Potential Energy Savings of Efficient Lighting Systems in Public Buildings: A Case Study of Petroleum Products Pricing Regulation Agency.

*Okorie Patrick Ube and [1]Saleh John.

Department of Electrical Engineering, Ahmadu Bello University, Zaria. Nigeria.
[1]Petroleum Products Pricing Regulation Agency, Plot 1012 Central Business District, ABUJA. Nigeria.

*Corresponding author: patrickubeokorie@yahoo.com

Abstract

Energy is an important aspect of buildings. It is stored in construction materials and required for lighting and electrical installations, as well as used for heating and cooling. The amount of energy required for all buildings can be reduced by adopting potential energy saving lighting system . The aim of this work is to present actions to be taken for the reduction of energy use in buildings and to introduce the concept and benefits of energy efficiency in buildings. These actions are based on suitable architectural design, controlled ventilation and good quality thermal-insulation envelopes, i.e. optimal insulation thickness, eliminating thermal bridges and providing air tightness. The policy for retrofitting the old lighting system with the new energy saving LEDs has produced 50% in savings when compared with fluorescent lamps. The result of the life span analysis reveals that after two year three months (27 Months), the selected building will bring profit for the investment.

Keywords: Energy, Energy savings, Energy efficiency, Heating and cooling, House/buildings concepts.

1. INTRODUCTION

More than 90 per cent of our time is spent in buildings i.e. either in the office or at home (Ardente,et al (2011). Energy used in buildings, either residential or commercial accounts for a significant percentage of a country's total energy consumption. This percentage depends greatly on the degree of electrification, the level of urbanization, the amount of building area per capita, the prevailing climate, as well as national and local policies to promote efficiency. The following are estimated figures for different regions of energy consumption in buildings are presented in Table 1:

Table 1: Regional Energy Consumption in Building

S/NO.	Regions	Estimated Energy Consumptions
1	Philippines	27.7% (www.doe.gov/2017-philippine-power-situation-report)
2	European Union countries	41% 2015 (http://www.europa.*eu*).
3	Brazil	42 % (Stica&de Caryaiho, 2011
4	Florida/USA	47 % Levinson, (2016).
5	Nigeria	61 per cent (IEA. Energy Access Outlook 2017)
6	California	66% Krarti, . (2016)

In many countries, buildings consume more energy than transport and industry. Good example is Brazil, Nigeria and USA (Stica and de Caryaiho, 2011, IEA Energy outlook, 2017 and Karti, 2016 respectively). The International Energy Agency (IEA) statistics estimate that globally, the building sector is responsible for more electricity consumption than any other sector, 42 per cent (IEA. 2004b). Good example is Brazil, Nigeria and USA (Stica and de Caryaiho, 2011, IEA Energy outlook, 2017 and Karti, 2016 respectively).

The building sector uses all type of appliances, which have different energy use implications. Space heating, space cooling and lighting, which together account for a majority of building energy use in industrialized countries, depend not only on the energy efficiency of temperature control and lighting systems, but also on the efficiency of the buildings in which they operate. Building designs and materials have a significant effect on the energy consumption. On the other hand, building design does not affect the energy use of cooking or cooking appliances, though these end uses are nonetheless attributed to the building sector. Appliance efficiency matters more for some end uses than for others. Water heating and refrigeration each account for significant shares of building energy use since they are in constant use. By contrast, cooking and small appliances (including computers and televisions sets) generally account for only small percentages of building energy consumption, owing to their intermittent use.

In general, building energy consumption is higher in industrialized countries. Thus, development has an important effect on energy demand from the building sector, implying that building efficiency becomes more significant as countries become more prosperous. The importance of energy efficiency in building sector is especially significant in developing countries, owing to rapid new construction with opportunities to employ efficient materials and best practices. This work presents energy-efficient retrofit of electricity consumption by replacement of conventional lamps with LED in the building of Petroleum Products Pricing Regulation Agency (PPPRA), Abuja. The efficient use of energy will enhance the sustainable of other resources and in turn contribute to the growth and development of a nation. The study by Trifunovic *et al* (2009), showed a potential energy saving of up to 27% in resid

Energy in Buildings

The urgent need or demand of sustainable development requires the use of natural resources so that future generations can meet up with their needs. One of these resources is energy. Today's energy is generated mostly from fossil sources, e.g. coal, oil and natural gas, and the demand is high while the supplies are limited. Statistics show that 41% of energy consumption in Europe is used for buildings and life in those buildings (http://www.europa.eu. 2015). Therefore, reduced needs would mean large energy savings. Sustainable development does not require a complete change in lifestyle but does oblige us to use energy appropriately. Reduction in the use of these energy forms would therefore result in beneficial effects for the environment and for human beings.

Retrofits with LED Lamps

The major issue in –'lighting'- today is probably the possible replacement of different lamp types by highly efficient LED lamps. Rapid developments in the area of Solid-State Lighting (SSL) technology have created a real reorganization of the lighting industry worldwide with great emphasis on enormous potential savings. An analysis of LED retrofit lamps offered on the market (as alternative and equivalent to linear fluorescent solutions) carried out indicated that these lamps have a reduced energy consumption (approximately 50%), a life time typically two to three times higher, a comparable color rendering and a beam angle of around 140° (William *et al*, 2012)

Studies about energy-efficient lighting retrofit generally suggest that most existing lighting installations consist of fluorescent lighting (with conventional ballasts) (Sweatman and Managan, 2010). Some recent studies, (Lehman et al., 2011; CIE, 2013), Poplawski& Miller (2013) proposed a light source evaluation using a flicker frequency dependent maximum flicker index. (Osterhaus, 2014) stressed the need for appropriate combinations of LED sources and LED drivers.

Lighting Fitting

The various energy lighting sources are classified under the following categories:

LED Lamps

LED is a "solid-state lighting" technology using light emitting diode. Basically, instead of emitting light from a vacuum or a gas, solid-state lighting emits light from a

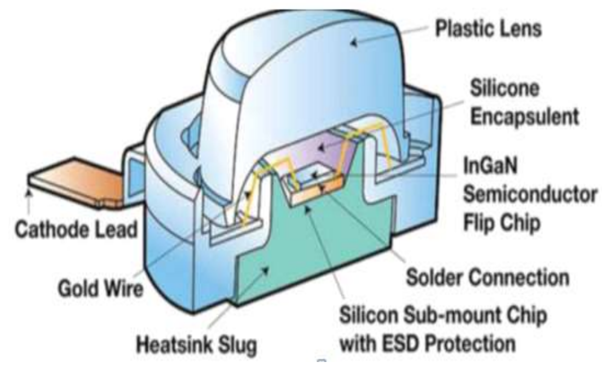

Figure 1: Components of a typical Light-Emitting Diode **Source:** (http://continuingeducation.construction.com/crs. php?L=223&C=947)

piece of semiconductor made of a positively charged and a negatively charged component. The light is emitted when electrons move around within the semiconductor structure from the negative to the positive layer. Several studies have been conducted on the benefits of retrofitting conventional lighting systems with the new low energy ones (Aghemo et al, 2014). Light emitting diode (LED) lamps are more effective than incandescent and compact fluorescent lamp (CFL) bulbs and have a longer lifetime while providing similar luminous. Uddin *et al*, (2011), found that LED lamps are more expedient than conventional bulbs and also advance in terms of environmental friendliness. Figure 1 shows various components of LED. (http://continuing education.construction.com/crs.php?L=223&C=947)

Incandescent Light Bulbs.

Incandescent light bulbs are the most commonly used bulbs. They are also called the "Edison Bulb." They have a simple technology. When connected to a power supply, the electric current heats the wires and tungsten filament to 4,000^{0}F and tungsten begins to evaporate. Without the inert gasses (argon and nitrogen), the tungsten particles would collect on the inside of the glass, causing it to darken. The gases, however, collect the tungsten particles and send them back to the filament. However, almost 90% of the energy generated by an incandescent bulb is released as heat, not light. Table 2: The range of luminous efficacies for different artificial light sources(US Department of Energy. 2007).

Fluorescent Lamps

A fluorescent lamp is a low-pressure gas discharge light source. Mainly this light is produced by fluorescent powders activated by ultraviolet radiation generated by discharge in mercury. Generally, this lamp is in form of a long tubular bulb with an electrode at each end, it contains mercury vapor at low pressure with a small amount of inert gas for starting. The electrodes are coated with a material that, when heated

Table 2: Luminous Efficacies

Light source	Typical luminous efficacy range in lm/w (varies depending on wattage and lamp type)
Incandescent (no ballast)	10-18
Halogen (no ballast)	15-20
Linear fluorescent (including ballast)	50-100
Compact fluorescent lamp (CFL) (including ballast)	35-60
Metal halide (including ballast)	50-90
Cool white LED->4000K (including driver)	60-92
Warm white LED ->4000K (including driver)	27-54

Source: (US Department of Energy. 2007).

upon by switching the lamp, emits electrons that establish a current across the lamp. Because of the negative voltage-current characteristics of fluorescent lamps it required a device to limit the lamp current, else the ever-increasing current would destroy the lamp. Fluorescents lights can be used in many applications Industrial, commercial, and residential. Fluorescents provide a shadow free lighting in all applications (Figure 2).

Compact fluorescent lamps (CFL)

A compact fluorescent lamp(**CFL**), also known as a compact fluorescent lighter energy saving light, is a type of fluorescent lamp. Most CFLs are designed to replace incandescent lamps and fit into most existing light fixtures. Compared to general service incandescent lamps giving the same amount of visible light, CFLs use less power and have a longer rated life. CFLs typically have a rated lifespan of between 6.000 and 10.000 hours, whereas incandescent lamps usually have a lifespan of 750 hours or 1.000 hours. Figure 3 shows a compact fluorescent lamp.

2. PROPOSED APPROACH

The sample of public building was considered for this study. The Petroleum Products Pricing Regulation Agency (PPPRA) head office building was specifically selected for the evaluation of the lighting system. PPPRA head office building is located at the Central Business District (CBD) of Abuja Federal Capital Territory. Energy security, environmental concerns, thermal comfort, and economic matters are driving factors for the development of research on reducing energy consumption and the associated greenhouse gas emissions in every sector of the economy Fumo, (2014).

Figure 2: Fluorescent Fitting

Figure 3: Compact Fluorescent Lamp (Philips Lighting Company SAG100 2006)

The rapid development of human population, buildings and technology application currently have caused electricity consumption to grow rapidly Ahmad *et al,* (2014). Therefore, efficient energy management and forecasting energy consumption for buildings are important in decision-making for effective energy saving and development. The building consists of seven floors with wing A and B on each floor illuminated by fluorescent lighting fittings. Access Bank is also housed on the ground floor of the building. The working days for both Access Bank and PPPRA are five days. Due to the nature of job carried out by the organizations, the working hours are estimated to be 13 hours per day. This information was obtained from the maintenance department and the security unit who are

Table 3: Estimation of Total Number of Lighting Fitting (Saleh, 2017)

Floor	Wing A	Wing B	Lobby	Total quantity
G	48	48	14	110
1	51	52	14	117
2	74	64	14	152
3	66	69	14	149
4	79	80	14	173
5	74	81	14	169
6	56	44	14	114
		TOTAL		984

Figure 5: Fluorescent tube lighting fitting 72W 2 feet x 2ft (Saleh, 2017)

always in the building. Figure 4 describes the location and indicating area of the research work.

Existing Lighting

The existing lighting lamps in the building are of fluorescent type. It is a two (2) by two (2) ft fitting consisting of four (4) fluorescent tubes with two ballasts of thirty six (36W) Watts each meaning, the wattage rating of each fitting is seventy two (72W) Watts. There are a total of Nine Hundred and Eighty four (984) lighting fittings. The number of the lighting fittings were counted manually and the results were double checked with the lighting layout to minimize data gathering error. The lighting layout was obtained from Maintenance Department and it shows the location and type of lamp used in the building in details. It has been identified that the lighting tubes used are philips and Osram fluorescent lamps. Table 3 presents the arrangement of lighting fitting in the building and Figure 5 shows the compacted fluorescent unit lighting fitting.

Potential Energy Saving

LED is a highly energy efficient lighting technology and has the potential to fundamentally change the future of lighting in the world. It uses at least 75% less energy, and lasts longer life span than fluorescent and incandescent lamp. Widespread use of LED lighting will have great potential impact on energy savings in Nigeria. The computation of daily energy consumption, saving and electricity tariff are given in eqns. 1 to 3:

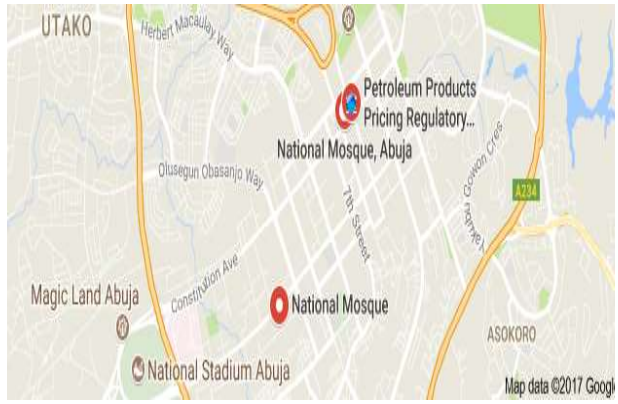

Figure 4: Description of the location of PPPRA

The total daily energy consumption (EC) is calculated by multiplying the total number of lamps fitting (N), power consumed by the lamp (W), and total hoursof operation (OH), which is assumed to be 13 hours. The formula is interpreted in the following equations.

$$EC = (N \times W \times OH)/1000 \quad (1)$$

where;
EC is energy consumption,
N is number of lamps and
OH is operating hours per day.

Total energy saving (ES) would be the difference between energy consumption of existing lighting system (ECexisting) and the retrofit lighting system

Table 4: Variable Parameters Analysis

Variables	LED Fittings	Fluorescent Fitting	Unit
Power rating of lamp	36	72	Watts
Single unit provisional Price of lamp	12,000	7,000	Naira
Number of lamps	984	984	Lamps
Running time per day	13	13	Hours
Operational days per month	20	20	Days
Cost of energy/KWh	47.09	47.09	Naira
Life span	50,000	15,000	Hours

Table 5: Energy Consumption Comparison.

Variables	LED Fitting	Fluorescent fitting
Electrical load of lamps in (Watts)	35,424	70,848
Running time per month	260	260
Energy consumption per month (kwh)	9,210.24	18,420.48
Energy to be saved per month (kwh)	**9,210**	0
Total cost of energy per month in Naira	433,710.20	867,420.40
Amount to be saved per month in Naira	**433,710.20**	0
Total Cost of Purchase of lamp	11,808,000	6,888,000
Recovery period of amount spent on purchase of lamp	27 months	0

(ECRetrofiting):

$$ES = ECexisting - ECretrofitting \quad (2)$$

where;

ES is energy savings,

ECexisting is energy consumption of the existing lamps (fluorescent) and

Ecretrofitting is energy consumption of LED lamp.

Bill saving (BS) is calculated by the product of energy saving (ES) with electricity tariff (ET).

$$BS = ES \times ET \quad (3)$$

where; BS is bill saving,

ES is energy savings and ET is electricity tariff.

RESULTS AND DISCUSSION

This section presents and discusses extensively the results and analyses performances of the two types lamp comparing their energy conservation with one another

Lighting Audit

A walk-through lighting audit was carried out to ascertain the number of existing fluorescent fittings in the building and the result is as presented in Table 2 This was necessary to help come up with the required number of LED fittings to be used to retrofit the fluorescent fittings. Furthermore, the rating of the existing fluorescent was also identified to be 72W while a 36W LED fitting was recommended to retrofit the existing fluorescent fitting.

Energy Consumption

Considering the latest electric tariff rate by Abuja Electricity Distribution Company (AEDC), the electricity provider, the tariff rate for a public building is 47.09 Naira per kWh. In this survey the policy for retrofitting the old lighting system with the energy saving LEDs is considered. The variables considered in the analysis are presented in Table 4. The total energy consumption for the lighting application of the selected building for both fluorescent and LED is presented in Table 4.

Equation (1) and the variables in Table 4,were used to determine the energy consumption for both LED and fluorescent lamps. Then using Equations (1 – 3), we computed energy consumption for both, LEDs and Fluorescent fittings, Table 5 is a representation of the summary of the results obtained from the computation. In term of fluorescent lamp, no energy was save both in kWh and amount in Naira, the recovery period of the lamps purchase were equally zero.

Economic Analysis of LED Lamp Compared with Fluorescent Lamp

As a result of retrofitting, the overall amount of energy consumption decreases and consequently a decrease in the monthly electricity bill. There is also a significant improvement on the environment because of decrease of the harmful effect of the heats radiations. As shown in Table 5, the total energy consumption using 72 W fluorescent fitting is 18,420.48kWh while the total energy consumption using 36 W LED fitting is 9,210.24 kWh. The energy to be saved when retrofitting is carried out using the recommended LED is 9,210.24 kWh which translates to N433,710.20 in savings considering AEDC energy billing rate of 47.09 /kWh for public buildings. The amount of energy saved in terms of Naira and kWh by using fluorescent lamps was approximately zero, while there was great tremendous saving saving and benefits derived from using LED lamps. The lifespan of fluorescent is 15,000 hours translating to three years considering 13 hours of daily operation while the life span of LED is 50,000 hours translating to ten years considering 13 hours of daily operation.

Amount of money needed for the purchase of fluorescent fitting is N6, 888,000 and the amount needed for the purchase of LED is N11, 808,000. In view of the foregoing, it was noted that the initial capital investment for LED is high. However, considering the lifespan of fluorescent and LED lamps the recovery period for the high initial capital investment on LED is 27 months which is two years 3 months. It is therefore worthy of note that the lifespan of LED provides additional advantage over fluorescent lamp. Table 6 presents the comparison of the three model of existing lamps.

CONCLUSION

There is great potential in buildings for energy savings. Different types of buildings that efficiently save energy prove that the issue is no longer how to make energy efficient building but what type to choose. In this work energy saving has been analyzed based on the comparison between the conventional lighting system and the proposed LED retrofitting. The policy for retrofitting the old lighting system with the new energy saving LEDs has produced 50% in savings when compared with fluorescent lamps. The result of the life span analysis reveals that after two year three months (27 Months), the selected building will bring profit for the investment. Furthermore, LED is almost maintenance free.

Table 6: Comparison of three Models

	Incandescent	Fluorescent	LED
Input power (watts)	40	11	2
Yearly energy (kwh)	350	96	18
Lamps Life (years)	0.25-0.5	1-2	20+
Estimated energy cost/year (N47.09)	N16,481.5	N4,520.64	N847.62

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