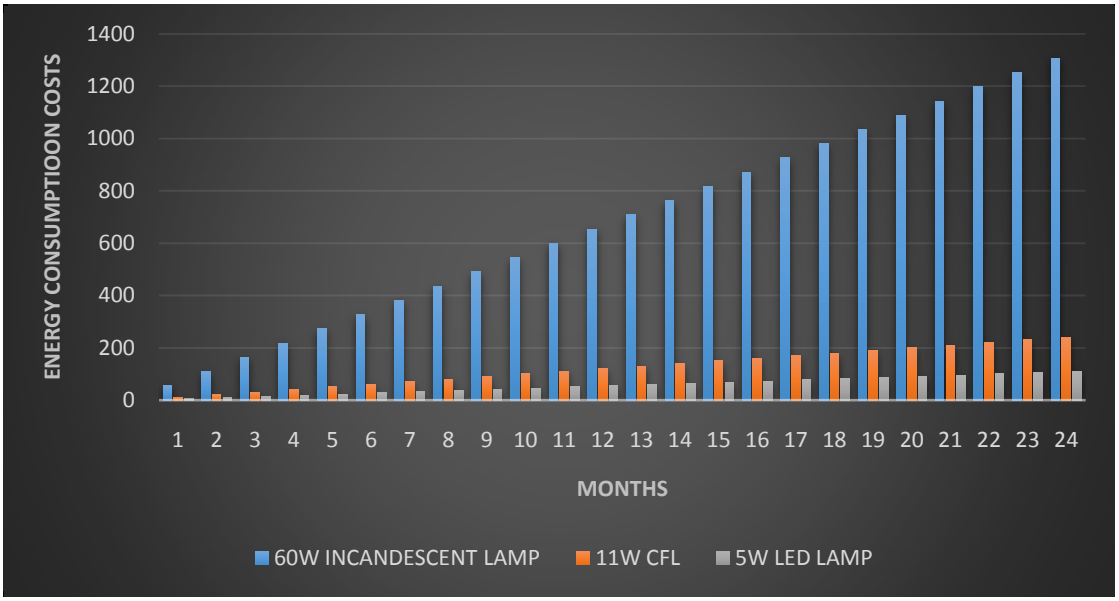

Figure 2: Energy Consumption Cost Chart of 60W Incandescent Lamp, 11W CFL, and 5W LED Lamp

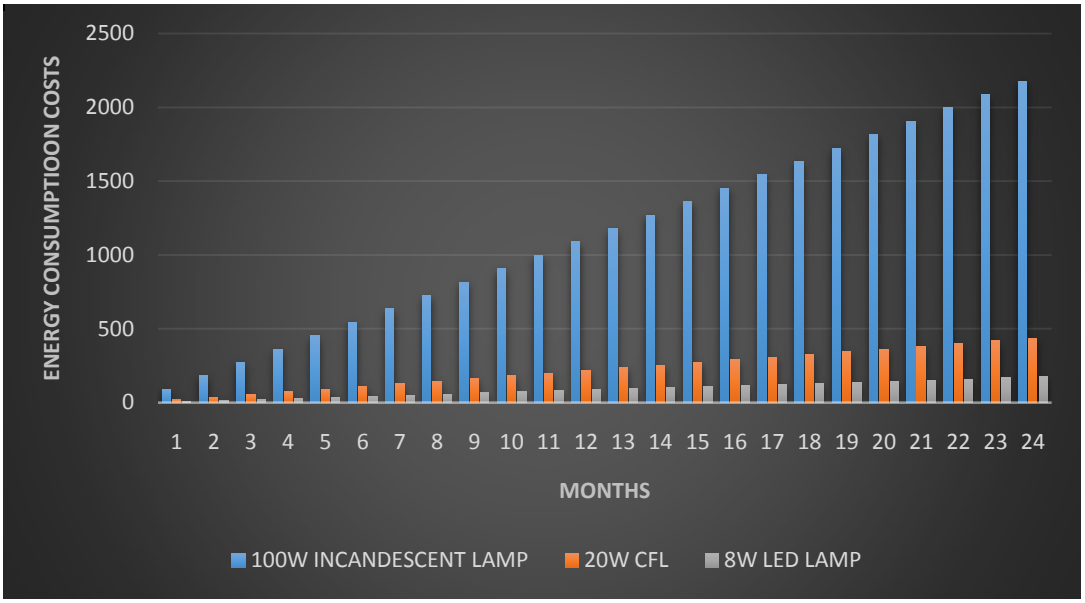

Figure 3: Energy Consumption Cost Chart of 100W Incandescent Lamp, 20W CFL, and 8W LED Lamp

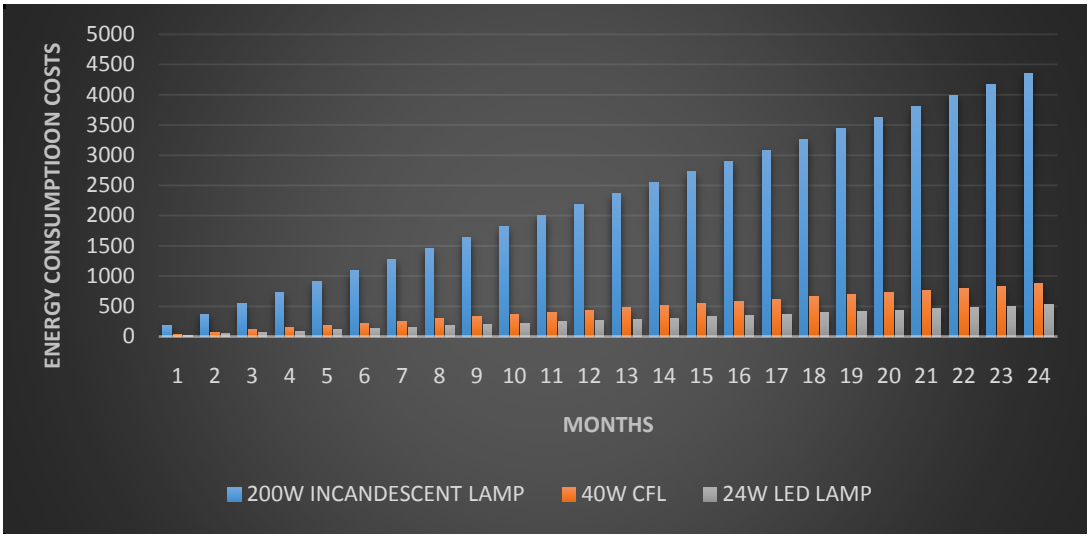

Figure 4: Energy Consumption Cost Chart of 200W Incandescent Lamp, 40W CFL, and 24W LED Lamp

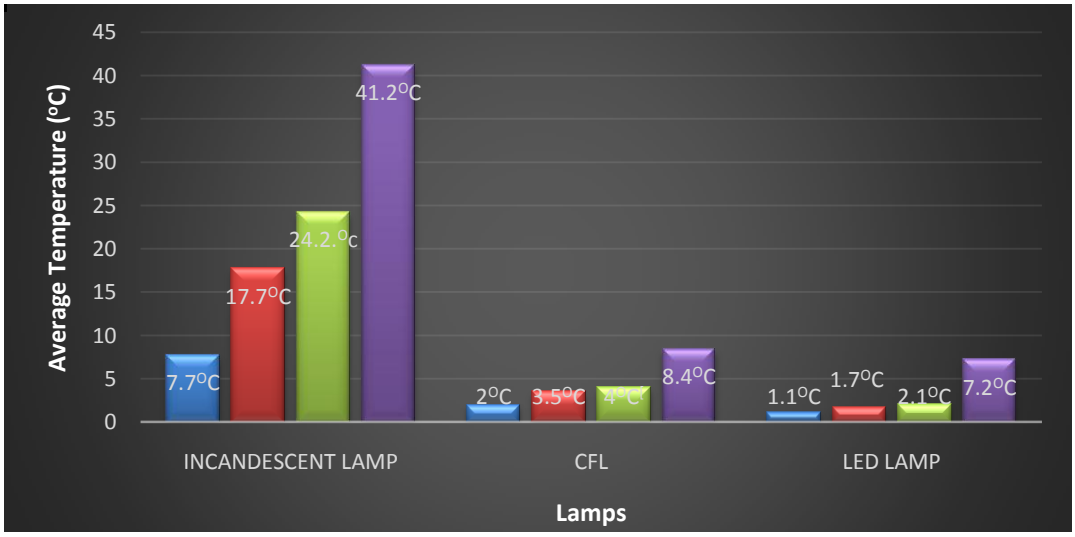

Figure 5: Average temperature heat dissipation chart of lamps

4. Discussions

Table 1 showed the estimation results of energy consumption and electricity bill saved replacing incandescent lamp with CFL and LED lamp over 30,000 hours operation. According to [5] a five LED lamp could save 400kWh of electricity over 50,000 hours, and when compared with CFL, and 2700kWh when compared with incandescent lamp. About ₦37555 was saved which happened to be the highest amount out of replacing the traditional 40watt incandescent lamp with 3watts LED lamp. But when replaced with its equivalent of 9 watt CFL, an electricity bill of ₦31114 was saved. Then, considering the energy saved, a 40watt incandescent lamp when replaced with it equivalent of 9watt CFL and 3 watt LED lamp will saved energy of 930kWh and 1110kWh respectively. Also, 60watt incandescent lamp when replaced with 11watt CFL, saved a bill of ₦47138 and when compared with 5watt LED lamp, about ₦53679 was saved. Where the energy saved when replaced with 5watt LED lamp and 11watt CFL were 1650kWh and 1470kWh respectively.[6] reported that CFL consume energy of 1.32 times higher than LED lamp and incandescent lamp consume energy of 2.74 times than LED lamp. Again, when 100watt incandescent lamp was replaced with 20watt CFL and 8watt LED lamp, the energy consumption and electricity bill saved were 2400kWh, 2760kWh, and ₦75252 and ₦87035 respectively. With the same stipulated period, the costs saved due to replacing 200W incandescent lamp to 24W LED lamp was ₦161,814 and when it was replaced with 40W CFL, the cost saved ₦147504. [7] reported that the total cost of purchasing and running 39 of 14watt CFLs simultaneously for fifteen years period would be $3578.25, but if the 39 CFL were to be replaced with 39 of 10.5watt LED lamps, the total cost would be 3073.69, therefore saving about $500 within the fifteen years period. The energy consumption and electricity bill saved replacing with the 40watt CFL and 24watt LED lamp were 4800kWh and 5280kWh respectively.

Figure 1 described the comparison between incandescent lamps, CFLs, and LED lamps over one hour operation per day at utility rate of ₦30.23 per energy. This showed how much a consumer will need to budget making choice in any of the lamps operating within the rate of one hour per day. The figure showed that every month, a consumer using 40watt incandescent lamp were made to spend ₦36.28 and in two years he/she is expected to pay ₦870.62 for the energy consumption within the time frame, whereas, a cost of ₦8.16 will be spent monthly for a total of ₦195.89 in two years using 9watt CFL, and for 3watt LED lamp, a small amounts energy consumption cost of ₦2.72 and ₦65.3 were spent monthly and annually respectively. Energy consumption cost savings increases with increase in months of operation. In the first month of operation,₦28.12 (78%) was saved when 40watt incandescent lamp was replaced with 9watt CFL and when it was replaced with 3watt LED lamp it saved₦33.56 (93%). According to [8] a 66.8% cost saving will be obtained by replacing incandescent lamp with CFL at one hour per day operation. ₦435.31 was spent annually when 40watt incandescent lamp was used, but when replaced with it equivalents of 9watt CFL it saved 77% throughout the year and saved 92% when replaced with 3watt LED lamp. According to [9] $58 will be save replacing 40watt incandescent lamp with 8watt LED lamp.

Figure 2 showed the responds of 60W incandescent lamp, 11W CFL, and 5W LED lamp of energy consumption cost. It showed that ₦54.41 was spent monthly to run a 60W incandescent lamp and ₦652.97 annually. Then relatively, when its equivalent of 11W CFL was used, it showed that consumers need to budget ₦9.98 monthly for the electricity bill. Also, a cost ₦4.53 monthly was utilized to run 5watt LED lamp. By estimation, it showed that it is better to use 5watt LED lamp, because of the cost saved the consumer will achieve. When a 60watt incandescent lamp was replaced with 5watt LED lamp, about ₦49.88 (92%) was saved monthly, but when replaced with 11W CFL, it saved ₦44.43 (82%) monthly. [10] reported that LED lamp save 90% of the energy used by incandescent lamp, and can last for 10 years or more when operating 8 hours per day. So, a very high percentage of the cost was saved when a 60W incandescent lamp was replaced with just 5W LED lamp, making the energy efficient lamp the best for the consumers.

Figure 3 showed that, a 100W Philips incandescent lamputilised ₦90.69 monthly for the energy usage, whereas, its equivalent 20watt Everlite CFL utilized ₦18.14, and when replaced with 8watt AKT LED lamp it utililsed ₦7.26. It will be beneficial for a consumer to use 8W AKT LED lamp over 20W Everlite CFL and 100W Philips incandescent lamp. Monthly cost of ₦72.55 (80%) was saved when a 100W incandescent lamp was replaced with 20W CFL, but when it was replaced with 8watt LED lamp it saved₦83.43 (92%). So, this proved that 8W LED lamp is economically better, because large percentage of money were saved when it was used.

Figure 4 showed the expenses that will be made to 200W incandescent lamp, 40W CFL, and 24W LED lamp. Energy cost of ₦181.38 was utilised by 200W incandescent lamp monthly, whereas, 40W CFL and 24W LED lamputilised ₦36.28 and ₦21.77 respectively. It is pertinent to note that between 200W incandescent lamp, 40W CFL and 24W LED lamp, the 24W LED lamp is the best to use, because of the cost savings derived from it. Furthermore, when the 200W incandescent lamp replaced 24W LED lamp a huge amount (percentage) of ₦159.61 (88%) was saved monthly and when replaced with 40W CFL the percentage amount saved was ₦145.1 (80%).

Figure 5 showed that incandescent lamp emitted higher degree of heat into the environment as compared to CFL and LED lamp which makes it absolutely not good enough to use at home. The power rating have a greater contribution factor to determining the level of heat dissipation into a system of any kind of lamps, meaning that, the higher the power rating (wattage), the higher the heat dissipation into the system. A 40wattLuxram incandescent lamp dissipated a heat of average temperature 7.7^{O}C, while its equivalent of 9watt ZXM CFL was 2^{O}C and 3watt AKT LED lamp as low as 1.1^{O}C. But, according to [11] a 3watt Evenso, 4watt Oscram of LED lamp dissipate average temperature of 70.9^{O}C and 70.7^{O}C respectively. It was also noticed that a 200wattJungsram incandescent lamp dissipated about 41.2^{O}C of heat into the confined space, making it the highest among its equivalents of 40watt Torch CFL and 24wattSiase LED lamp with heat dissipation of 8.4^{O}C and 7.2^{O}C respectively. The average temperature saved when a 200wattJungsram incandescent lamp was replaced with its equivalent of 40watt Torch CFL was 32.4^{O}C (80%) operating for one hour, and with 24wattSiase LED lamp, about 34^{O}C (83%) was saved just within one hour. 20.2^{O}C (83%) of heat was saved when a 100watt Philips incandescent lamp was replaced with 20wattEverlite CFL, but when replaced with 8watt AKT LED lamp, 22.1^{O}C (91%) was saved. According to this result, we have noticed that, a greater percentage of heat was saved due to replacing incandescent lamp with LED lamp.

5. Conclusion

LED lamp and CFL have significant vantages as compared to incandescent lamp. According to the theoretical cost estimations, LED lamp is certainly the best alternative lamp to substitute incandescent lamp and CFL. The energy savings of LED lamp fall within 14% to 92% based on the lamp replaced. The choice of best lamp always rely on the saving capacity during operation. The energy efficient lamps are designed by the manufacturers such that to regain the high procurement cost, the energy consumption cost savings is within the time frame of the lifespan.

Pragmatically, LED lamp which happens to be solid state lamp, is certainly the best alternative to substitute CFL and incandescent lamp considering the fact that it dissipate the least heat into the system.

Acknowledgement

I give my heartfelt thanks to Professor V.B. Omubo-Pepple and Dr M.A Alabraba for devoting so much time making sure that I followed the path of norm in achieving the desired result, patience and the constructive censure. God will continue to bless you.

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