Assessment of Energy Efficiency of Customer Care Buildings of Telecommunications Companies in Selected Towns in Nigeria

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ABSTRACT

The importance of energy to human development cannot be overemphasised as it is a key determinant of the economic development of all nations. However, the supply of energy has hardly ever been sufficient to meet up with the ever-increasing demands exerted by multiplying population and industrialisation. Buildings are accountable for nearly 40% of the total global annual energy consumption most of which is used for lighting and air conditioning. With the building sector having a relatively high potential for energy efficiency improvements compared to other sectors, this research aimed to assess the energy efficiency of the customer care buildings of telecommunication companies in selected towns in north-west Nigeria. This was done by finding out where and how energy is being used in the buildings by estimating the energy consumption of the buildings through assessment of the energy bills and a preliminary energy audit and benchmarking with set standard. Descriptive statistical analysis was done and it was found that 85.71% of the buildings have their HVAC systems consuming over 50% of their total energy with an average consumption of 74.58% per year. Also, 57.14% of the buildings have higher energy use and energy use intensities than the benchmarks. It was concluded that the major energy-consuming systems are the HVAC and lighting. It is therefore recommended that grid electricity which is the main source of energy to the buildings should be stabilised; while greater advantage should be taken of passive ventilation and cooling rather than mechanical HVAC systems.

Keywords: *Buildings, business machines, energy benchmark, energy efficiency, lighting.*

INTRODUCTION

Energy is one of the most important building blocks of human development, and as such, acts as a key factor in the advancement of all nations. However, resource augmentation and increased energy supply have failed to satisfy the ever-growing demand caused by multiplying population, rapid urbanisation and developing economies. In addition to these mentioned factors responsible for the surge in energy use in buildings are increased demand for building services and the level of comfort provided inhabitants by the buildings as well as the amount of time spent indoors (Perez-Lombard, Ortiz & Pout, 2008). There is, therefore, an earnest need to conserve energy and reduce energy requirements through demand-side superintendence and by using more efficient technologies in all sectors (Asheesh, Kamal, Tyagi & Biswas, 2013; Allouhi, El Fouih, Kousksou, Jamil, Zeraouli & Mourad, 2015). The International Energy Agency, IEA, (2011) estimated that residential, public and commercial buildings account for 30 to 40 percent of the world's energy consumption and contributes 25 to 35 percent of the current world carbon dioxide (CO_2) emissions.

Abdeen (2009) and more recently Liu *et al* (2017) stated that globally, buildings are accountable for nearly 40% of the total world annual energy consumption, most of which are for lighting, heating, cooling, and air conditioning. In its annual energy outlook, the Energy Information Administration, EIA, (2010) reported that total global energy consumption in 2007 was 145,000 terawatt-hour (495 quadrillions BTU), meaning that the buildings sector consumed about 58,000 terawatt-hours (198 quadrillions BTU) (Hayter & Kandt, 2011). EIA (2010) also projected that worldwide energy consumption is expected to increase by 1.4% per year through 2035, implying that buildings will consume 87,000 terawatt-hours (296 quadrillions BTU) by the year 2035.

United Nations Development Programme, UNDP, (2000) observed that for so long, energy interests have been driven by one simple abstraction: increasing the supply of energy. However, great doubts have arisen over the past few decades, about the good sense of pursuing a supply obsessed approach. Attention is beginning to shift towards a more equitable view that also looks at the demand side of energy requirements. Commercial buildings have high energy requirements and can cause great strain on the nation's power grids during peak periods. Constructing more efficient buildings and making the existing stock more energy efficient will help to ensure a stable supply of affordable power and considerably lower operating costs for businesses.

The energy efficiency of a building is defined by United Nations Industrial Development Organisation, UNIDO, 2006) as the extent to which the energy consumption per square meter of the floor area of the building agrees with established energy consumption benchmarks for that particular type of building under defined climatic conditions. Hayter and Kandt (2011) proposed that reducing existing building energy consumption lie in two synergistic approaches namely to reduce energy requirements through the implementation of energy-efficient measures and to offset the remaining building energy needs through the use of renewable energy systems.

It is, however, important to consider building energy efficiency measures, as the outlay cost to invest in efficiency measures is about half the cost of installing renewable energy generating capacity equal to what the efficiency measures offset (IEA, 2006; UNIDO, 2006). Forsström, Pekka, Esa, Miika, Jari, Kari and Irmeli (2011) stated that by the year 2050 buildings could be emitting as much as12, 600 teragrams of CO_2 higher than what they are emitting at present if no proactive measures are taken to abate their energy demands. Reducing energy requirements in buildings lessens the principal and running costs of the stand-by systems, thereby translating to energy savings, reduction in the costs of energy, profitability of business ventures and reduction in CO_2 emissions from buildings. Different commercial building activities have unique energy needs, but the biggest users in the average commercial building are Lighting and Heating, Ventilation and Air Conditioning, HVAC, (EIA, 2012).

The customer care outlets of telecommunication companies in Nigeria being studied are examples of commercial buildings. The companies use the buildings to portray their image to the public and hence are always interested in the optimum functionality of the installed facilities which in turn depends on a constant supply of electricity. According to Leah (2008), most building owners and operators lack basic information about how their properties perform compared to peers or best practices, hence benchmarking to obtain this information is crucial to make decisions about controlling energy use and costs. The aim of this study is the assessment of the energy efficiency of customer care buildings of major telecommunication companies operating in selected Northwestern cities of Nigeria. This was done by estimating the energy consumption and energy efficiency of the buildings by comparing the energy use intensities of the buildings to standards.

LITERATURE REVIEW

Energy Use in Commercial Buildings

Heating, Ventilation and Air conditioning (HVAC) and lighting are both vital to a productive building environment and are the energy of the main area are typically consumed in an average commercial building (Application-Specific Intelligent controls, ASI, 2017). Based on its Commercial Buildings Energy Consumption Survey (CBECS), the U.S. Department of Energy, DOE (2003) showed that HVAC was the main energy end-use with a weight close to 50%, followed by lighting with 15% and appliances with 10%. Table 1 presents a summary of energy consumption in offices by end-use in some countries. In all the countries, HVAC and lighting are the greatest consumers even though the percentages differ slightly.

Straube (2011) identified the major challenge with HVAC systems to be operating them to provide the needed comfortable indoor environment in an energy-efficient manner.

Table 1: Energy consumption in offices by end-use

Energy end-use	USA (%)	UK (%)	Spain (%)
HVAC	48	55	52
Lighting	22	17	33
Office appliances	13	5	10
Other loads	17	23	5

Source: Perez-Lombard *et al* (2008)

Energy used for lighting contributes significantly to the total energy consumption of buildings (Bhusal, 2009). The amount of electricity used for lighting in buildings differs according to the type of building. In some buildings, lighting constitutes the biggest single category of electricity use. As electric lighting is one of the important end-uses of electricity in buildings, energy-efficient lighting could make a huge contribution to the general energy efficiency of buildings. A wide range of technological options are available to achieve energy savings in electric lighting; these include using greater efficient lamps and ballasts, luminaires with a high light output ratio, retrofitting of incandescent lamps, installing lighting control systems, and the increased utilization of daylight for indoor lighting (Bhusal, 2009).

Concept of Energy Efficiency in Buildings

Energy efficiency in buildings is a multifaceted topic which emphasizes that energy should be utilized in a manner that will minimize the amount needed to provide services. This according to the Community Research and Development Centre, CREDC, (2009) is achievable with better energy use practices (behavioural approach) and use of more energy-saving products (technological approach). United Nations Industrial Development Organisation, UNIDO, (2006) defined energy efficiency of a building as the extent to which the energy consumption per square meter of the floor area of the building measures up with established energy consumption benchmarks for that particular type of building under defined climatic conditions while the Federal Ministry of Power, Works and Housing, FMPWH, (2017) defined energy-efficient buildings as buildings that do not consume too much energy in maintaining the desired comfort conditions for the occupants and processes accommodated compared to standard buildings.

FMPWH (2017) stated that Nigeria is faced with many challenges about realising improvements in the energy efficiency of buildings. Some of the identified barriers are lack of awareness of the benefits of energy efficiency, inadequate policy, legal and regulatory frameworks, lack of technical expertise and a dearth of showcased green buildings to draw experience and inspiration from. Some of the measures that will ensure that buildings do not use more energy than is needed as identified from literature are integrated design approach, incorporation of the use of natural lighting and ventilation, retrofitting of old and inefficient appliances, use of more efficient light-emitting diodes (LED) for lighting, intelligent control of systems, change in behaviours and attitudes of the users of the buildings, etc. (Salsbury, Mhaskar & Qin, 2013; Gul & Patidar, 2015; Allouhi, El Fouih, Kousksou, Jamil, Zeraouli and Mourad, 2015; Ruparathna, Hewage & Sadiq, 2016; Khan & Halder, 2016).

Measuring Energy Efficiency of Buildings

Commercial building energy performance, or energy efficiency, is often measured to a certain degree to judge how well a building is doing. However, energy performance measurement involves a comparison of building energy use to some standard, which in the past has typically been the energy use of other similar buildings (European PPP Expertise Centre, EPEC, 2012).

Five generic classes of building energy data analysis methods have been identified as useful in measuring the energy performance of commercial buildings (Michael, 2004). The methods are:

i. Total annual energy and energy intensity comparisons.

ii. Linear regression and end-use component models.
iii. Multiple regression models.
iv. Building simulation programs.
v. Dynamic thermal performance models.

All of these analytical approaches can be used to develop building energy performance measurement methods, but the most effective approach in use today, based on results achieved, is the multiple regression models (Michael, 2004).

Energy Audit Process

The energy audit process proposed by Barun (2015) entails a walk-through inspection of the buildings to:

i. Assess the physical condition of the buildings through a condition survey.
ii. Observe the operational and maintenance trends of the buildings.
iii. Find functional and defective appliances.
iv. Enumerate the number of functional appliances and obtain their energy consumption ratings, duration of use per day and the number of days of use per year.
v. Estimate their energy consumptions.
vi. Calculate the energy use intensities of the buildings by dividing total consumption per year by the total floor area.
vii. Benchmark the energy consumptions of the buildings with established standards.
viii. Identify the most probable and the easiest areas for attention.

Benchmarking Energy Consumption

The term **"**benchmarking**"** describes the procedure of tracking the energy consumed over time of an existing building and comparing the results to similar buildings or an applicable standard. Harvard Energy and Facility, HEF, (2015) also described energy benchmarking as a method used to determine whether a property is using a higher or lower amount of energy than its peer facilities with similar occupancies, climates, and sizes. HEF (2015) further highlighted that benchmarking was done by dividing the total energy used by a building by its total floor area to obtain its Energy Usage Intensity (EUI) which was then correlated to buildings of similar use to determine how efficiently the building was utilizing energy. Lack of dependable data for office and residential buildings makes it difficult to set local benchmarks in Nigeria but for a sub-tropical coastal climate, recent South African regulations set a maximum target of 190kWh/m^2/year for office buildings (FMPWH, 2017).

METHODOLOGY

Research Design

Three approaches used to accomplish this work are review of existing literature, collection of data required and analyzing data using statistical tools. The study collected mainly quantitative data and descriptive statistics were used for analyses. The study essentially involved the following steps:

i. Analyzing selected literature to gain a better understanding of the subject
ii. Using a checklist to get a comprehensive record of electrical appliances, their ratings and average durations of use in each of the buildings
iii. Taking physical measurements using a measuring tape
iv. Tabulation and analysis of the data

Study Area

The office buildings studied are located in Birnin-Kebbi, Gusau and Sokoto. The towns have average annual temperatures and rainfall of 28.4°C and 800mm, 26.5ºC and 888mm, and 28.3°C and 629mm respectively (Cometonigeria Staff, 2011). The population of the study is the customer care buildings of the four major telecommunication companies in Nigeria namely, Airtel, Etisalat, Globacom and MTN and there are nine of such buildings across the three metropolises.

Data Collection

Grid electricity consumption data was obtained from both metered and estimated billings, while diesel and petrol consumption data were obtained from purchase invoices. The equipment in the buildings was grouped into four classes namely:

a. Lighting which includes compact fluorescent lamps (CFL) and light-emitting diodes (LEDs)
b. HVAC which is mainly air conditioners and fans
c. Business machines including computers, printers, photocopiers and scanners
d. Other plug loads such as TV sets, money counting machines, refrigerators, phone chargers, water dispensers, internet servers, satellite decoders, microwave ovens, Wi-Fi routers and water pumping machines.

Data on the lighting systems, the heating, ventilating and air-conditioning (HVAC) systems and other equipment used in the buildings were collected using a checklist. Physical measurements were made to obtain the gross internal floor areas of the buildings. This was done by measuring the external length and breadth of each building and deducting the thickness of the external walls. The gross internal floor areas were obtained by multiplying the internal length by the internal breadth measured. The survey enumerated the number of functional appliances and also obtained their energy consumption ratings, duration of use per day and the number of days of use annually.

Data Analysis

ENERGY STAR Portfolio Manager was used to analyse the data and the results are presented as tables. Prior to this, the energy consumption of the appliances in the buildings has been calculated using the formula given by Asheesh *et al* (2013) in equation 1. Equation 2 was used to calculate the energy use intensity while equation 3 as given by DOE (2011) was used in computing the percentage of floor area air-conditioned.

$$Ec = \frac{N \ x \ H \ x \ W \ x \ D}{100} \qquad equation\ 1$$

Where Ec = Energy consumed
N = Number of appliances
H = Hours of use of appliance per day
W = Power rating of the appliance
D = Number of days of use of the appliance

$$Energy\ use\ intensity\ (KWh/m^2/year) = \frac{total\ energy\ consumed}{gross\ floor\ area} \qquad equation\ 2$$

$$Floor\ area\ air\ conditioned\ (\%) = \frac{floor\ area\ air\ conditioned}{floor\ area\ of\ the\ building}\ x\ 100 \qquad equation\ 3$$

Rating of Grid Electricity Supply Trends

The trend of grid electricity supply has been assessed on a five (5) point Likert scale viz:

i. No supply (there is a complete absence of supply) = 1
ii. Poor supply (supply is of poor voltage i.e. it is not able to power most appliances and it is intermittent in nature) = 2
iii. Intermittent supply (supply is of good voltage i.e. it can power most appliances but it is intermittent in nature) = 3
iv. Stable supply (supply voltage is not good enough but is mostly available) = 4
v. Good supply (supply is of good voltage and is also stable) = 5

Benchmarks

The benchmarks used for comparative analysis of the energy consumptions of the buildings were obtained from Portfolio Manager based on the 4th edition of the commercial buildings energy consumptions survey (CBECS) of the Energy Star Programme by the U.S Department of Energy (DOE, 2003). The Chattered Institute of Building Services Engineers (CIBSE, 2008) used the terms 'typical', 'good practice' and 'measured' to describe the energy consumption by the buildings. Typically refers to the average amount of energy consumed by the majority of buildings with similar characteristics as the one under study; a good practice is the amount of energy that the building should consume if the principles of energy efficiency are adhered to in the design, construction and operation of the building while measured is the actual amount of energy consumed by the building.

RESULTS AND DISCUSSION

Demographic Information on Sampled Buildings

Four of the nine buildings forming the population of the study are in Sokoto. These are Etisalat office (E1), Globacom office (G1) and two MTN offices (M1 & MM1). Two are in Birnin – Kebbi namely Globacom office (G2) and MTN office (M2) while the remaining three namely Airtel office (A3), Globacom office (G3) and MTN office (M3) are located in Gusau. G2 declined to participate in the study while MM1 was not surveyed due to its mixed-use nature which will result in non-discrete data for the study; so, seven of the buildings were surveyed.

Characteristics of the Buildings

Data required to analyze buildings energy performance metrics were collected. These include a description of the building characteristics such as basic function, location, gross internal floor area (GFA) and nature of occupancy (NOO), building use details such as the average number of occupants (ANOO), daily operating hours (DOH), working days/week (WDPW), types and the number of the different types of equipment (Appendices) and percentage of building floor area that is air-conditioned (%FAAC). The data generated is presented in Table 2.

Table 2: Characteristics of the Buildings

Building	NOO	ANOO	GFA (m^2)	%FAAC	WDPW	DOH
A3	Rented	22	108	60	5	10
E1	Rented	27	136	80	5	10
G1	Owned	90	448	90	5	10
G3	Owned	30	155	90	5	10
M1	Rented	22	111	90	5	10
M2	Owned	43	217	90	5	10
M3	Owned	22	108	90	5	10

Table 2 shows that five of the buildings (71.43%) have gross internal floor areas between 100m² - 200m² while the other two have 217m² (14.23%) and 448m² (14.23%) respectively. All the buildings (100%) were used by an average of fewer than 100 people at all times. Five of them (71.43%) had between 20 – 30 occupants; the remaining two had 43 (14.29%) and 90 (14.29%) occupants respectively. All the buildings (100%) had a similar daily operating time of 10 hours, five days a week. One of the surveyed buildings (14.29%) had 60% of its total internal floor area air-conditioned; in another, 80% of the gross internal floor area was air-conditioned while in each of the remaining five, 90% of the internal gross floor area air was conditioned. Table 2 shows that 57.14% of the buildings were owned by the operators while the remaining 42.86% were rented.

Energy Supply Trends and Use Patterns in the Buildings

Results of the analysis on the trends of energy supply and use patterns of the buildings are presented in this section. Intermittent supply was the prevalent trend of grid electricity. Greater use was made of the alternative sources to grid electricity by all the buildings; all the sources of energy had a significant effect on total energy consumption. HVAC was the highest energy-consuming system in the buildings (Figure 2) even though all the systems had significant effects on total energy consumptions. Compared to the benchmarks, three of the buildings were energy efficient while the remaining four were not.

Table 3: Trend of Grid Electricity Supply in the Surveyed Buildings

Building	No supply (1)	Poor (2)	Intermittent (3)	Stable (4)	Good (5)
A3			✓		
E1		✓			
G1			✓		
G3	✓				
M1			✓		
M2				✓	
M3			✓		
Freq.			4	1	0
%	14.29	14.29	57.14	14.29	0

Table 3 shows that one of the buildings (14.29%) had no supply of grid electricity; two of them, each representing 14.29% reported poor supply and stable supply respectively, while the remaining four (57.14%) reported intermittent supply. None of the buildings reported a good supply of grid electricity. The implication of this is that the buildings were operated mostly on alternative energy sources which were highly polluting.

Table 4: Energy Billing Plans

Building	Grid Electricity		Diesel		Petrol	
	Metered	Estimated	Metered	Invoices	Metered	Invoices
A3		✓				✓
E1	✓			✓		
G1	✓			✓		
G3	NIL			✓		
M1	✓			✓		
M2	✓			✓		
M3	✓			✓		

Table 4 shows the way energy consumption by the buildings was read by the utility company. Grid electricity consumption in A3 was estimated by the supply company because of the absence of electricity meter. All the other buildings have meters installed which indicates the amount of electricity consumed monthly. The other exception here is G3 that was not connected to grid electricity. All diesel and petrol consumptions were obtained from purchase invoices.

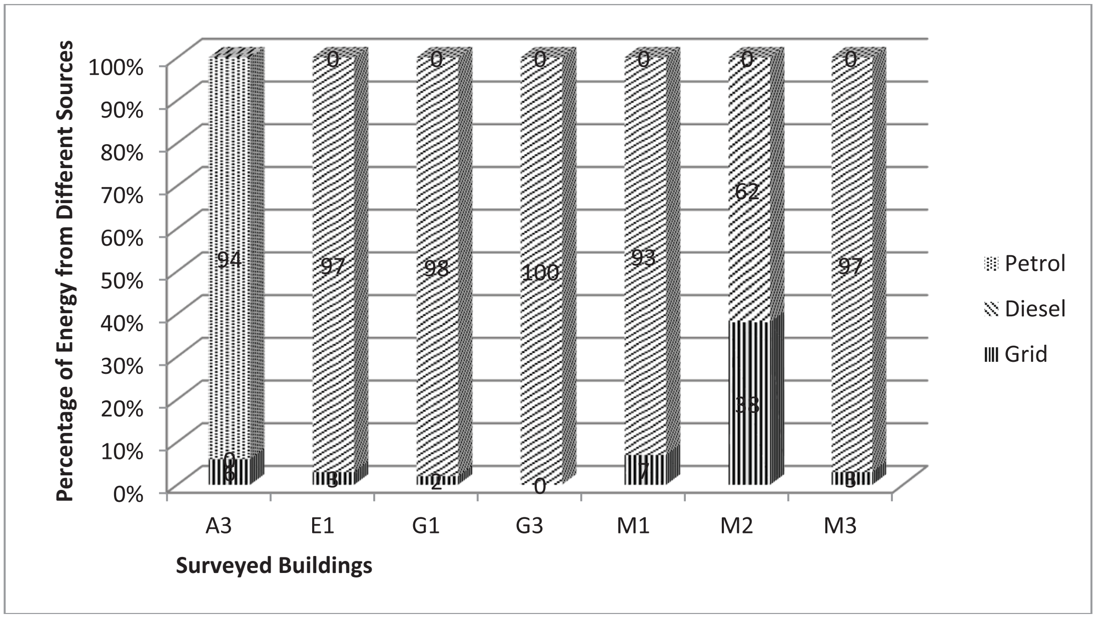

Figure 1: Sources of Energy to the Buildings

One of the seven buildings surveyed was not connected to the grid electricity supply; it relies solely on diesel as its source to power the generator used for generating electricity. The others that were connected to the national grid supply also used alternative sources of energy, mainly diesel and petrol. Five of them (71.43%) used diesel as alternative to grid supply, and one (14.29%) uses petrol as alternative to grid supply. Figure 1 shows that all the buildings used more of their alternative sources of energy (diesel and petrol) to grid electricity at over 60% of their total energy consumption within the period of the study. Only one of the buildings got 38% of its energy needs from the national grid, while the remaining six got less than 10% of their energy needs from the national grid. This shows a trend of greater reliance on other supply sources than the national grid in all the studied buildings.

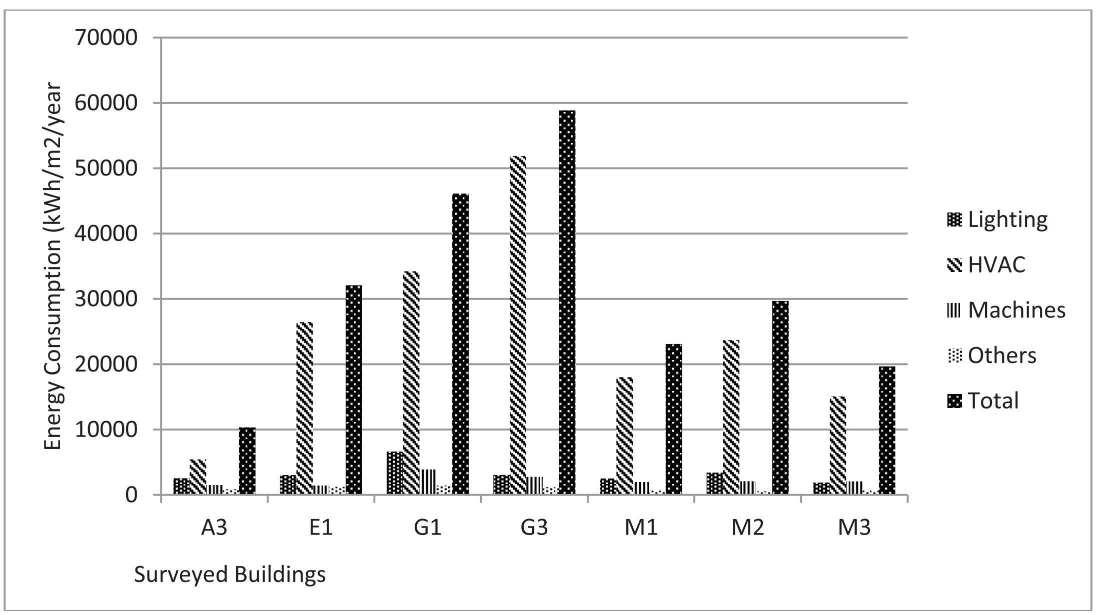

Figure 2: Annual Energy Consumption of the Buildings by End-Uses

Figure 2 shows that the major energy-consuming system was the HVAC with its lowest consumption at 53% and the highest at 88% of all supplied energy. This is followed by lighting with its lowest consumption at 5% and highest at 24% of the total supplied energy. Business machines follow in the hierarchy with 4% and 15% as lowest and highest consumptions respectively; other plug loads consumed the least with lowest and highest consumptions at 2% and 8% respectively. The average total consumptions in percentage (%) of the various end-uses in all the buildings were: lighting 12%, HVAC 76%, Business Machines 8% and other Plug Loads 4%. DOE (2003) earlier depicted that a greater proportion of the energy in commercial buildings was used for HVAC purposes. Figure 2 also shows that all the buildings (100%) used over 50% of their energy on HVAC systems and six (6) of the buildings (85.71%) use less than 20% of their energy on lighting.

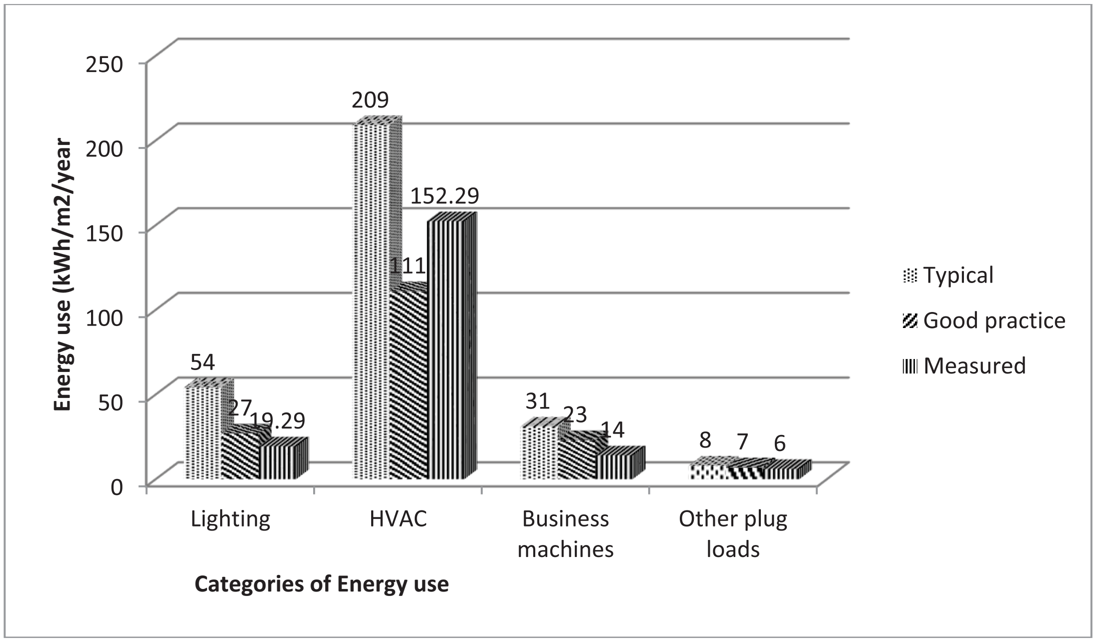

Figure 3: Comparison of the Energy Use Patterns of the Buildings with Benchmarks

Figure 3 shows that all the buildings (100%) were using energy efficiently for lighting (consumption was below the good practice value). The energy use for lighting in the buildings can be made even more efficient by retrofitting the CFLs with LEDs which have higher luminous efficacy than the CFLs mostly in use currently. Three of the buildings (A3, G1, and M2) were using energy for HVAC efficiently, while the remaining four (E1, G3, M1, M2 and M3) also consumed less than the typical value for this category of energy use in this type of buildings. However, the consumption exceeds the good practice value implying that some level of improvement in energy efficiency for air conditioning in these buildings is achievable. Looking at consumptions from business machines, it can be said that all the buildings were operating efficiently as the average measured consumption was lower than both typical and good practice values. For other plug loads, three buildings, A3, E1 and G3 were consuming above the good practice value while the remaining four G1, M1, M2 and M3 were consuming within the good practice range. All the buildings were energy efficient in the use of business machines except E1 whose consumption was greater than even the typical value and closer investigation of the equipment can provide useful insights into why this is so.

Table 5: Comparison of the Energy Use (kWh/year) in the Buildings to Benchmarks

Buildings	Consumption from Bills	Consumption from Audit	Benchmarks	Difference from Bills (%)	Difference from Audit (%)
A3	30222	10338	44028	-31%	-77%
E1	79444	32082	58944	35%	-46%
G1	514000	46114	197472	160%	-77%
G3	330000	58843	71667	360%	-18%
M1	32389	23085	44861	-28%	-49%
M2	32389	29680	55611	-42%	-47%
M3	67944	19660	47139	44%	-58%

Table 6: Comparison of Energy Intensities (Kwh/m²/year) of the Buildings to the Benchmarks

Building	Energy Bills	Energy Audit	Benchmarks	Difference from Bills (%)	Difference from Audit (%)
A3	280	96	408	-31%	-76%
E1	585	236	433	35%	-45%
G1	1148	103	442	160%	-77%
G3	2129	380	461	362%	-18%
M1	292	208	403	-28%	-48%
M2	150	137	256	-41%	-46%
M3	630	182	436	44%	-58%

Tables 5 and 6 compare the total annual energy consumptions and the energy use intensities of the surveyed buildings to the benchmarks respectively. The tables show that based on consumptions from energy bills, three of the buildings; A3, M1 and M2 which represented 42.86% of the studied buildings used less energy and had lower energy use intensities compared to the benchmarks, indicating efficient use of energy in these buildings while the remaining four E1, G1, G3 and M3 representing 57.14% of the houses surveyed used more energy and had higher energy use intensities than the benchmarks, indicating inefficient use of energy in the buildings. However, the estimations from the energy audits show that all the buildings were energy efficient. This implies that all the buildings including those that were energy-efficient from the bills can be operated on lower quantities of energy if some measures aimed at avoiding wasteful use of energy are adopted. The variations in the quantity of energy between consumptions from energy bills and estimates from the audit could be as a result of differences in actual durations of use of appliances and the durations used in the estimations, weather conditions, behaviour of end-users and poor energy efficiency and management practices. It will also be observed from Table 5 that the differences in consumption from the bills and the audits were quite large. The implication of this is that the companies will be able to significantly reduce their expenditure on energy if some of the assumptions used for the audits are adopted.

CONCLUSION AND RECOMMENDATIONS

The energy efficiency assessment of the buildings shows that three of the buildings A3, M1 and M3 were energy efficient while the remaining four E1, G1, G3 and M3 were not. HVAC was by far the highest consumer of electricity in all the surveyed buildings. This was followed by lighting. There is an indication from the comparison of the energy consumption estimates to the benchmarks that all the buildings can be operated more efficiently if proper efficiency measures are put in place and proper design and operation of HVAC equipment and lighting provide the greatest opportunities for this. The variations in the quantity of energy consumed between consumptions from energy bills and estimates could be as a result of differences in duration of use of appliances in the estimates and the reality, the attitude of end-users and poor energy efficiency and management practices. Since the audited energy consumption in all the buildings was lower than the actual consumption, the implication is that the actual consumptions can be lower in these buildings if the principles used for the audit are adopted in the use of these buildings.

Grid electricity which is the main source of electricity supply to the buildings should be stabilized to reduce the use of the alternative sources of electricity. Improved building design that incorporates passive design strategies should be adopted to reduce the requirements for artificial lighting and mechanical HVAC systems which are seen to be the major energy guzzlers in all the buildings. Equipment controls should be made more obvious and easily accessible to encourage end-users to switch off equipment when not in use, as the successful implementation of energy efficiency strategies lies greatly with the end-users. Building (energy) management systems such as occupancy sensors, automatic switches, dimmers and timers etc. should be installed in the buildings to reduce energy use, especially for spaces that are intermittently occupied such as stores, restrooms, etc. The government should have in place policies that seek to reward energy efficiency, such as efficiency certification, incentives and policies such as higher demand charges to sanction inefficiency. More emphasis, however, should be on making energy use in the operation of

HVAC equipment more efficient as the results show that this is the single highest consumer of electricity in all the surveyed buildings consuming more than all other uses combined.

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APPENDICES

Energy Audit Raw Data (A3)

	Rating (KW)	Quantity (No)	Hours /day	Days/ year	Sub-Total (KWh/year)	Total (KWh/year)
LIGHTING						
Compact fluorescents	0.026	32	10	261	2172	2537
Compact fluorescents	0.05	2	14	261	365	
HVAC					0	
Split Unit	1.125	4	3	261	3524	
Packaged Unit	1.5	1	3	261	1175	5429
Fans	0.07	4	10	261	731	
BUSINESS MACHINES					0	
Desktop Computers	0.08	3	10	261	626	
Laptop Computers	0.063	10	5	261	822.2	1515
Photocopier	1.2	1	0.2	261	63	
Printers	0.04	2	0.2	261	4.176	
OTHER PLUG LOADS					0	
TV Set	0.085	3	10	261	666	
Money Counting Machine	0.02	1	0.5	261	3	857
Refrigerator	0.11	1	5	261	144	
Phone Chargers	0.005	7	5	261	46	
TOTAL						10338

Energy Audit Raw Data (E1)

	Rating (KW)	Quantity (No)	Hours/ day	Use Days/year	Sub-Total (KWh/year)	Total (KWh/year)
LIGHTING						
Compact fluorescents	0.026	37	10	261	2511	3022
Compact fluorescents	0.07	2	14	261	512	
HVAC						
Split Unit	1.125	9	10	261	26426	26426
BUSINESS MACHINES						
Desktop Computers	0.08	2	10	261	418	
Laptop Computers	0.063	5	10	261	822	1402
Photocopier	1.2	1	0.5	261	157	
Printers	0.04	1	0.5	261	5	
OTHER PLUG LOADS				261		
TV Set	0.085	2	10	261	444	
Money Counting Machine	0.02	2	0.5	261	5	
Refrigerator	0.11	1	10	261	287	1232
Water Dispenser	0.065	1	10	261	170	
Internet Server	0.09	1	10	261	235	
Decoder	0.015	1	10	261	39	
Phone Chargers	0.005	8	5	261	52	
TOTAL						32082

Energy Audit Raw Data (G1)

	Rating (KW)	Quantity (No)	Hours/ day	Days/ year	Sub-Total (KWh/year)	Total (KWh/year)
LIGHTING						
Compact fluorescents	0.026	28	10	261	1900	6616
Compact fluorescents	0.05	2	14	261	365	
Compact fluorescents	0.07	4	14	261	1023	
Compact fluorescents	0.085	15	10	261	3328	
HVAC					0	
Split Unit	1.125	11	10	261	32299	36214
Packaged Unit	1.5	1	10	261	3915	
BUSINESS MACHINES					0	
Desktop Computers	0.08	6	10	261	1253	3881
Laptop Computers	0.063	15	10	261	2466	
Photocopier	1.2	1	0.5	261	157	
Printers	0.04	1	0.5	261	5	
OTHER PLUG LOADS					0	
TV Set	0.085	1	10	261	222	1403
Refrigerator	0.085	3	10	261	666	
Microwave Oven	2	1	0.2	261	104	
Water Pumping Machine	1.125	1	0.2	261	59	
Internet Server	0.09	1	10	261	235	
Decoder	0.015	1	10	261	39	
Phone Chargers	0.005	12	5	261	78	
TOTAL						48114

Energy Audit Raw Data (M1)

	Rating (KW)	Quantity (No)	Hours/ day	Days/ year	Sub-Total (KWh/year)	Total (KWh/year)
LIGHTING						
Compact fluorescents	0.022	24	10	261	1378	2490
Compact fluorescents	0.026	11	10	261	746	
Compact fluorescents	0.05	2	14	261	365	
HVAC		0				
Split Unit	1.125	6	10	261	17618	18009
Fans	0.075	2	10	261	392	
BUSINESS MACHINES		0				
Desktop Computers	0.08	7	10	261	1462	1958
Laptop Computers	0.063	2	10	261	329	
Photocopier	1.2	1	0.5	261	157	
Printers	0.04	2	0.5	261	10	

OTHER PLUG LOADS	261	0				
TV Set	0.085	1	10	261	222	
Money Counting Machine	0.02	1	0.5	261	3	
Refrigerator	0.11	1	10	261	287	628
Wi-Fi Router	0.012	1	10	261	31	
Decoder	0.015	1	10	261	39	
Phone Chargers	0.005	7	5	261	46	
TOTAL						23084

Energy Audit Raw Data (M2)

	Rating (KW)	Quantity (No)	Hours/ day	Days/ year	Sub-Total (KWh/year)	Total (KWh/year)
LIGHTING						
Compact fluorescents	0.02	28	10	261	1462	
Compact fluorescents	0.026	8	10	261	543	3393
Compact fluorescents	0.05	2	14	261	365	
Compact fluorescents	0.07	4	14	261	1023	
HVAC				261	0	
Split Unit	1.125	8	10	261	23490	23686
Fans	0.075	1	10	261	196	
BUSINESS MACHINES				261	0	
Desktop Computers	0.08	6	10	261	1253	
Laptop Computers	0.063	4	10	261	658	2072
Photocopier	1.2	1	0.5	261	157	
Printers	0.04	1	0.5	261	5	
OTHER PLUG LOADS				261	0	
TV Set	0.085	1	10	261	222	
Money Counting Machine	0.02	5	0.5	261	13	
Water Dispenser	0.065	1	10	261	170	
Water Pumping Machine	0.0125	1	0.2	261	1	529
LED Lamps	0.006	5	10	261	78	
Phone Chargers	0.005	7	5	261	46	
TOTAL						29680

Energy Audit Raw Data (M3)

	Rating (KW)	Quantity (No)	Hours/ day	Days/ year	Sub-Total (KWh/year)	Total (KWh/year)
LIGHTING						
Compact fluorescents	0.022	18	10	261	1034	
Compact fluorescents	0.026	5	10	261	339	1884
Compact fluorescents	0.07	2	14	261	512	
HVAC				261	0	
Split Unit	1.125	5	10	261	14681	15073
Fans	0.075	2	10	261	392	
BUSINESS MACHINES				261	0	
Desktop Computers	0.08	5	10	261	1044	2057
Laptop Computers	0.063	5	10	261	822	

Photocopier	1.2	2	0.3	261	188	
Printers	0.04	1	0.3	261	3	
OTHER PLUG LOADS				261	0	
TV Set	0.085	1	10	261	222	
Water Dispenser	0.065	2	10	261	339	646
Decoder	0.015	1	10	261	39	
Phone Chargers	0.005	7	5	261	46	
TOTAL						19660