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# Evaluation of Potential Energy Savings and Emission Reductions from a Typical Building in a Nigerian University Campus

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Different types of buildings all over the world have been identified to be major consumers of energy in different forms and especially grid generated electricity. Past studies have observed that significant reductions in energy use and carbon dioxide emission could be achieved if energy is used more efficiently in buildings. This study sought to determine the extent of reductions in energy use, costs incurred and reduction in carbon dioxide emissions achievable if some no-cost and low-cost measures are implemented in an institutional building in Nigeria. A survey of the building was conducted and both quantitative and qualitative data were collected. The results show that lighting produces the greatest percentage cut in energy use if all light bulbs presently in use are retrofitted with LEDs but in terms of absolute quantities, the highest cut in energy use is from cooling and ventilation. The conclusion from the study is that the energy performance of the building (65.36kWh/m$^2$/year; 1648 hours annually) is not efficient compared to established standard (80kWh/m$^2$/year; 2448 reference hours). It is recommended that the bulbs should be retrofitted with LEDs and the window air conditioners with split units while the LaserJet printers should be substituted with inkjet printers and maintenance of equipment should be done promptly. Also, no-cost measures are recommended to be implemented by the managers of the building to further boost its energy efficiency.

**Keywords:** Efficiency, emission, energy, equipment, campus, office, saving.

## Introduction

Efficient and effective operation of all types of buildings almost entirely depends on sufficient availability of one form of energy or the other. Buildings are becoming increasingly more complex and energy intensive because of man's insatiable desire to improve his environment for an enhanced living standard (Community Research and Development Centre, CREDC, 2009; United Nations Industrial Development Organisation, UNIDO, 2009; Saidur, 2009; Cao *et al.*, 2016).

Humans, the world over also understand the vital role education has to play in the advancement of all aspects of their lives. This is the reason education is usually given priority by most countries of the world and especially the developed world and the international humanitarian organizations like the united nations (UN), united nations educational, scientific and cultural organisation (UNESCO) and united nations children's fund (UNICEF). The serious developing countries that have also come to accept the indispensability of education in a nation's advancement are also not left behind in ensuring that the sector is given the needed attention in terms of funding and other requirements.

Human activities except just a few that are naturally outdoors in nature are conducted in one type of building or the other. Education is not an exception to this rule. Educational buildings apart from the structure itself accommodate different devices and equipment that are a sine qua non for conduct of researches and teaching. All these facilities need electricity from at least one of the numerous sources to operate them. Availability of electricity in sufficient quantities at all times for the diverse uses is a serious problem in Nigeria.

Successive administrations in the last two decades all identified provision of adequate and stable electricity to meet demands from the various sectors of the economy as vital and made it one of their cardinal goals (Bernard *et al.*, 2016). They all have failed after sinking large funds into the sector. Completion of many of the power projects initiated and being executed over the years have become a mirage and the different sectors of the economy have to rely on alternative sources of energy some of which are unsustainable.

Experience as well as published data has shown that energy misuse and wastage are widespread practices across Nigeria (Oyedepo, 2012; Federal Republic of Nigeria, FRN, 2017). These may be due to people's ignorance of the effects of their actions on the environment. Energy wastage is a practice that should not be tolerated in any sector or part of the Nigerian society for the following reasons:

i. The available quantity is a far cry from what is needed. It makes more sense to be prudent in the use of what is available.
ii. Consumption of almost all types of energy has some damaging effects on the global climate system either in the short or the long run.
iii. Nigeria has one of the fastest growing populations in the world. The rate of growth of infrastructural facilities may not be able to meet up with the population growth.
iv. Developing countries have low adaptive capacities to the likely catastrophic effects of man's disruption of the global climate system.

Reducing electricity consumption of office equipment and appliances in educational institutions can be realized by a study of the use of such equipment as well as the users to identity sources of energy wastage if there are any and to identify measures through which electricity can be used more efficiently. It has been observed that if the building energy efficiency code is properly implemented, it has the potential to save up to 40% of the current energy use by buildings in Nigeria (FRN, 2017). Even though the focus of the code is on new buildings, it is believed that the principles if implemented in existing buildings can bring about marked reductions in energy use. This study was conducted to assess electricity use in a building in a Nigerian university campus to determine possible savings in resources (energy, cost and emissions). The study will also add to the existing literature as the available data on energy use and conservation measures in buildings are mostly for residential buildings (Boyano *et al.*, 2013).

## Literature Review

### Energy Use in Buildings

Different types of buildings employ energy for various purposes depending on their functions. However, most types of buildings would almost need energy for lighting, cooling and ventilation and operation of appliances at least at some times of the day. Different past studies have established that the building sector consumes the largest share of all generated electricity in Nigeria. The figure ranges from 50% given by Geissler *et al.* (2018) to as much as 78% given by Federal Ministry of Power, Works and Housing, FMPW&H, (2016). Uihlein and Eder (2010) found energy use by buildings in the EU to be about 40% of the total generated. A more recent study by Ruparathna *et al* (2016) put the energy consumption of the building sector globally at 40%. Other studies that emphasized the energy intensive nature of buildings (and the need to reduce same) from different parts of the world are Lee and Yik (2004), Iqbal and Al-Homoud (2007), Kneifel (2010) and Popescu *et al.* (2012).

Among the many factors that determine the energy intensity of buildings are location and weather, the size of the building, building envelope, orientation, indoor environmental parameters, type of equipment installed and the behaviour of the occupants (Boyano *et al.*, 2013). The variety of uses to which energy is put in educational buildings includes but are not limited to lighting, ventilation and cooling, operation of office and laboratory equipment and water pumping. Rahman *et al.* (2010) found out from their study on an institutional building in Australia that office equipment, HVAC and lighting account for 48.34%, 32.51% and 19.15% of energy consumption respectively (Figure 1). Figure 2 shows the three greatest consumers of electricity in office buildings in the hot and dry climate region of Nigeria (FMPW&H, 2016).

The study of Rahman *et al.* (2010) is specifically on an institutional building as against FMPW&H that considered large offices generally. Many energy-intensive appliances are used in educational institutions and this could be the reason for appliances consuming the highest amount of energy in Figure 1.

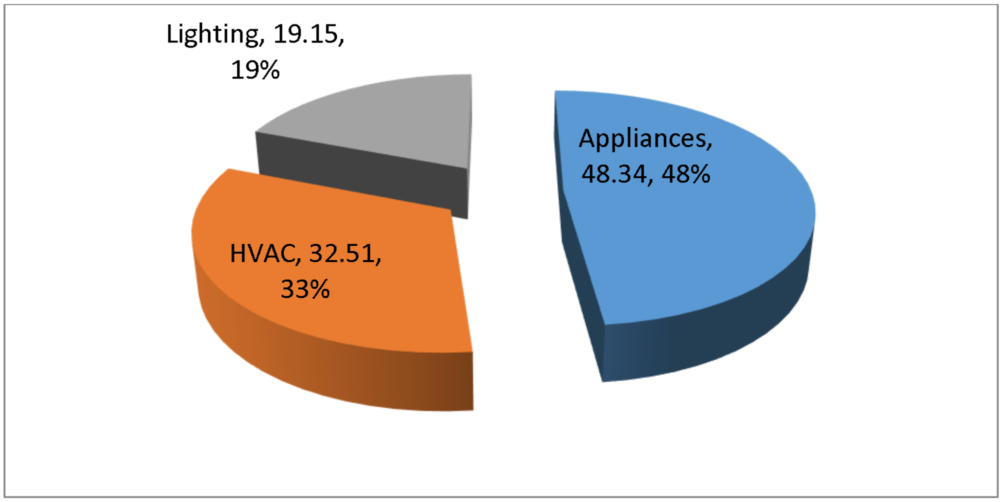


**Figure 1: Total building energy consumption breakdown**
Source: Rahman *et al.* (2010)

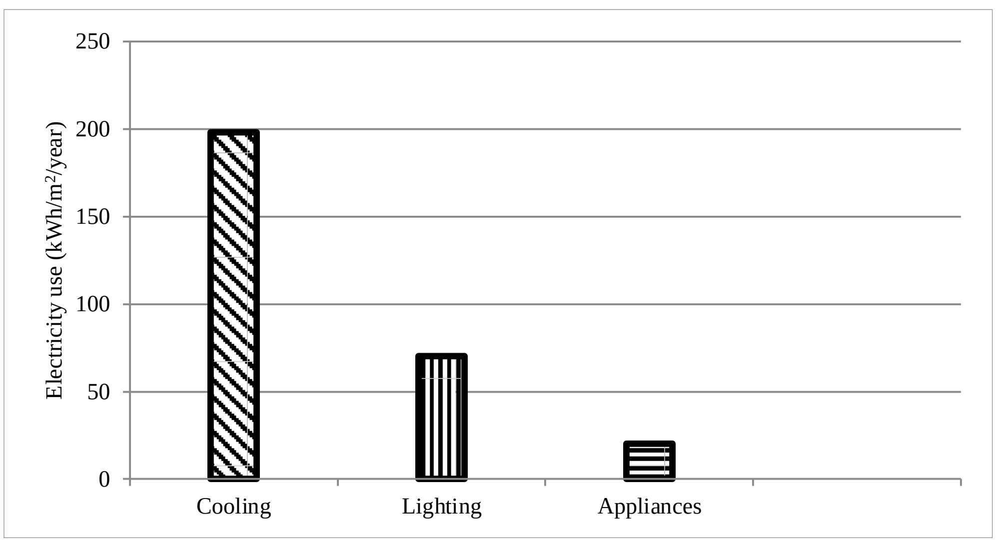


**Figure 2: Breakdown of electricity use in large offices in hot and dry climate**
Source: FMPW&H (2016)

**Energy Saving in Buildings**

Energy saving in buildings can be achieved through both energy conservation and energy efficiency. While energy conservation emphasizes reduction in energy usage, the thrust of energy efficiency is more effective utilization of energy to avoid wastages. Iqbal and Al-Homoud (2007) and Rahman *et al.* (2010) classified energy saving measures into three as follows:

a. No-cost measures which can be achieved through behavioural adjustments without incurring any cost. Examples are adjustment of temperature set point, nighttime setback and scheduling of lighting and equipment run times.
b. Low cost measures such as insulation of walls and roofs, use of more efficient glazing and retrofitting existing inefficient bulbs with more efficient ones.
c. Major investment measures such as system renovation and major alterations to the building.

Energy efficiency is the process of reducing the energy consumption of buildings while still ensuring that the comfort of the occupants is not adversely affected. UNIDO (2009) defines energy efficiency of a building as the extent to which the energy use per square metre of floor area of the building conforms to established energy consumption benchmark for that particular building type under defined climatic conditions. Energy efficiency does not only make buildings produce less impact on the environment but also makes them more resilient and economically more sustainable (FMPW&H, 2016; Ruparathna *et al,* 2016). Lee and Yik (2004) posited that the two approaches to making buildings energy efficient are regulatory control (through codes and legislation) and voluntary commitment.

Energy efficiency can be achieved by improving in both the practices of and the products used by building occupants. In other words, efficient use of energy can be achieved by both behavioural and technological approaches (CREDC, 2009). The behavioural approach to energy efficiency entails the users of buildings involving in practices that will assist in eliminating unnecessary use of energy such as switching off appliances and fittings when they are not needed while the technological approach involve installation of less energy intensive appliances and retrofitting old inefficient ones with new and more efficient ones (Chwieduk, 2003). Ruparathna *et al.* (2016) posited that improving the energy performance of a building will involve some or all of the following measures:

i. Awareness creation among the building users of the benefits of energy efficiency
ii. Improvements in the management of energy use in the building
iii. Adoption of energy efficient technologies
iv. Use of renewable energy

Khan and Halder (2016) posited that changes in the behaviour of the users of a building can go a long way in meeting the energy demands of the building even without increasing generation. Allouhi *et al.* (2015) are also of this view in the assertion that energy efficient measures have been identified as one effective way of reducing energy use in buildings. The first and perhaps the most important step in implementing energy saving measures in buildings is identification of areas of energy losses and misuse. The next will be to estimate the amount of losses or wastage and device measures through which they can be counteracted. According to Alajmi (2012) the implementation of these energy efficient strategies is capable of saving about 42% of energy consumption in existing institutional buildings. Doukas *et al.* (2009) put the possible reduction in energy use through energy efficiency by buildings in the EU at a minimum value of 20%.

**Energy Benchmarks for Nigeria**

Building energy consumption benchmarks are representative values for common building types against which a building's actual performance in terms of energy use can be measured (UNIDO, 2009). The benchmarks permit the comparison of the performance of a building to established standards to know whether or not the building's use of energy is efficient (Chung, 2011). The FMPW&H (2016) has adopted the benchmarks developed for South Africa with similar office construction and where consumption of energy is mainly in the form of electricity. The benchmark is under 130kWh/m²/year for best practice air-conditioned office. Since this benchmark does not address the peculiarity of university campuses, the chartered institution of building services engineers, CIBSE, (2008) is relied upon. CIBSE (2008) specifications for benchmarking buildings for electrical energy consumption on university campuses are summarized in Table 1.

**Table 1: Electricity benchmarks for university campuses**

| Category | Name | Electricity benchmark | Carbon benchmark |
|---|---|---|---|
| 18 | University campus | 80 kWh/m² | 44 $kgCO_2/m^2$ |

Source: CIBSE, 2008.

## Methodology

The research design adopted is the survey approach. Both qualitative and quantitative data were collected. A checklist was prepared and used to collect some of the needed data for the study. The checklist was used to collect information about the various types of fittings and equipment in the building as well as their numbers and locations. The itemization was done according to the various spaces in the department such as the staff offices, classrooms, laboratories, corridors and sanitary conveniences. This approach facilitated a comprehensive compilation of the relevant data for the study. The power rating was obtained from the name plates for those appliances on which this could be seen and for the others, they were obtained from literature.

The next stage of the work was to ascertain the daily average duration of use of each of the fittings and equipment from the users and operators. This information was obtained from the interview responses. In the case of infrequently used equipment for which the daily hours of use could not be easily ascertained, a daily duration of use of 0.1 hours was adopted as suggested by ABS Alaskan (2008). Equations 1, 2 and 3 respectively were used to estimate daily, monthly and annual energy consumption of the various installations (U.S. Department of Energy, USDOE, 2016) and equation 4 was used to estimate carbon dioxide ($CO_2$) emissions (World Resources Institute, WRI, 2006).

$$E_c^d = A_r \times HU_d \times 0.001 \quad (1)$$
$$E_c^m = E_c^d \times ND_m \quad (2)$$
$$E_c^a = E_c^m \times NM_y \quad (3)$$
$$Em_c = E_c \times EF \quad (4)$$

Where $E_c^d$ is the daily electricity consumption by the appliance/fitting in kilowatt hour (kWh), $A_r$ is the appliance power rating in kilowatts (kW), $HU_d$ is daily hours of use of the appliance, $E_c^m$ is monthly consumption of electricity (kWh) by an appliance, $ND_m$ is number of days in a month that the appliance is used, $E_c^a$ is annual electricity consumption by the appliance and $NM_y$ is the approximate number of months in a year that the appliance is operated. $Em_c$, $E_c$ and $EF$ respectively represent $CO_2$ emission, electricity consumption and emission factor.

The monthly and annual energy consumptions were estimated by making some calculated assumptions. The university runs two semesters each session. The usual practice is to observe two weeks and eight weeks as holidays at the end of first and second semester respectively. If one more week is assumed for public holidays that fall outside the ten weeks, the total number of days spent as holidays annually is as estimated:

No. of days in a year (less weekends) = 261
Eleven weeks of holiday = 55
Estimated no. of working days/annum = 206

The cost of energy consumption was estimated by applying the Kaduna Electricity Distribution Company

(KEDCO) tariff plan for office buildings to the computed amounts of electrical energy. Table 2 shows the amount charged special customers by KEDCO for each kilowatt hour of electricity consumed. KEDCO (2016) defined special customers as educational institutions, hospitals, nursing homes, dispensaries and clinics, water boards, religious houses, government and teaching hospitals, airports, military and paramilitary formations and other government establishments.

According to KEDCO description, the building under study belongs to Class A2 and the tariff for this Class in 2018 is ₦43.13. Therefore, the cost of electricity consumed is kWh × 43.13. The carbon dioxide ($CO_2$) emissions resulting from the use of electricity were obtained by applying the electricity emission factor (EF) for Nigeria as given by Brander *et al* (2011). The EF is 0.43963136 $kgCO_2/kWh$.

Some users of the building including staff members and students were asked questions whose responses gave an insight into how the various electrical installations in the department are operated. A comparison of their behaviours with global best practices gave an indication of possible savings of energy and money as well as reductions in emissions that could be achieved. The amounts of possible savings were arrived at by considering only the period of useful or beneficial operation of the fittings and appliances (that is by eliminating possible wastages) and by retrofitting inefficient appliances with efficient ones as suggested by Rao *et al.* (2016).

The questions asked during the interview are as follows:

a. How many hours do you use the office equipment and appliances per day?
b. Do you switch off electrical equipment when not in use or when out of the office?
c. Do you use the fan at the same time with the air conditioner?
d. Do you request for replacement of appliances and equipment as soon as they are faulty?
e. How often is maintenance carried out on equipment and appliances in your office?
f. How old are the equipment and appliances in your office?

The building under study is a three-storey structure accommodating two departments. The data was collected from one of them with a total floor area of 1717.74$m^2$ over the three storeys. The daily hours of use of the equipment were arrived at based on average of the interview responses.

## Findings

Due to the many types and numbers of energy consuming equipment and fittings, the data generated from the study has been grouped together to reduce the volume. The groupings are lighting, cooling and ventilation, office equipment and laboratory equipment. The spaces within the building were also delineated as classes, offices, laboratories, library, studios, corridors and staircases. Table 3 shows the different types and numbers of spaces within the building.

**Table 2: Cost of Electricity for Special customers (₦/kwh)**

| Class | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 |
|---|---|---|---|---|---|---|---|---|---|
| A1 | 33.17 | 35.34 | 37.09 | 27.66 | 25.51 | 25.52 | 25.20 | 25.04 | 24.83 |
| A2 | 38.56 | 41.10 | 43.13 | 32.16 | 29.66 | 29.67 | 29.30 | 29.11 | 28.87 |
| A3 | 39.13 | 47.13 | 49.45 | 36.87 | 34.01 | 34.02 | 33.59 | 33.38 | 33.10 |

Source: KEDCO, 2016.

**Table 3: The number and types of spaces in the Department**

| S/N | Type of space | Number | Location | Users |
|---|---|---|---|---|
| **i.** | Classrooms | 4 | Ground & 2nd floor | Students |
| **ii.** | Offices | 27 | All 3 floors | Staff |
| **iii.** | Computer laboratory | 1 | Ground floor | Staff/students |
| **iv.** | Concrete laboratory | 1 | Ground floor | Staff/students |
| **v.** | Library | 1 | Second floor | Staff/students |
| **vi.** | Drawing studio | 2 | Second floor | Students |
| **vii.** | Store | 2 | 1st & 2nd floors | Staff |
| **viii.** | Carpentry workshop | 1 | Ground floor | Staff/students |
| **ix.** | Conference room | 1 | First floor | Staff/students |
| **x.** | Toilets | 12 | All 3 floors | Staff/students |
| **xi.** | Corridors | 6 | All 3 floors | Staff/students |

## Light bulbs

Three types of light bulbs were observed in use in the Department. These are incandescent bulbs (filament bulb), fluorescent bulbs and compact fluorescent lamps (CFL). Their power ratings, numbers and electricity consumption as well as cost are given in Table 4. Table 4 shows some level of energy efficiency in relation to lighting in the building. However, this can be improved by retrofitting the filament lamps and the CFL with light emitting diodes (LEDs) which are less energy intensive than the former two as observed in PHILIPS (2013) and Ruparathna *et al.* (2016). The responses from interview suggest that the bulbs in most of the offices are not less than four years old and they are promptly changed when the need arises.

## Cooling and ventilation equipment

Table 5 presents the types, numbers, power ratings, duration of use of equipment for cooling and ventilation of spaces as well as for refrigeration and the associated costs. The window unit air conditioner is the greatest consumer of energy among this group of appliances. Its rating is almost twice that of the split unit without a corresponding effect on cooling capability. Retrofitting the window units with split units will bring about significant reduction in electricity consumption. The interview indicates that servicing of air conditioners is done once in two years or when they cease functioning. Only a few of the offices use air conditioners and fans at the same time for even distribution of the cooled air. The window units are also very old while the split units are relatively new suggesting that the trend is to replace the older window units with the more efficient split units when the former wears out. If this trend is sustained, it is expected that the use of window units will gradually be phased out in the very near future in this building.

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**Table 4: Types of light bulbs in use**

| S/n | Type of bulb | Number | Rating (W) | Hrs/day | kWh | Cost (₦) |
|---|---|---|---|---|---|---|
| i. | Incandescent | 2 | 100 | 4 | 0.80 | 34.50 |
| ii. | Fluorescent | 36 | 43 | 12 | 18.58 | 801.36 |
| iii. | CFL | 65 | 85 | 8 | 44.20 | 1906.35 |
| | Total | | | | | 2,742.21 |

**Table 5: Cooling and ventilation equipment**

| S/n | Equipment | Number | Rating (W) | Hrs/day | kWh | Cost (₦) |
|---|---|---|---|---|---|---|
| i. | Ceiling fan | 56 | 75 | 8 | 33.60 | 1449.17 |
| ii. | Split air conditioner | 17 | 800 | 6 | 81.60 | 3519.41 |
| iii. | Window unit | 10 | 1500 | 6 | 90.00 | 3881.70 |
| iv. | Refrigerator (small) | 15 | 350 | 8 | 42.00 | 1811.46 |
| v. | Refrigerator (big) | 4 | 500 | 8 | 16.00 | 690.08 |
| | | | | | | 11351.82 |

## Office equipment

Table 6 shows the variety of office equipment used in the building. All the needed details as well as the financial implication of using these machines on a daily basis have been computed and shown in the table. The interview responses indicate that there is no established routine of maintenance of the office equipment and that they are serviced only when they refuse to function properly.

## Laboratory equipment

Table 7 gives the details of laboratory equipment and daily cost of energy use by the machines. These set of equipment are also only serviced when they malfunction even though most of them are very old as revealed by the interview responses from the chief technologist.

**Table 6: Office equipment**

| S/n | Office equipment | Number | Rating (W) | Hrs/day | kWh | Cost (₦) |
|---|---|---|---|---|---|---|
| a. | Desktop computer | 61 | 300 | 4 | 73.2 | 3157.12 |
| b. | Laptop computer | 45 | 75 | 6 | 20.25 | 873.38 |
| c. | UPS | 43 | 240 | 8 | 82.56 | 3560.81 |
| d. | Projector | 5 | 300 | 2 | 3 | 129.39 |
| e. | Inkjet printer | 15 | 20 | 2 | 0.6 | 25.88 |
| f. | LaserJet printer | 14 | 400 | 2 | 11.2 | 483.06 |
| g. | Digital decoder | 4 | 18 | 8 | 0.58 | 25.02 |
| h. | Television | 4 | 120 | 4 | 1.92 | 82.81 |
| i. | Photocopier | 3 | 1500 | 0.25 | 1.13 | 48.74 |
| j. | Scanner | 1 | 20 | 0.05 | 0.001 | 0.04 |
| k. | Internet WIFI router | 1 | 20 | 8 | 0.16 | 6.90 |
| l. | Smart phone charger | 80 | 25 | 5 | 10 | 431.3 |
| m. | Electric kettle | 18 | 1800 | 0.1 | 3.24 | 139.74 |
| n. | Microwave oven | 1 | 800 | 0.25 | 0.2 | 8.63 |
| | | | | | | 8972.82 |

**Table 7: Laboratory equipment**

| S/n | Name of equipment | Number | Rating (W) | Hrs/day | kWh | Cost (₦) |
|---|---|---|---|---|---|---|
| **a.** | Block moulding machine | 1 | 1800 | 0.2 | 0.36 | 15.53 |
| **b.** | Concrete mixer | 1 | 600 | 0.2 | 0.12 | 5.17 |
| **c.** | Table top oven | 1 | 1480 | 1 | 1.48 | 63.83 |
| **d.** | Furnace | 1 | 2000 | 0.2 | 0.40 | 17.25 |
| **e.** | Electric oven | 1 | 1350 | 0.2 | 0.27 | 11.65 |
| **f.** | Electric Sieve shaker | 1 | 2500 | 1 | 2.50 | 107.83 |
| **g.** | Compressive testing machine | 1 | 850 | 0.2 | 0.17 | 7.33 |
| **h.** | Air compressor | 1 | 1400 | 0.2 | 0.28 | 12.08 |
| **i.** | Vibrating table | 1 | 2500 | 1 | 2.50 | 107.83 |
| **j.** | Compression machine | 1 | 1000 | 0.2 | 0.20 | 8.63 |
| **k.** | Table saw | 1 | 1800 | 0.2 | 0.36 | 15.53 |
| **l.** | Multipurpose plane | 1 | 550 | 0.2 | 0.11 | 4.74 |
| **m** | Spray machine | 1 | 250 | 0.2 | 0.05 | 2.16 |
| **n.** | Welding machine | 1 | 3000 | 0.2 | 0.6 | 25.88 |
| **o.** | Electric drill | 1 | 1600 | 0.2 | 0.32 | 13.80 |
| **p.** | Band saw | 1 | 1100 | 0.2 | 0.22 | 9.49 |
| **q.** | Electric powered gas tank | 1 | 1300 | 0.2 | 0.26 | 11.21 |
| | | | | | | 439.94 |

## Summary of Electricity Consumption, Costs and Emission

Table 8 presents the summary of the mean daily, monthly and annual energy consumption, associated costs and emissions from the use of the various machines in the building. The carbon emissions were calculated using equation 4. Table 8 shows cooling and ventilation to be the highest consumer of electricity in the studied building. This agrees with the previous studies of Alajmi (2012) and FMPW&H (2016). The use of office equipment comes next in the rate of energy consumption. This is not unexpected because of the high usage rate of a variety of the equipment by the different occupants including students and academic as well as the non-academic staff members of the department.

Lighting comes third in the list of energy intensive activities in the building consuming an average of 63.58kWh of electricity daily and costing two thousand, seven hundred and forty-two naira. The most obvious reason for this low consumption by lighting is the use of energy efficient CFLs in the building. The laboratory equipment accounts for the lowest consumption of 10.20kWh daily despite their greater numbers and ratings contrary to Rahman *et al* (2010) in which case they are the highest consumers. This is because they are only used occasionally and for short periods of time. The university spends four million, eight hundred and forty-two thousand, three hundred and ninety-nine naira annually on electricity to operate the building. Table 9 present the energy and emission data for the building.

CIBSE (2008) gave an average energy consumption value of 80kWh/m$^2$/year specifically for university campuses. The surveyed building with an energy intensity of 65.36kWh/m$^2$/year consists of different spaces for different uses and the extent of energy use in these different spaces are not the same. If the performance metrics of the building under study (65.36kWh/m$^2$/year at 1648 hours) is compared with the CIBSE standard (80kWh/m$^2$/year at 2448 hours), the building can be said to be inefficient in the use of energy. The classes and the drawing studios which occupy the greatest floor area of the building use electricity only for lighting and operation of the fans most of the times with occasional use of projectors for lectures. The offices in which most of the energy intensive appliances are used occupy a smaller fraction of the floor area and this is the major reason for the relatively low level of energy consumption per meter square in the building. The study however observed the possibility of improving on the energy performance of this building through the no-cost and low-cost energy efficiency measures and these are explained in the sections that follow.

## Estimation of Potential Reductions in Electricity Consumption

The potential reductions in energy from the different categories of use are based on the estimates of energy use in the foregoing sections, the interview responses and some assumptions. The responses from the interview indicate that electricity can be used more efficiently in the surveyed building. The estimations are as follows:

**Table 8: Summary of energy consumption, costs and $CO_2$ Emissions**

| S/n | Energy use | Duration | Consumption (kWh) | Cost (₦) | Emission (kg) |
|---|---|---|---|---|---|
| a. | Lighting | Daily | 63.58 | 2742.21 | 27.95 |
| | | Monthly | 1091.46 | 47074.61 | 479.84 |
| | | Annual | 13097.48 | 564895.26 | 5758.06 |
| b. | Ventilation and cooling | Daily | 263.20 | 11351.82 | 115.71 |
| | | Monthly | 4518.27 | 194872.90 | 1986.36 |
| | | Annual | 54219.20 | 2338474.90 | 23836.26 |
| c. | Office equipment | Daily | 208.04 | 8972.82 | 91.46 |
| | | Monthly | 3571.35 | 154033.4 | 1570.06 |
| | | Annual | 42856.24 | 1848400.9 | 18840.76 |
| d. | Laboratory equipment | Daily | 10.20 | 439.94 | 4.48 |
| | | Monthly | 175.10 | 7552.30 | 76.90 |
| | | Annual | 2101.20 | 90627.64 | 922.88 |
| | Total | Daily | 545.02 | 23506.79 | 239.61 |
| | | Monthly | 9356.17 | 403533.22 | 3858.93 |
| | | Annual | 112274.12 | 4842398.74 | 49359.22 |

**Table 9: Energy and emission data for the surveyed building**

| S/n | Parameters | Values | Units |
|---|---|---|---|
| i. | Total floor area | 1717.74 | $m^2$ |
| ii. | Electrical energy consumption | 112274.12 | kWh |
| iii. | Energy intensity | 65.36 | $kWhm^{-2}year^{-1}$ |
| iv. | Carbon dioxide emission | 49359.22 | Kg |
| v. | Carbon dioxide intensity | 28.73 | $kgm^{-2}year^{-1}$ |

**Savings from lighting**

In the case of lighting, energy use reduction can be achieved by retrofitting all the three types of light bulbs currently in use namely incandescent bulbs, fluorescent bulbs and CFL with the more efficient and less energy intensive light emitting diodes (LED). Also, if the bulbs are always switched off when the offices are unoccupied, this can also lead to a significant reduction in the amount of energy consumed.

*Savings from light retrofits*

The choice of the LED that replaces each of the three types of bulbs was based on the light output of each bulb measured in lumens. That is each bulb is replaced with a LED with the closest lumen output as obtained from PHILIPS (2013).

Therefore two 100 watts incandescent lamps producing a maximum of 1250 × 2 lumens and are replaced with two 16 watts LED each releasing 1400 lumens of light.

Annual electricity consumption of the retrofit = 2 × 16 × 4 × 206 = 2.64 kWh @ ₦43.13

Two 22.5 watts LED (2500 lumens each) will replace each 43 watts straight tube fluorescent lamp (4275 lumens). Each 85watt CFL (6000 lumens) will be replaced with three 22.5watt LEDs (2500 lumens each). The computations for the fluorescents and CFLs are as follows:

Fluorescent = 36 × 2 × 22.5 × 12 × 206 = 4004.64 kWh @ ₦43.13

CFL = 65 × 3 × 22.5 × 8 × 206 = 7230.6 kWh @ ₦43.13

Therefore, total annual electricity consumption due to light retrofits = 11237.88kWh

Energy savings from the retrofit = 13097.48 – 11237.88 = 1859.60 kWh and the saved cost is ₦80204.55 annually.

*Savings from switching off when not needed*

The study observed that the lights are always switched on throughout the day in most of the spaces within the building. While this is inevitable in the corridors and the laboratories, majority of the offices and classes can rely solely on daylight for most parts of the day during most times of the year. The only barrier to the realization of this is glare towards the evening time. However, it was observed that daylight is hardly utilised by the occupants of this building. If the occupants can be persuaded to switch off the lights and use daylight when it is available and also always switch the lights off when the offices are to be left unoccupied for a reasonable length of time when going for lectures, meetings and breaks, at least 20% savings in energy and cost could be achieved (Doukas *et al.,* 2009).

20% of energy consumption due to lighting = 13097.48 × 20/100 = 2619.50 kWh

Cost savings from switching lights off when not in use = 2619.50 × 43.13 = ₦112978.86

Potential energy savings from lighting = 1859.60 + 2619.50 = 4479.10 kWh

Potential cost savings = 80204.55 + 112978.86 = ₦193183.41

**Savings from cooling and ventilation**

The most obvious area where some energy saving could be achieved in cooling and ventilation is the retrofitting of the window air conditioners with the split units. If the ten window units are retrofitted with split systems, the amount of energy and operating cost savings that would accrue are as estimated below:

kWh consumed by 10 window units daily = 10 × 1500 × 6/1000 = 90

kWh consumed by 10 split units daily = 10 × 800 × 6/1000 = 48.

Therefore, potential annual energy savings = (90 – 48) × 206 = 8652kWh and the amount of money that would be saved from this action annually will be 8652 × 43.13 = ₦373160.76.

**Savings from office equipment**

The identified measures through which electricity can be saved from equipment used in the offices are as enumerated below:

a. Changing all the 14 LaserJet printers rated 400 watts to inkjet printers rated 20 watts
b. Retrofitting all the eighteen 1800 watts electric kettles with more energy efficient ones rated 750 watts each.

Savings from (a) = (14 × 400 × 2/1000) – (14 × 20 × 2/1000) = 11.2 – 0.56 = 10.64 kWh daily.
Therefore, annual energy savings from this measure is (10.64 × 206) = 2191.84 kWh and the amount of money that would be saved is (2191.84 × 43.13) = ₦94534.06.
Savings from (b) = (18 × 1800 × 0.1/1000) – (18 × 750 × 0.1/1000) = 3.24 – 1.35 = 1.89 kWh daily. The annual energy savings is (1.89 × 206) = 389.34 kWh and the cost saving is ₦16792.23 annually. The computers automatically switch to the energy saving mode once they are left unused for a long time.
Total annual energy savings from office equipment = 2191.84 + 389.34 = 2581.18 kWh
Total annual cost savings from office equipment = 2581.18 × 43.13 = N111326.29.

**Savings from laboratory equipment**

The interactions with the chief technologist reveal that the machines in the laboratory are operated only when needed and are highly unlikely to be misused. No estimates could be made for energy and cost savings for this group of equipment indicating that they are being used efficiently.

Table 10 presents a summary of potential reduction in energy use, the associated reduction in the cost of energy as well as $CO_2$ emission that would be avoided as a result of implementing the energy efficient measures described in the foregoing sections of this work. The table also shows that although lighting is not the highest consumer of electricity, it presents the greatest opportunity (34.20%) for electrical energy and cost savings in the surveyed building. The implication of this is that the amount of electrical energy consumption initially attributed to lighting (13097.48kWh) can be further reduced by 34.20% to 8618.14kWh if the measures explained are implemented. This is followed by ventilation and cooling of spaces (with a potential reduction of 15.96%), operation of office equipment with 6.02% potential reduction and operation of laboratory equipment. The absolute emission reduction in percentages attributable to the different uses of electricity is presented in Figure 3.

**Table 10: Potential reduction in annual energy use, cost and carbon dioxide emission**

| S/n | Energy use | Energy (kWh) | Cost (₦) | % reduction | Emission (kg) |
|---|---|---|---|---|---|
| a. | Lighting | 4479.10 | 193183.41 | 34.20 | 1969.15 |
| b. | Vent. & cooling | 8652.00 | 373160.76 | 15.96 | 3803.69 |
| c. | Office equipment | 2581.18 | 111326.29 | 6.02 | 1134.77 |
| d. | Lab. equipment | 0 | 0 | 0 | 0 |
| | Total | 15712.28 | 677670.46 | | 6907.61 |

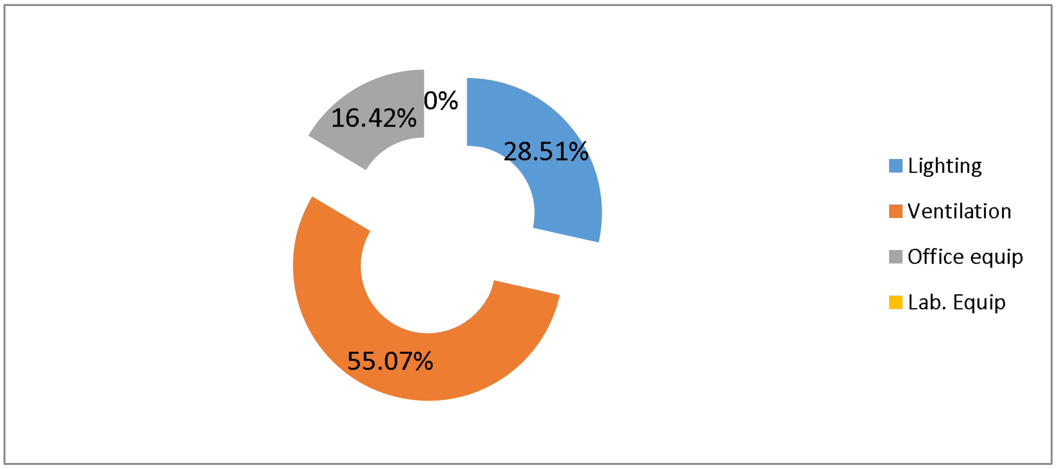


**Figure 3: Percentage reduction in emission from different uses of electricity**

The monetary savings accruable from the implementation of the stated measures amount to NGN677670.46. The overall percentage savings in energy use achievable through the implementation of the measures outlined in the foregoing sections of this work is 14% which is short of the possible 20% and 40% observed by Doukas *et al* (2009) and FRN (2017) respectively. It is believed that the implementation of major investment measures will bring about much more savings in energy consumption in the building.

## Conclusion and Policy Suggestions

Lighting produces the highest percentage reduction (34.20%) from all categories of use but in terms of the absolute quantity of energy, cost and emission reduction that could be achieved by the implementation of the identified measures, ventilation and cooling with 55.07% comes first because of the high amount of electricity consumed by the window air conditioning units. The implementation of the various identified measures is capable of reducing the energy consumption in the building from 112274.12kWh/m$^2$/year to 96561.84kWh/m$^2$/year which is equivalent to a 14% cut in energy consumption, cost and carbon dioxide emission as they are all related. The seemingly high energy efficiency of the building is due to the larger percentage of the floor area being occupied by the classrooms which use energy mainly for lighting and running of the fans while the offices accommodating the high energy consuming appliances take up a relatively smaller fraction of the floor area.

The study recommends that all the existing light bulbs be retrofitted with more efficient LEDs. The window air conditioners are also suggested to be changed to split units, LaserJet printers should be retrofitted with inkjet printers and maintenance should be done on the different equipment to forestall breakdown. All very old appliances should also be replaced with new and more energy efficient ones. In addition to these, the study recommends the adoption of no cost measures which are achieved through behavioural adjustments by the users of the building to further make the building more energy efficient.

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