Design and Evaluation of Electrical Services for an Energy Efficient Home

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Abstract- Nigeria is facing an acute shortage of electric power that drives economic activities. Consequently, all sectors of the economy are facing a retrogression in productivity. Besides, even much of the power made available either from the grid or self-generation is wasted due to poor installation design and use of inefficient devices and equipment such as filament bulbs, and fluorescent lamps (among others). This work examines the present common practice of electrical services that wastes energy with the viewing to advancing the best practice that minimises overall energy / power loss. A three-bedroom flat and an eatery in Nigeria were used as a case study. Load audit, analysis and calculations were made to assist in making vital decisions as to the types and sizes of luminaires, cables and protective devices (among others) to be used in accordance with known standards and regulations. The results show that 71.8% and 69.1% respectively of energy is saved for lighting in three-bedroom flat and eatery; 37.4% and 30.8% in other loads used in three bedroom and eatery respectively. All this is as a result of use of frugal design and energy saving – saving devices. This further implies a saving in absolute cost of energy consumed in a particular situation.

Indexed Terms- Design, Electrical services, energy efficiency, model

I. INTRODUCTION

Energy efficiency is a concept which involves the utilization of energy in the most economical way for efficient service delivery, thereby reducing energy wastage and the overall consumption of energy resources. (Adejumobi et al, 2016)

Imbibing energy efficiency culture will help more people to have access to electricity. It also helps to minimize the building of power stations, thus the money for building power stations will then be spent on other sectors of the economy. The promotion of large scale, concrete, national energy efficiency program is a critical demand-side initiative to help reduce the energy consumption of a series of major end-use appliances, in particular air-conditioners, refrigerators, electrical motorized equipment, heating equipment and lighting. This will assist the Nigerian Government to increase access to electricity and at the same time mitigate the emission of greenhouse gases resulting from energy generation (UNDP, 2013).

The major objective of the paper to design and evaluate energy efficiency home of series of end-use appliances (lighting, air conditioner, refrigerators, fans, heating equipment etc) for two different classes of apartment (three bedrooms flat and an eatery).

II. METHODOLOGY

Energy efficiency cannot be obtained by mere selection of more efficient lamps alone. Efficient luminaires along with the lamp of high efficacy achieve the optimum efficiency.

After rigorous examination of several literature review on the present practice of electrical services design, the wasteful practice was identified and a better ways and methods was suggested for designing electrical services for an energy efficient home.

The tables 1.0 indicate the various types of loads and their ratings that will be considered in the design.

Table 1.0: Load type and power requirement in (W) of Conventional Model and Energy Saving equipment / appliances.

S/N	Load Type	Conventional Model (CH) in W	Efficiency Energy Saving Model (EESM) in W
1	Lighting	24, 40, 50, 60	3, 6, 9, 10
2	Ceiling Fan	75	75
3	Standing Fan	120, 150, 210	75, 85
4	Extractor Fan	30	12, 18
5	Refrigerator	750	250
6	Air Conditioner	900	746
7	Water Heater	4500	2000
8	Electric Cooker	3600	2100

Source: (AKT Lighting and LG Electronics)

Two major kind of building was used, a three-bedroom flat and an eatery as a case study, in this paper the lumen method was used to calculate the lighting point needed in each room and the total lumen is expressed mathematically as follows.

$$\text{Total lumen} = \frac{\text{Luminance x Area of working plane}}{\text{Maintenance factor x Utilization factor}}$$

$$\emptyset = \frac{\text{E x A}}{\text{MF x UF}}$$

$$\text{N} = \frac{\text{Total Luminance}}{\text{Luminance/ Lamps}}$$

Where,

N = number of lamps required.

E = illuminance level required (lux)

A = area at working plane height (m^2)

∅ = average luminous flux from each lamp (lm)

MF= maintenance factor, an allowance for reduced light output because of deterioration and dirt.

UF= utilization factor, an allowance for the light distribution of the luminaire and the room surfaces.

- Lighting Design Calculation

For the calculation, the table 2.0 shows building area with their different illumination levels, the light level used in this design is based on the type of building under consideration.

Table 2.0 shows the standard values for illuminance (IES lighting handbook)

Building Area	Light level (lux)
Executive Office	150 - 200
Living room / den	200 – 500
Bedroom, Dormitory	200 - 300
Kitchen	150 - 300
Hall, landing / stairway	100 - 500
Restroom / toilet	150 - 300
Cafeteria – eating,	200 - 300
Store	150
Lobby – office, corridor	150 - 300
Storage room	50 - 200

Source: Illuminating Engineering Society (IES) lighting handbook

Table 3.0 and 4.0 below show the room type with the calculations for the number of luminaire to be used. The type of luminaire used for this calculation work is Compact fluorescent lamp (also known as energy saving lamp) which have different lumens for various purposes. In this design four major types of wattages used are: 24W (2400 lumen); 100W (2400 lumen); 40W (1600 lumen) and 150W, 4800 lumen respectively.

Table 3.0: Determination of number of luminaire for a three-bedroom flat.

S/N	Room Type	$N = \frac{E \times A}{\emptyset \times MF \times UF}$	Number of Luminaire (CFL) to be used
1.	Veranda	$N = \frac{200 \times 11.20}{2400 \times 0.8 \times 0.7} = 1.67 \approx 2$	2
2.	Pre-Sit	$N = \frac{200 \times 14.10}{2400 \times 0.8 \times 0.7} = 2.1 \approx 2$	2
3.	Sitting room	$N = \frac{200 \times 32}{2400 \times 0.8 \times 0.7} = 4.75 \approx 5$	5
4.	Dinning	$N = \frac{200 \times 18.40}{2400 \times 0.8 \times 0.7} = 2.74 \approx 3$	3
5.	Kitchen	$N = \frac{200 \times 15.30}{2400 \times 0.8 \times 0.7} = 2.29 \approx 2$	2
6.	Store	$N = \frac{150 \times 5.10}{1600 \times 0.8 \times 0.7} = 0.85 \approx 1$	1
7.	Bedrooms	$N = \frac{200 \times 20}{2400 \times 0.8 \times 0.7} = 2.98 \approx 3$	3 x 3 = 9
8.	Toilets	$N = \frac{150 \times 6.20}{1600 \times 0.8 \times 0.7} = 1.04 \approx 1$	1 x 3 = 3
9.	Lobby	$N = \frac{200 \times 12.54}{2400 \times 0.8 \times 0.7} = 1.87 \approx 2$	2
10.	Security	$N = \frac{200 \times 125.65}{2400 \times 0.8 \times 0.7} = 9.34 \approx 9$	9

Table 4.0: Determination of number of luminaire for an Eatery

S/N	Room Type	$N = \frac{E \times A}{\emptyset \times MF \times UF}$	Number of Luminaire to be used
1.	Main Dinning	$N = \frac{200 \times 80}{1600 \times 0.8 \times 0.7} = 17.86 \approx 18$	18
2.	Private Dinning	$N = \frac{200 \times 34.22}{1600 \times 0.8 \times 0.7} = 7.64 \approx 8$	8
3.	Staff Quarters	$N = \frac{200 \times 14.48}{2400 \times 0.8 \times 0.7} = 2.15 \approx 2$	2
4.	Dish Washer	$N = \frac{200 \times 15.10}{2400 \times 0.8 \times 0.7} = 2.25 \approx 2$	2
5.	Storage	$N = \frac{150 \times 4.80}{2400 \times 0.8 \times 0.7} = 0.54 \approx 1$	1
6.	Kitchen	$N = \frac{200 \times 18.45}{2400 \times 0.8 \times 0.7} = 2.75 \approx 3$	3
7.	Food Service Counter	$N = \frac{200 \times 24.88}{1600 \times 0.8 \times 0.7} = 5.55 \approx 6$	6
8.	Manager Office	$N = \frac{200 \times 12.24}{2400 \times 0.8 \times 0.7} = 1.82 \approx 2$	2
9.	Changing room	$N = \frac{200 \times 15.40}{2400 \times 0.8 \times 0.7} = 2.29 \approx 2$	2
10.	Rest room	$N = \frac{150 \times 4.82}{1600 \times 0.8 \times 0.7} = 0.81 \approx 1$	1 x 3 = 3

11.	Lobby	$N = \frac{200 \text{ x } 30.89}{2400 \text{ x } 0.8 \text{ x } 0.7} = 4.60 \approx 5$	5
12.	Security	$N = \frac{200 \text{ x } 192.11}{4800 \text{ x } 0.8 \text{ x } 0.7} = 14.3 \approx 14$	14

Table 5.0 and 6.0 display the lighting load audit of the three-bedroom flat and the eatery of both the conventional model which was used for the calculation and the efficiency energy saving model respectively in accordance with the number of luminaire calculated from table 3.0 and 4.0 respectively.

Table 5.0: Lighting Load Audit of a three-bedroom Flat

S/N	Load Type	Conventional Model (CH) in W	Efficiency Energy Saving Model (EESM) in W	Differences = Energy Saved in W
1	Veranda	24 x 2 = 48	10 x 2 = 20	28
2	Pre-Sit	24 x 2 = 48	10 x 2 = 20	28
3	Sitting Room	24 x 5 = 120	10 x 5 = 50	70
4	Dinning	24 x 3 = 72	10 x 3 = 30	42
5	Kitchen	24 x 2 = 48	10 x 2 = 20	28
6	Store	24 x 1 = 24	5 x 1 = 5	19
7	Bedroom 1	24 x 3 = 72	10 x 3 = 30	42
8	Bedroom 2	24 x 3 = 72	10 x 3 = 30	42
9	Bedroom 3	24 x 3 = 72	10 x 3 = 30	42
10	Toilets	24 x 3 = 72	5 x 3 = 15	57
11	Lobby	24 x 2 = 48	10 x 2 = 20	28
12	Security	100 x 9 = 900	20 x 9 = 180	720
	Total Lighting	1,596	450	1,146

Table 6.0: Lighting Load Audit of an Eatery

S/N	Load Type	Conventional Model (CH) in W	Efficiency Energy Saving Model (EESM) in W	Differences = Energy Saved in W
1	Main Dinning	40 x 18 = 840	12 x 18 = 252	588
2	Private Dinning	40 x 8 = 320	12 x 8 = 96	224
3	Staff Quarters	24 x 2 = 48	5 x 2 =10	38
4	Dish Wash	24 x 2 = 48	5 x 2 =10	38
5	Storage	24 x 1 = 24	5 x 1 = 5	19
6	Kitchen	24 x 3 = 72	10 x 3 = 30	42
7	Food Service Counter	40 x 6 = 240	12 x 6 = 72	168
8	Manager Office	24 x 2 = 48	5 x 2 =10	38
9	Changing Room	24 x 2 = 48	5 x 2 =10	38
10	Rest Room	24 x 3 = 72	5 x 2 =10	62

11	Lobby	24 x 5 = 120	5 x 5 = 25	95
12	Security	150 x 14 = 2100	50 x 14 = 700	1400
	Total Lighting	3,980	1,230	2,750

Table 7.0 and 8.0 show the full load audit of the three-bedroom flat and the eatery of both the conventional model, efficiency energy saving model and the wattage of energy saved respectively.

Table 7.0: Load Audit of a Three Bedroom (for other loads)

S/N	Load Type	Conventional Model (CH) in W	Efficiency Energy Saving Model (EESM) in W	Differences = Energy Saved in W
1	Ceiling Fan	85 x 6 = 510	75 x 6 = 450	60
2	Electrical Cooker	3600 x 1 = 3600	2100 x 1 = 2100	1500
3	Water Heater	4500 x 2 =9000	2000 x 2 = 400	5000
4	Air Conditioner	900 x 6 = 5400	746 x 6= 4476	924
5	Extractor Fan	40 x 3 = 120	16 x 3 = 48	72
6	13A Socket Outlet	300 x 13 = 3900	250 13 = 3250	650
7	Refrigerator	750 x 1 = 750	250 x 1 = 250	500
	Total Load	23, 280	14,574	8,706

Table 8.0: Load Audit of an Eatery (for other loads)

S/N	Load Type	Conventional Model (CH) in W	Efficiency Energy Saving Model (EESM) in W	Differences = Energy Saved in W
1	Standing Fan	120 x 10 = 1200	75 x 10 = 750	450
2	Electrical Cooker	6500 x 1 = 6500	4500 x 1 = 4500	2000
3	Electric Oven	3000 x 1 = 3000	1200 x 1 = 1200	1800
4	Air Conditioner	1920 x 6 = 11520	1493 x 6 = 8960	2560
5	Extractor Fan	40 x 6 = 240	12 x 6 = 72	168
6	13A Socket Outlet	300 x 15 = 4500	250 x 15 = 3750	750
7	Electric Freezer	1000 x 2 = 2000	400 x 2 = 800	1200
	Total Load	28,960	20,032	8,928

III. RESULTS AND DISCUSSION

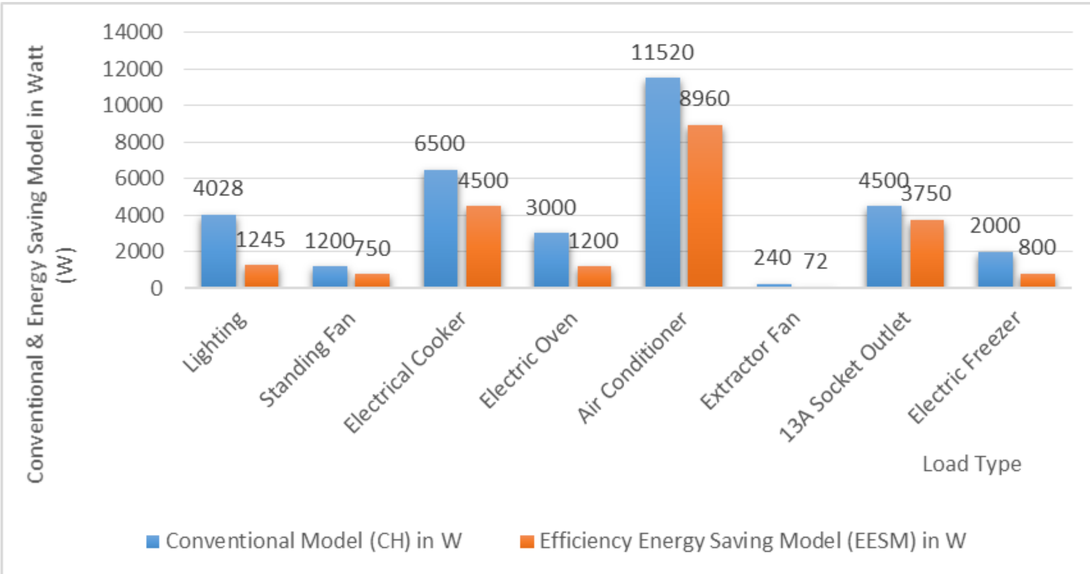

Fig. 1.0: Conventional & Energy Saving Model of a Three Bedroom Flat (all loads i.e lighting & other loads)

Percentage of energy saved (on lighting for a three bedroom flat)

$$= \frac{1146}{1596} \times \frac{100}{1} = 71.8\%$$

Percentage of energy saved (on lighting for an eatery)

$$= \frac{2750}{3980} \times \frac{100}{1} = 69.1\%$$

Percentage of energy saved
(on other loads for a three bedroom flat)

$$= \frac{8706}{23280} \times \frac{100}{1} = 37.4\%$$

Percentage of energy saved (on other loads for an eatery)

$$= \frac{8928}{28960} \times \frac{100}{1} = 30.8\%$$

It should be observed that there is a remarkable reduction in energy waste and consequent saving in energy all through this discussion. The results show that 71.8% and 69.1% respectively of energy is saved for lighting in three-bedroom flat and eatery; 37.4% and 30.8% in other loads used in three bedroom and eatery respectively. In most cases, this is achieved by the use of energy saving compact fluorescent lamps (CFLs), Light emitting diode lamps, installation of lighting control devices such as timers, photocells, and occupancy sensors in bedrooms, stores and other places used frequently in the building. Lighting control devices turn 'on' or 'off' or even dim it as the need arises (Oyedepo, 2012).

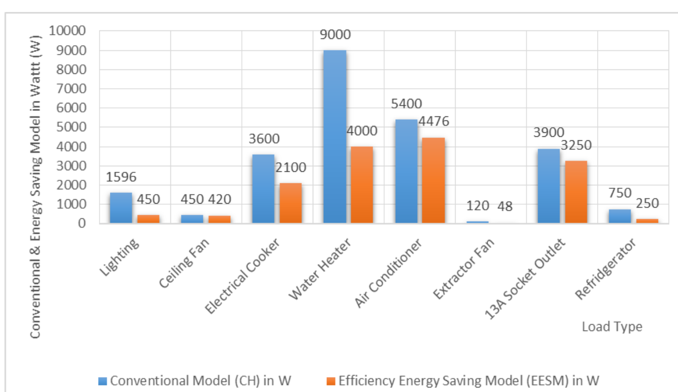

Fig. 2.0: Conventional & Energy Saving Model of an Eatery (all loads i.e lighting & other loads

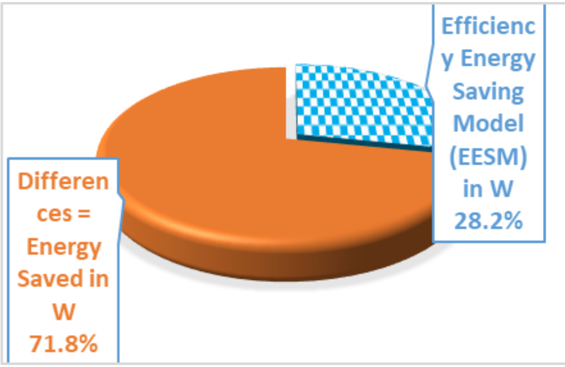

Fig. 3.0: Percentage of Efficiency Energy Saving Model & Energy Saved in W (on lighting for three-bedroom flat)

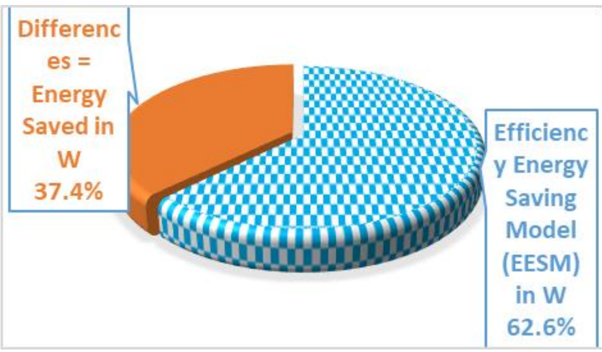

Fig. 5.0: Percentage of Efficiency Energy Saving Model & Energy Saved in W (on other loads for three-bedroom)

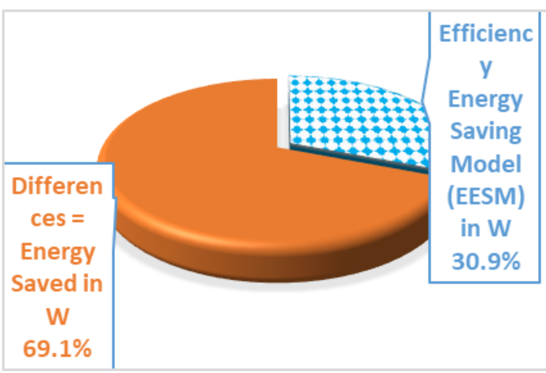

Fig. 4.0: Percentage of Efficiency Energy Saving Model & Energy Saved in W (on lighting for an eatery)

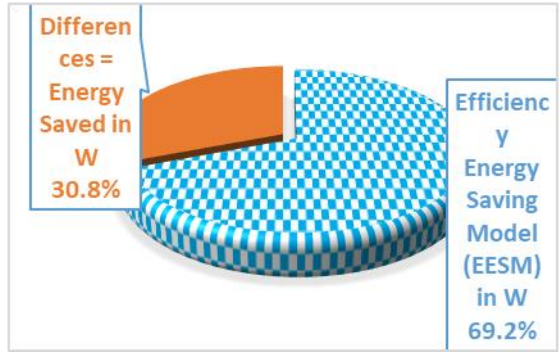

Fig.6.0: Percentage of Efficiency Energy Saving Model & Energy Saved in W (on other loads for an eatery)

IV. CONCLUSION

Design and Evaluation of electrical services for an energy efficient home has been attempted and carried. The long term benefit is immeasurable. The significant of Energy efficient home cannot be over emphasized especially now that we have acute shortage of electric power made available either from the grid or self-generation, most of which is wasted due to poor installation design and use of inefficient devices and equipment such as filament bulbs, and fluorescent lamps (among others). With the reduction of power consumed by virtue of building an energy efficient home, which can also guarantee availability of electricity due to less wastage, one can adopt the use of an appropriate renewable energy to generate power needed so that one can be independent of public power supplied by the Electricity Company.

It will help more people to have access to electricity. It also helps to minimize the building of power stations, thus the money for building power stations will then be spent on other sectors of the economy.

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