Empirical study on rainfall patterns and construction programme provisions in Jos, Nigeria

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ABSTRACT
Weather conditions affect the duration and cost of construction activities while many companies have neglected the need to consider the exact empirical effect it has on the delivery of construction projects. This prompted an investigation on the precipitation patterns in Jos Metropolis of Plateau State, Nigeria and its effects on the delivery of construct3ion projects. The study evaluated the amount and frequency of yearly precipitation in Jos, and compared it with the provisions made by Builders and Construction Managers in preparing construction programmes and determined its effect on the construction projects delivery. A Mixed design approach was adopted with Rainfall data collected from the Nigerian Meteorological Agency for over a 10 year period as well as from structured questionnaires. The Data was analysed using mean and percentages. The study concluded that the provisions made for idle or rain days in preparation of work programmes for construction projects were in most cases inaccurate and thus affected the performance of the construction projects. The study suggests measures to be adopted by stakeholders towards better project outcome.

Keywords: Precipitation, Climate change, Weather, Construction Projects and Work programmes**.**

INTRODUCTION

Climate change increases the risk of embarking on construction projects and has been defined by (Pachauri *et al*., 2007) as modifications in the state of the weather over a long period of time. Bello *et al*. (2012), also defined climate change to be the result of variations in weather conditions such as temperature, wind patterns, precipitation, and relative humidity. Weather events have been known to delay transport and delivery of materials; affecting site programming, costs, and availability of various construction materials (Carbon Disclosure Project - CDP, 2010). Precipitation has been reported to be one of the main factors causing delay and cost overruns on construction projects (Baldwin *et al*., 1971; Koehn and Meilhede, 1981; Laufer and Cohenca, 1990). Precipitation is described as water in a solid or liquid form that falls from the sky to the earth's surface under the influence of gravity. Ewona *et al*,, (2014) classified precipitation by form, type, intensity, and character, however it is the product of condensed atmospheric water vapour; which includes drizzles, rain, sleet, snow, glaze and hail. Precipitation affects many aspects of work on a construction site such as quality, timely completion of activities, and the capacity of site-based personnel to meet the objectives of procedures and plans (Makulsawaudom and Emsley, 2001). Precipitation causes reworks on a construction project and reworks adversely affects the productivity of labour on the site leading to large amounts of unproductive and wasted time (Makulsawaudom and Emsley, 2001, Alinaitwe *et al.*, 2007). In Summary construction projects are carried out in outdoor environments and therefore are affected by weather conditions. The effects on the construction process are usually labour-dependent activities (Thomas and Yiakoumis, 1987; Koehn and Brown, 1985). Extreme weathers affect the health and safety of site workers and labourers and this will in turn delay site construction activities and associated costs (CDP, 2010). Research has confirmed that 50% of construction activities are sensitive to weather conditions (Benjamin *et al.*, 1973). The impact of weather on construction activities can be in the form of reduced labour productivity, quantifying this impact is, clearly, valuable to contractors in preparing realistic schedules, cost estimates, and reliable bids. The productivity loss due to the impact of weather on construction activities can be either partial or total; a partial loss is generally attributed to reduced labour productivity while total loss implies work stoppage which interrupts those activities.

This study determines the climatic variations of rain in Jos based on empirical data for a period of 11years and compared their averages with the provisions made by builders, construction managers, project managers and other key personnel involved in construction scheduling. Construction scheduling or planning has been described as the overall co-ordination and control of a construction project from inception to completion with the aim of meeting a client's requirements functionally and financially that will be completed on time within authorized cost and to the required quality standards (Hendrickson, 2008). The rainfall intensity duration-frequency (IDF) relationship is commonly required for planning and designing of various resource-based projects (El-sayed, 2011). Knowledge about Short term weather and long term climate conditions are essential to adequately design and successfully manage construction projects (National Oceanic and Atmospheric Administration - NOAA, 2010**).** The previous experience of projects provides basic planning logic. Then difference between previous projects and current projects shall be known to make any exceptional features in the basic planning logic. Long term climate impacts, such as sea level rise, coastal erosion, and drought, and short term weather related impacts, such as high winds and flooding influence the choice of site for construction, building techniques, and materials for construction.

PRECIPITATION PATTERN IN NIGERIA

Nigeria has a tropical climate and the amount and intensity of rainfall received in any location is a function of the climate. Two major seasons exist in Nigeria namely; the wet or raining season and the Harmattan or dry season. Two transition periods usher in these seasons, and they are as follows:

- (April to October) – This period represents the wet or raining season in Plateau, Nassarawa and most parts of the country and accounts for about 75% of the total annual rainfall. Steady rains commence in April under the influence of the Humid Tropical Maritime Air mass also known as the South-West Monsoon. Rainfalls in the tropics are generally attributed to frontal, convection or orographic precipitation. The Frontal rainfall occurs when the dry intercontinental air mass comes in contact with the maritime air mass thereby resulting in cooling, condensation and rainfall. The point at which these two air masses meet on land is called Inter Tropical Discontinuity (ITD), and the precipitation patterns are determined by this meeting position.

- (November-March) – This period represents the Dry season. Cold and dusty Harmattan winds commence in November as a result of the Tropical continental air mass or North-East Monsoon. The ITD continues northward till March so that by April the land comes under the influence of moist Maritime air Mass, (Ayoade, 1983; Binbol, 2007).

It is worthy to note that Jos experiences fog and mist also categorised as suspensions and hail stones which is another form of precipitation.

RESEARCH METHODOLOGY

A descriptive design was adopted for the study and a mixed research approach was chosen to combine both qualitative and quantitative data. The study area selected for this research is Jos Metropolis of Plateau State, North Central Nigeria (Figure 3.1) and records of daily precipitation were obtained for the period of 11 years (2005 – 2015*)* from the Nigerian Meteorological Agency, Abuja for Jos. Builders, Construction Managers and Civil Engineers involved in construction planning formed the population of the study. A purposive sampling technique was chosen to gather data from ongoing and completed construction projects in Jos Metropolis.

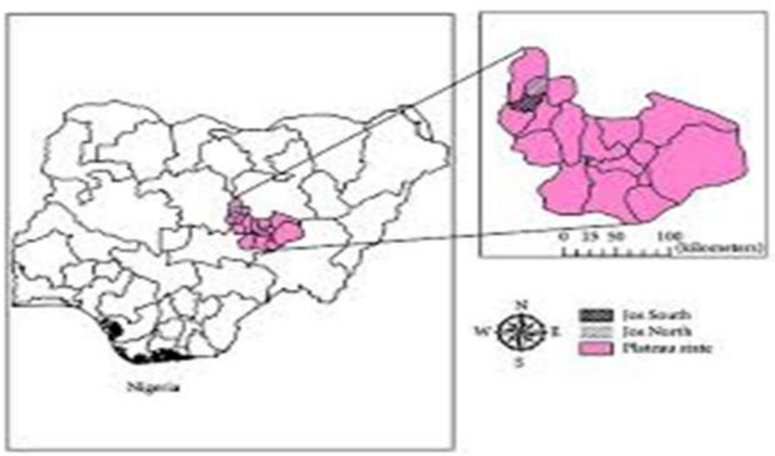


Figure 0.1: Picture Map of Jos, Plateau State, Nigeria

A Total of 40 questionnaires were administered, out of which 31 responses (77.5%) were received indicating. The Questionnaire was divided into two major parts; Section A consists of the characteristics of respondents involved in construction planning or scheduling, while section B consists of data used in scheduling of construction projects adopted for construction projects. Data on provisions made in preparing construction programmes were collected using structured questionnaires and past work programmes.

RESULTS AND DISCUSSION

Results of the data collection and analysis in the study are presented in Tables and Charts with appropriate discussions under each sub-section. Table 4.1 presents biodata of respondents while Table 4.2 shows their consideration in construction programme preparation.

Respondents Biography

Results of Table 4.1, shows that 93.5% of the respondents are Builders while only 6.5% are Civil/Structural Engineers. The results also shows that majority of respondents had Master's Degree as their highest educational qualification with 61.2%, 22.6% were B.Sc. holders, 9.7% holds PhD while 6.5% are HND holders. 67.7% of the respondents are involved strictly in contracting works, 19.4% does both contracting and consulting while those involved in consulting alone are 12.9%. 54.7% of respondents possess 6-10 years working experience, 19.4% had 11-15 years, and 9.7% had above 20years while 6.5% had 16 - 20 years' experience. All the respondents are experienced with construction work programming with varied years of involvement as reflected on Table 4.1.

Table 0.1: Respondents Characteristics

Characteristics	Parameters	Value	%
Area of Specialisation	Builders	29	93.5
	Civil/ Struct. Engrs.	2	6.5
Highest Educational Qualification	PhD	3	9.7
	M.Sc.	19	61.2
	B.Sc.	7	22.6
	HND	2	6.5
Nature of Business	Contracting	21	67.7
	Consulting	4	12.9
	Contracting & Consulting	6	19.4
	Specialized services	-	-
Respondent Experience in years	1 – 5	3	9.7
	6 – 10	17	54.7
	11 – 15	6	19.4
	16 – 20	2	6.5
	20 – Above	3	9.7
Respondents Experience in Construction Work Programming	1 – 5	4	12.9
	6 – 10	10	32.2
	11 – 15	13	41.9
	16 – 20	2	6.5
	20 – Above	2	6.5
Total		**31**	**100**

Source: *Field survey, 2016*

Table 0.2: Programme Planning Considerations

Characteristics	Parameters	Value	%
Time Provisions made in construction for rain days	0 – 7	2	6.5
	8 – 14	10	32.2
	15 – 21	12	38.6
	22 – 28	3	9.7
	29 – 35	2	6.5
	36 - 42	2	6.5
Peak rain Months	June	-	-
	July	7	22.6
	August	22	70.9
	September	2	6.5
Frequency of Construction Programme review	Once	3	9.7
	Twice	6	19.4
	Thrice	18	58
	Four times	4	12.9
	>Four times	-	-
Total		**31**	**100**

Source: *Field survey, 2016*

Provisions made in Construction programmes for Rain days

Results of Table 4.2 show that 38.6 % of respondents involved in preparing construction work programming adopted 15-21 working days /annum as provisions made for delays caused by rains; 32.2 % indicated 8-14 working days/annum; 9.7% made allowance of 22-28 working days/annum, while 6.5% each allowed 0-7; 29-35; and 36-42 working days/annum respectively, for delays caused by rains in construction work programming.

The results in Tables 4.2 also show that 70.9% of respondents involved in construction work programming in Jos indicated August as the peak month in the year for major delays in construction work because of heavy precipitation. 22.6% indicated July as the peak month for the rains while 6.5% indicated September as the month to observe for peak rains in the year. Table 4.2 further revealed that 58% of respondents involved in Construction work programming had reasons to review their work programmes three times in the course of a project, 19.4% had two reviews, 12.9% had the programme reviewed four times, while 9.7% had only one review. These results revealed that all the Professionals involved in construction work programming have spent additional hours revisiting and reviewing the original work programmes. This could be as a result of inaccurate provision made in the first place.

Comparative Analysis of Rainfall Pattern in Jos

Table 4.2 revealed that majority of the respondents involved in scheduling of building projects adopted 15 - 21 days/annum as provisions for delays in construction works in their construction programmes; this is by far six times below the average records of raining days (112 days/annum) as shown in Table 4.3.

Table 0.3: Rainfall patterns (i.e. Raining days/Month) for Jos Metropolis for (2005 - 2015)

Month/Yr.	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	**2015**	**Sum**	**Mean**
January	0	0	0	0	0	0	0	0	1	0	0	0	0
February	0	3	0	0	0	0	1	0	0	1	2	7	1
March	0	4	1	1	0	4	0	0	2	2	2	16	1
April	5	8	10	6	10	7	4	10	9	13	1	83	8
May	11	18	14	16	9	18	11	15	9	18	16	155	14
June	18	15	20	15	16	17	16	15	16	15	15	178	16
July	26	21	22	25	20	20	21	21	18	22	19	235	21
August	24	23	27	26	25	23	23	22	20	20	26	259	24
September	20	21	12	17	16	20	12	20	18	22	16	194	18
October	6	7	2	7	15	12	9	6	8	6	3	81	7
November	0	0	0	0	2	0	0	0	0	0	0	2	0
December	0	0	0	4	0	0	0	0	1	0	0	5	1
Total days	**110**	**120**	**108**	**117**	**113**	**121**	**97**	**109**	**101**	**119**	**100**	**1215**	**112**

Source: Nigerian Meteorological Agency; station point located at Airport Heipang in Jos 2016.

This goes ahead to support evidences shown in Table 4.2 that majority of the construction programmes prepared by respondents have been inaccurate and resulted in repeated reviews (i.e. twice or three times) during the construction phase of a project. The use of inaccurate data in practice can be argued as the cause of time overrun in construction project delivery. The results further revealed that respondents indicated August as the month with the highest frequency of occurrence of rain; this is confirmed with an average of 24 days of rainfall/month and hence adjudged the peak months annually. Results presented on Table 4.4 also confirmed that the Month of August had higher rainfall volumes been the peak month in six (2006 (25%), 2008 (24%), 2009 (25%), 2010 (24%), 2011 (24%) & 2015 (27%)) of the 11years studied with an overall average minimum volume of about 25%. The month of June was peak in two years (2005 (26%) and (2007 (23%)); July was peak in 2013 (30%) while May was peak in 2012 with 29% volume of rainfall for the year.

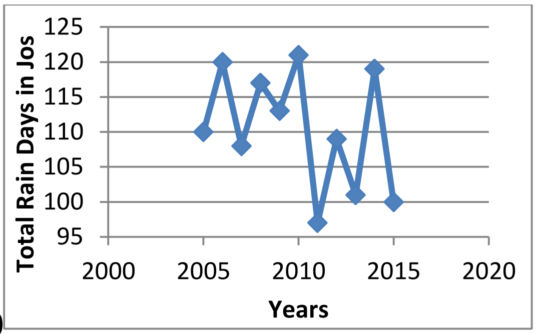
Table 0.4: Rainfall Amounts in mm for Jos for the period of (2005 -2015)

Mth/Yr	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	**2015**
Jan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	0.0	0.0
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.4)	(0.0)	(0.0)
Feb	0.0	35.5	0.0	0.0	0.0	0.0	7.4	0.0	0.0	4.8	37.6
	(0.0)	(2.8)	(0.0)	(0.0)	(0.0)	(0.0)	(0.6)	(0.0)	(0.0)	(0.4)	(3.1)
Mar.	0.0	1.5	11.1	0.3	0.0	48.4	0.0	0.0	1.0	6.6	20.3
	(0.0)	(0.1)	(0.8)	(0.02)	(0.0)	(3.4)	(0.0)	(0.0)	(0.1)	(0.5)	(1.7)
April	92.5	51	82.5	69.2	87.6	76.6	45.9	66.6	166.6	242.7	8.8
	(7.7)	(4.1)	(6.1)	(5.3)	(7.4)	(5.3)	(3.9)	(4.5)	(14.9)	(19.6)	(0.7)
May	124.6	222.9	176.6	224	135.8	142.1	193.9	315.4	95.5	140.3	136.9
	(10.3)	(17.7)	(13.0)	(17.2)	(11.4)	(9.9)	(16.4)	(21.5)	(8.5)	(11.3)	(11.3)
June	310.6	146.6	310	117.1	100.4	218.1	170.5	240.3	172.1	191.4	185.5
	(25.7)	(11.7)	(22.9)	(8.98)	(8.5)	(15.2)	(14.4)	(16.4)	(15.4)	(15.4)	(15.3)
July	223.8	178.2	303.5	272.7	167.8	245.3	240.2	429.0	333.8	248.8	264.7
	(18.5)	(14.2)	(22.4)	(20.9)	(14.1)	(17.1)	(20.3)	(29.2)	(29.8)	(20.0)	(21.8)
Aug.	263.4	307.9	286	307.6	299.4	345.4	281.4	156.9	161.0	139.0	332.1
	(21.8)	(24.5)	(21.1)	(23.9)	(25.2)	(24.1)	(23.8)	(10.7)	(14.4)	(11.2)	(27.4)
Sept.	138.1	245.6	184.1	195.2	190.3	263.5	170.2	201.2	104.2	191.2	205.2
	(11.4)	(19.5)	(13.6)	(15.0)	(16.0)	(18.4)	(14.4)	(13.7)	(9.3)	(15.4)	(16.9)
Oct.	55.9	67.9	1.8	93.6	176	93.2	75.3	58.6	70.7	76.5	23.0
	(4.6)	(5.4)	(0.1)	(7.2)	(14.8)	(6.5)	(6.4)	(4.0)	(6.3)	(6.2)	(1.9)
Nov.	0.0	0.0	0.0	0.0	30.4	0.0	0.0	0.0	0.0	0.0	0.0
	(0.0)	(0.0)	(0.0)	(0.0)	(2.6)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)
Dec.	0 .0	0.0	0.0	24.7	0.0	0.0	0.0	0.0	9.8	0.0	0.0
	(0.0)	(0.0)	(0.0)	(1.9)	(0.0)	(0.0)	(0.0)	(0.0)	(0.9)	(0.0)	(0.0)

Values in parenthesis (*) refers to the percentage of the monthly rain amount for the specific year.
Source: Nigerian Meteorological Agency; station point located at Airport Heipang Jos 2016.

Figures 4.1 a and b further revealed the variations in climate over the 11 years period and the fact that even though the month of August experienced the peak of rains, it is not a rule of the thumb as the Month with peak rainfall for all year round.

The records showed that the Months of July and August have the highest percentage of rain volume in the 11 year period and therefore are not suitable for major outdoor construction works or activities, this was largely confirmed by respondents involved in construction planning or scheduling from Table 4.2.

(a)


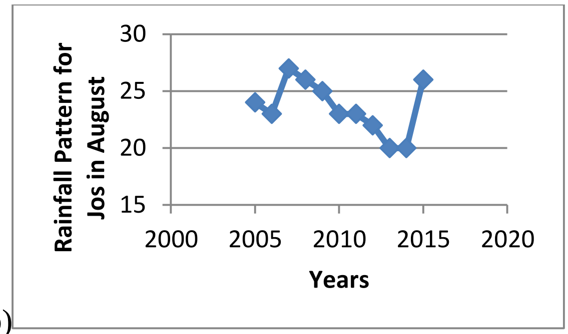
(b)


Figure 0.1: Graphical Representation of Rainfall Pattern in Jos (a) the Rainfall variations for 2005 – 2015;

(b) Rainfall Pattern in August

Figure 4.2 confirms the fact that the months of August and July experience at least 20 working days of rain each on the average. These raining days are not suitable for carrying out major or critical outdoor construction activities such as concreting, excavation works and landscaping. It is important for Builders and Construction Managers involved in construction scheduling to be observant and stay updated with the current trends in the weather and climate change.

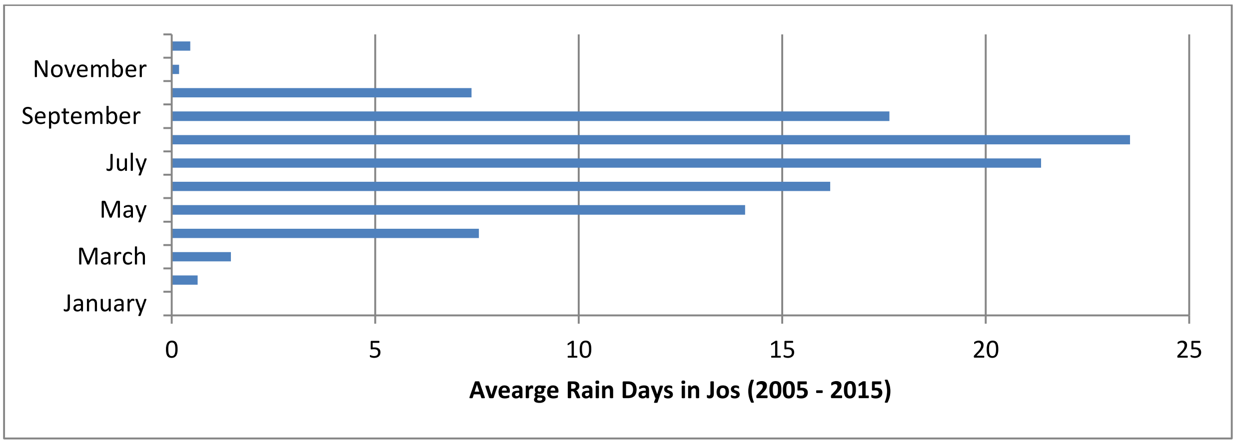


Figure 0.2: Bar Chart Indicating the Average Rain days in Jos for the period (2005 – 2015)

CONCLUSIONS AND RECOMMENDATIONS

The frequency at which work programmes are being reviewed determines the length of the time spent on a construction project and hence the time overrun. It is no doubt that the longer a Contractor stays on a construction site, the more the amount spent in running the site i.e. cost overrun. It follows that making work programmes with inaccurate data will indirectly affect the time and cost of a construction project. This study therefore emphasises the need for Builders and Construction Managers to work with reliable data in construction planning and make effort to update their knowledge of weather conditions as climate is not a constant phenomenon. Construction work involves selection of building materials, purchase, transportation, warehousing or storage, on site or offsite fabrication and lastly the installation or erection of elements and components. This process requires inputs of various participants in the construction supply chain. It is therefore imperative for Builders and Construction Managers to not only plan work schedules that are reliable for them; but take a holistic consideration of others Stakeholders in the supply chain for an effective delivery of building and construction projects.

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Post Occupancy Evaluation on Some Selected Hotels in Minna, Nigeria

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ABSTRACT

Sustainable development goals call for urgent action to be taken to ensure access to affordable and clean energy as well as combat climate change and its impact which Nigeria is committed to achieving. However, Nigeria has two-fold energy challenges: energy sufficiency and a growing population. Fifty one percent of the population has no access to the national grid and 85% of businesses have to invest in back-up power generation. In addition, there is substantial energy wastage in commercial buildings, particularly hotels. Three hotels were evaluated using the Chartered Institute of Building Service Engineers (CIBSE) TM22 POE procedure. Hourly and daily energy use profiles were recorded using Mini CT sensor, Transmitter and Wireless energy monitor. The data obtained were compared with CIBSE established benchmark. Inferential statistic and regression were used to determine whether statistical significance did or did not exist between the dependent variable and the independent variables, also between a linear combination of the variables. The result of the study showed that the hotels are doing worse than good practice and the inferential statistical analysis indicate that the rating will get worse.

Keywords: Post Occupancy Evaluation, Energy Efficiency, Building Energy Audit, Hotels Rooms

INTRODUCTION

Energy Information Administration (EIA) forecast (2011) posits that energy consumption is set to increase by 36% by the year 2030 albeit with its negative consequences. In fact, long term energy availability in increasing amounts underpins future development and economic advancement. However, energy should be obtained from clean, safe, dependable and sustainable sources. Present energy consumption pattern is not sustainable and it is having substantial influence on the climate and environs in general. Fossil fuels use is responsible for the continual rise in carbon dioxide emission, this will require about 50% reduction in emissions until 2050 to stabilize the climate (Hennicke *et al*., 2005).

Energy consumption by hotel facilities is categorized in the top five with estimated consumption of 97.5 KWh of energy used worldwide in 2001 (Hotel Energy Solutions, 2011). According to Zubairu (2012), there is a growing global need to measure and evaluate performance of buildings after being occupied due to its huge influence on the occupants' health, safety, performance in the workplace and stakeholders' needs. In this dissertation, the energy performance of some selected hotels in Minna was evaluated to ascertain whether it is as expected using energy benchmark.

Post-occupancy Evaluation, as defined by some scholars, is a means of assessing the performance of a built environment in use, with reference to the brief, the objectives of the design team, and the activities and feelings of the users (Zubairu, 2006; Van-Wagenberg, 1989). Meir*et al.*, (2009) posited that Post Occupancy Evaluation is a vital and undoubtedly essential approach to constructing more sustainable buildings. Results of POE typically provide feedback and input to other phases of the building project, from initiation to closure. POE has the potential to expose problems, which are unknown by stakeholders of a building. According to Ozturk *et al.*, (2012), POE is not performed in the majority of building projects, which is due to the financial implication of real time data acquisition for POE.

A study conducted by Shiming and Burnett (2002) in sub-tropical climate revealed that electricity is the source, for an average of 73%, of total energy use in hotels; air conditioning is responsible for about 50% of the energy. Furthermore, analysis showed that the hotels' use of electricity is affected by both climate and occupancy level, with the climate being the dominant influencing factor. However, services such as lighting and other miscellaneous services are responsible for about 17 % and 31% respectively. Kamaruzzaman *et al.*, (2009) concluded that office equipment for hotel type building are responsible for high consumption of energy, typically above energy benchmarks hence should be given further attention. Presently, the use of electrical equipment in commercial buildings is rising. In fact, Hewlet Packard (2005) predicted that electrical equipment energy usage is set to increase by up to 500% in the next ten years. The developing countries are expected to witness the leading surge globally. This energy demand spike will happen between 2004 and 2030 (EIA, 2007) where the percentage of energy consumption globally is projected to increase from 46 to 58 percent. Resource depletion, environmental degradation, climate change, are some of the immediate and future impacts. Kelly (2010) avers that the world faces a particular triple challenge of Energy efficiency, Climate resilience and sustainability of consumption.

Furthermore, these concerns will be aggravated by the increasing world population which will result in more buildings and consequently, more energy consumption. Presently, buildings are responsible for significant proportion of global energy consumption. Therefore, building energy efficiency is a principal goal of energy policy at national, regional and international levels (Perez-Lombard *et al.*, 2007). The current trend of energy consumption is not sustainable and has enormous bearing on the climate. This realization has garnered support for green buildings thereby making energy efficiency strategies a priority. In fact, this may have been a real facilitator for the several rating schemes for green building that are presently used globally. Energy efficiency strategies are best integrated during the conceptual and design stage of a building's life cycle. However, recent studies have suggested that early modelling data used for estimating performance may not consistently predict the consumption of an operating building (Fowler and Rauch, 2008).

It is sensible to investigate whether these buildings are performing up to expected in unprejudiced manner. In order to validate the design or reduce the amount of energy used in residential, commercial, and industrial buildings, energy rating and labelling programs have been developed to make the energy use and/or energy performance of a building more appreciable. Energy rating and labelling programs provide an analysis of a building's energy use or energy features and allow comparison to similar buildings. The ability to compare buildings can help place a premium on energy efficient buildings, thereby encouraging building owners to implement energy efficient measures in existing buildings and design future buildings to be more energy efficient.

MATERIALS AND METHODS

The main aim of this paper was evaluating the energy use in some selected hotels after they have been occupied. To achieve this, historical energy consumption was gathered and factors affecting the consumption level will be investigated. As such, quantitative research approach was adopted for this endeavor. Quantitative approach seeks to collect the exact data, to study the association between facts and how these facts relate with theories and findings of any reviewed study (Fellows and Liu, 2008). According to Zikmund (2000), quantitative research lays considerable weight on measurement and analysis of relationships between variables, not process. Quantitative study utilizes a deductive theory to test the variables relationships rather than to develop it (Neuman, 2003), thereby being objective in nature (Jones *et al.,* 2000). Deductive research approach is defined as the use of literature to identify theories and ideas that a researcher will test using data. The researcher will use this to develop a theoretical or conceptual framework or conclusion from an unknown premise (Saunders *et al.,* 2009).

Three hotels were selected for the purpose of this paper. However, prior to commencement of data collection, unstructured interview was conducted for Electricity Distribution Company to confirm energy usage costs and tariff plans. Similarly, unstructured interview was conducted for the hotel managers to gauge their understanding of energy and its impact. The hotels were randomly selected from three categories predetermined by the total amount of tax remittance to the government which is indicative of the level of activity in the hotels.

The names and addresses of the hotels used in this paper have been deliberately withheld; this is in keeping with the condition of anonymity agreed to by all parties concerned. Hence, the three hotels used shall be referred to as Hotel A, Hotel B and Hotel C.

The hotel considered in this case as Hotel A was established in February 2013 with 38 rooms and put to operation in the same year. However, the hotel experiences low occupancy except for the bar that is usually full especially during football matches.

The hotel considered in this case as Hotel B was established in February 2003 with 26 rooms and put to operation in the same year. Letting out data of the hotel shows that the hotel enjoys moderate occupancy which peaked at of 45% in the year 2014.

The hotel considered in this case as Hotel C was established in March 1997 with 30 rooms and put to operation in the same year. However, the hotel experiences moderate occupancy with peak occupancy of 59% in 2014.

The primary source of power in all the hotels is grid electricity supply; however, there are backup generators. All hotels used grid electricity metered and billed in KWh but the generators are not metered in KWh rather a register of monthly diesel usage is kept.

Data Collection

In evaluating the energy use in hotels, the researcher adopted a single research strategy of case study to conduct this paper. As such, it is important to discuss the numerous data sources that can offer case study information which includes: Interview, Archival Records, Observation and Documentation.

Documentations and Instrumentations

This is pivotal to every case study topic, because it validates and supplements evidence acquired (Yin, 2009). To record hourly electricity use profile of the selected hotels, a Mini CT sensor, Transmitter and Wireless energy monitor was used (see plate 1).

Method of Data Analysis

The overall energy use of the hotels was compared with available benchmarks. If the building is performing less well than expected an attempt is then made to find out why. Unfortunately, there are no formal benchmarks developed by Nigeria. Therefore, the guide to CIBSE TM22; Energy assessment and reporting method (CIBSE TM22, 2006) was used (see figure 1).

Plate 1: Wireless Energy Monitor. Source: Fieldwork (2015)

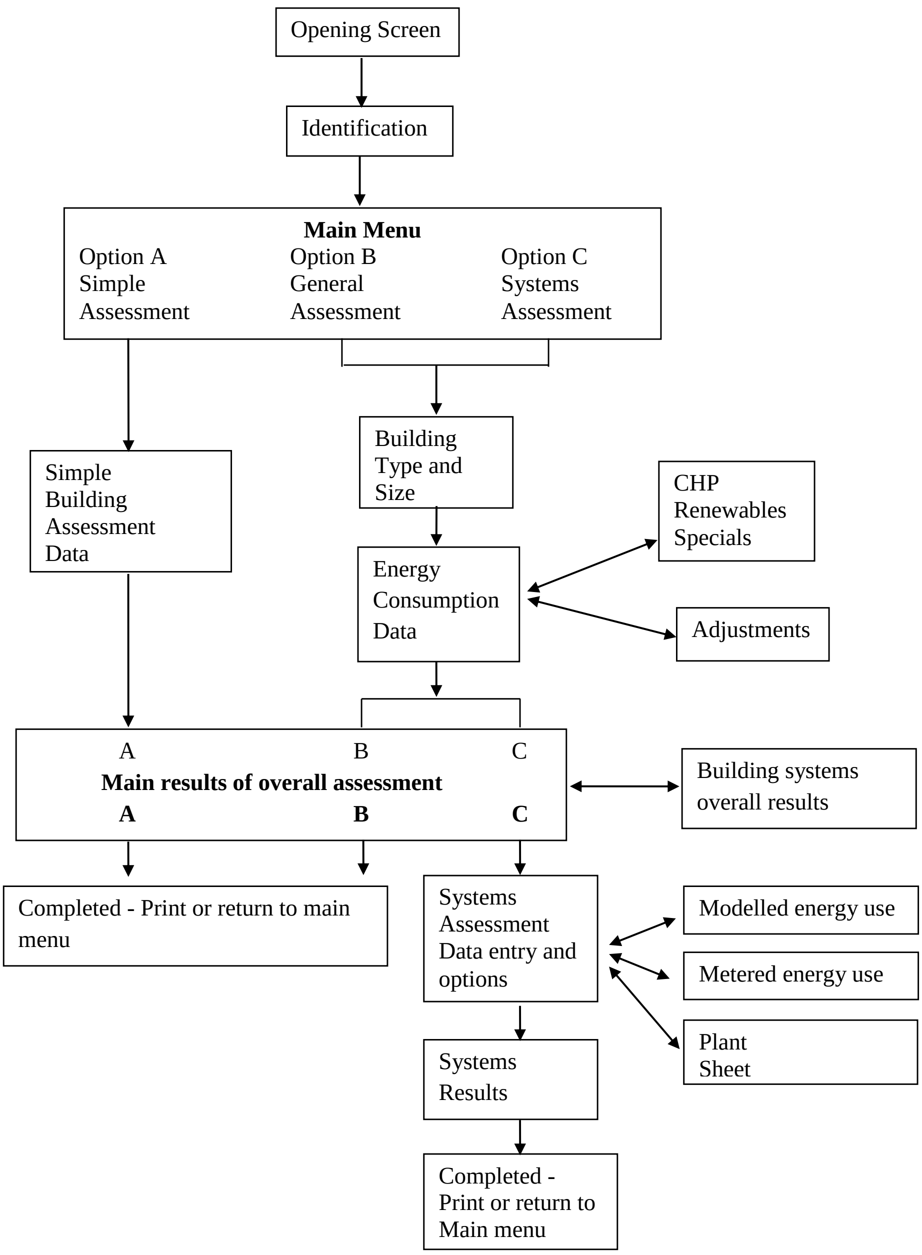


Fig.1:TM22 Procedure Map, Source: CIBSE TM22 (2006)

RESULTS AND DISCUSSION

Case Study of Hotel A

Results of the data collected in Hotel A are as presented in Tables (1&2) and Figures (2, 3 & 4).

The evaluation of the data acquired in figure 1, 2, 3, and 4 showed a steep rise in energy consumption in comparison to the outdoor temperature. In the subsequent months the energy consumption varied with the variation in the outdoor temperature until August when the outdoor temperature steadily increased, conversely, the energy consumption declined. Hypothetically, if same occupancy level experienced in the months with high energy consumption was maintained throughout the year then total energy consumption will diverge from the present profile on a large scale. In fact, the comparison the actual energy consumed with the CIBSE benchmark revealed that energy consumption of the hotel is 2% worse than good practice though 44% better typical electricity consumption of hotel of its profile. Therefore, to establish the significant influencing factor, Regression analysis will be used.

Simple regression analysis concludes that the first null hypothesis is rejected. There is a linear relationship between the independent variable and the dependent variable as p-value (0.024) is below α (0.05). Therefore, the relationship between Total energy consumed and outdoor temperature is statistically significant. Similarly, there is a statistically significant relationship between the dependent variable (Energy consumed) and independent variable (occupancy) as the p-value (0.001) is below α (0.05). Hence, the second null hypothesis is rejected. Multiple regressions were calculated using two independent variables (Temperature and Occupancy) and the dependent variable (Energy consumed).

Table 1: Grid Electricity Supply

Month	Cost of Grid Supply (N)	KWh Consumed
January	119,291.98	3405.42
February	101,923.50	2909.61
March	190,568.91	5440.16
April	161,798.96	4618.87
May	157,817.17	4505.20
June	151,680.83	4330.03
July	143,479.63	4095.91
August	129,829.59	3706.24
September	123,407.76	3522.92
October	111,874.21	3193.67
November	106,316.87	3035.02
December	116,622.09	3329.21
Total	**1,614,611.50**	**46,092.25**

Source: Fieldwork, 2015

Table2: Generator Electricity Supply

Month	Litres of Diesel Consumed	Cost of Diesel (N)	Ideal KWh Generated
January	1500	232,500.00	4922.78
February	1590	246,450.00	5218.14
March	1650	255,750.00	5415.05
April	1560	241,800.00	5119.69
May	1440	223,200.00	4725.86
June	1230	190,650.00	4036.68
July	1350	209,250.00	4430.50
August	1350	209,250.00	4430.50
September	1440	223,200.00	4725.86
October	1470	227,850.00	4824.32
November	1350	209,250.00	4430.50
December	1350	209,250.00	4430.50
Total	**17,280.00**	**2,678,400.00**	**56710.37**

Source: Fieldwork, 2015

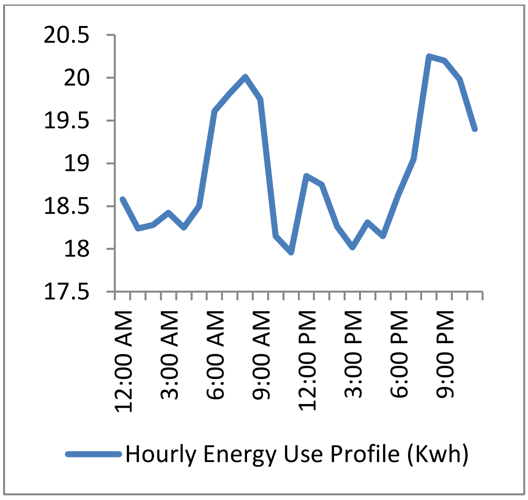


Fig. 2: Hourly Energy Use

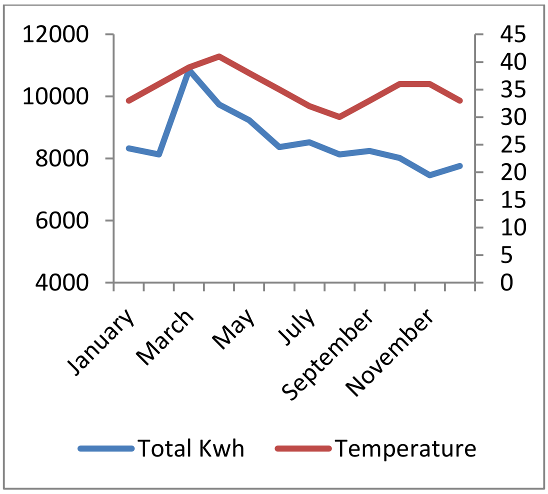
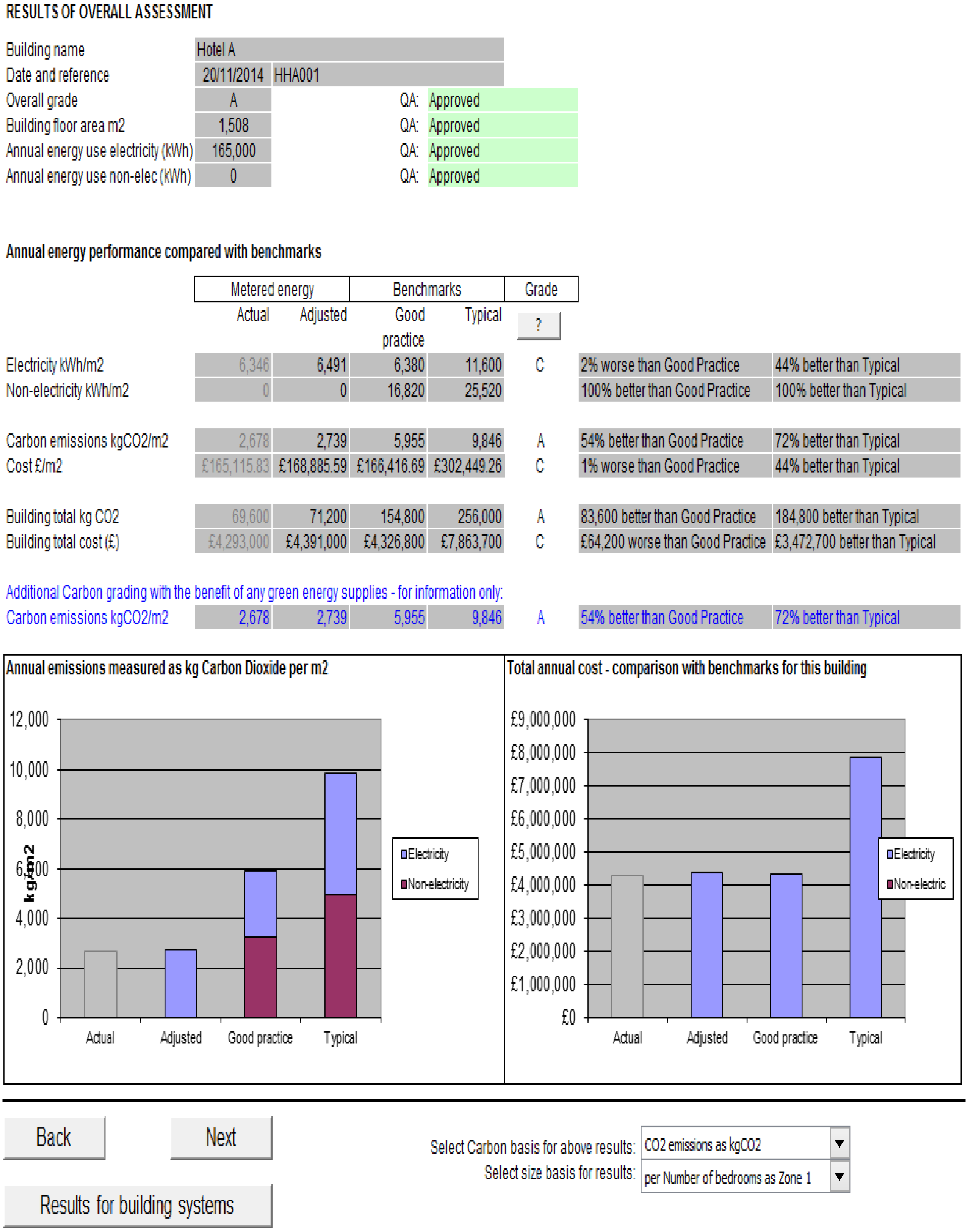


Fig. 3: Total kWh and Outdoor Temperature



RESULTS OF OVERALL ASSESSMENT

Building name	Hotel A			
Date and reference	20/11/2014	HHA001		
Overall grade	A		QA:	Approved
Building floor area m2	1,508		QA:	Approved
Annual energy use electricity (kWh)	165,000		QA:	Approved
Annual energy use non-elec (kWh)	0		QA:	Approved

Annual energy performance compared with benchmarks

	Metered energy		Benchmarks		Grade		
	Actual	Adjusted	Good practice	Typical	?		
Electricity kWh/m2	6,346	6,491	6,380	11,600	C	2% worse than Good Practice	44% better than Typical
Non-electricity kWh/m2	0	0	16,820	25,520		100% better than Good Practice	100% better than Typical
Carbon emissions kgCO2/m2	2,678	2,739	5,955	9,846	A	54% better than Good Practice	72% better than Typical
Cost £/m2	£165,115.83	£168,885.59	£166,416.69	£302,449.26	C	1% worse than Good Practice	44% better than Typical
Building total kg CO2	69,600	71,200	154,800	256,000	A	83,600 better than Good Practice	184,800 better than Typical
Building total cost (£)	£4,293,000	£4,391,000	£4,326,800	£7,863,700	C	£64,200 worse than Good Practice	£3,472,700 better than Typical

Additional Carbon grading with the benefit of any green energy supplies - for information only:

Carbon emissions kgCO2/m2	2,678	2,739	5,955	9,846	A	54% better than Good Practice	72% better than Typical

Fig.4: Assessment Result of Hotel A; Source: TM22 Excel Implementation Result Page

The outcome of the multiple regressions indicates statistical significance exists between temperature, occupancy and energy consumed (see Table 3).

The Excel model summary for the correlations contains the following information: R = 0.927, R Square = 0.859 and Adjusted R Square = 0.828. The two independent variables are statistically significant: temperature (p-value = 0.000), and occupancy (p-value = 0.006). The influence upon the dependent variable is in the order: Occupancy (beta =276.48), and Temperature (beta = 135.97).

Table 3: Regression Output for Hotel A

Variable	Coefficients	Standard Error	t Stat	P-value
Intercept	-7504.792284	2182.00029	-3.439409389	0.007397413
Temperature(°C)	135.9728906	38.75325097	3.508683457	0.006632334
Occupancy	276.488791	51.67972877	5.350043384	0.000462324

Source: Microsoft Excel Data Analysis Tool Pak

Case study of Hotel B

Tables (4 & 5) and Figures (5, 6 and 7) present results of data collected from Hotel B

Table4: Grid Electricity Supply

Month	Cost of Grid Supply (N)	KWh Consumed
January	191,850.60	5476.75
February	104,724.78	2989.57
March	177,840.30	5076.80
April	163,321.20	4662.32
May	145,034.10	4140.28
June	146,281.37	4175.89
July	148,681.42	4244.40
August	151,092.13	4313.22
September	160,981.58	4595.53
October	193,514.99	5524.26
November	213,170.27	6085.36
December	245,832.72	7017.78
Total	**2,042,325.46**	**58,302.18**

Source: Fieldwork, 2015

Table 5: Generator Electricity Supply

Month	Litres of Diesel Consumed	Cost of Diesel (N)	Ideal KWh Generated
January	700	115,500.00	2297.30
February	650	105,250.00	2133.20
March	660	108,900.00	2166.02
April	730	120,450.00	2395.75
May	680	112,200.00	2231.66
June	650	100,750.00	2133.20
July	630	97,650.00	2067.57
August	650	100,750.00	2133.20
September	620	102,300.00	2034.75
October	600	96,000.00	1969.11
November	660	102,300.00	2166.02
December	720	111,600.00	2362.93
Total	**7,950.00**	**1,273,650.00**	**26090.71**

Source: Fieldwork, 2015

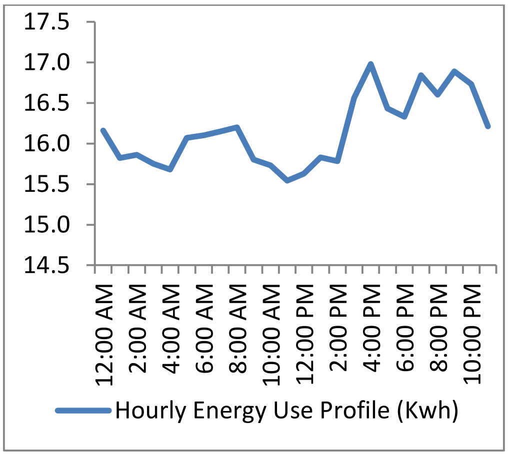


Fig. 5: Hourly Energy Use

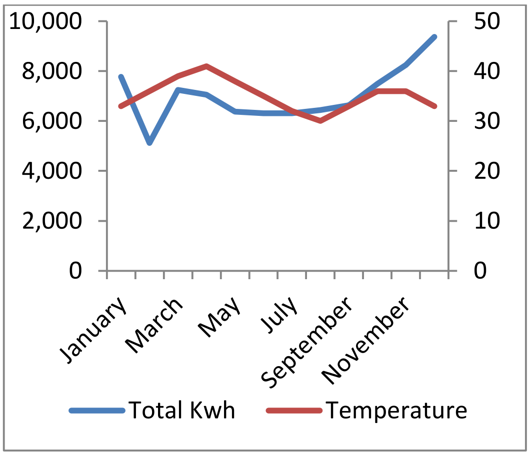


Fig. 6: Total kWh and Outdoor Temperature

RESULTS OF OVERALL ASSESSMENT

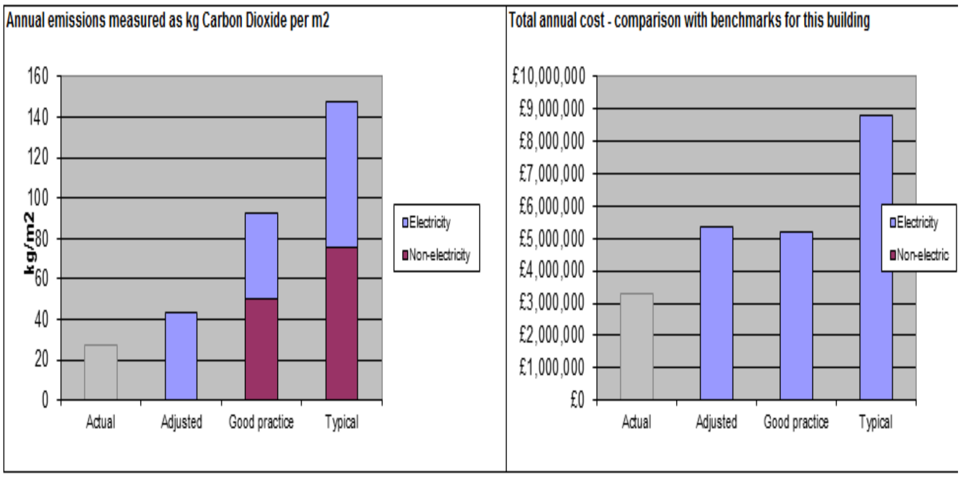
Building name	Hotel B		
Date and reference	20-11-2014 BHB001		
Overall grade	A	QA:	Not approved
Building floor area m2	2,204	QA:	Approved
Annual energy use electricity (kWh)	141,500	QA:	Not approved
Annual energy use non-elec (kWh)	0	QA:	Not approved

Annual energy performance compared with benchmarks

	Metered energy		Benchmarks		Grade		
	Actual	Adjusted	Good practice	Typical	?		
Electricity kWh/m2	64	103	100	170	C	3% worse than Good Practice	39% better than Typical
Non-electricity kWh/m2	0	0	260	390		100% better than Good Practice	100% better than Typical
Carbon emissions kgCO2/m2	27	44	93	147	A	53% better than Good Practice	70% better than Typical
Cost £/m2	£1,504.53	£2,424.56	£2,349.95	£3,993.61	C	3% worse than Good Practice	39% better than Typical
Building total kg CO2	59,700	96,200	204,200	324,900	A	108,000 better than Good Practice	228,700 better than Typical
Building total cost (£)	£3,316,000	£5,343,700	£5,179,300	£8,801,900	C	£164,400 worse than Good Practice	£3,458,200 better than Typical

Additional Carbon grading with the benefit of any green energy supplies - for information only:

Carbon emissions kgCO2/m2	27	44	93	147	A	53% better than Good Practice	70% better than Typical



Back | Next

Select Carbon basis for above results: CO2 emissions as kgCO2

Select size basis for results: per m2 Gross Internal floor area

Results for building systems

Fig. 7: Assessment Result of Hotel B; Source: TM22 Excel Implementation Result Page

The evaluation of the data acquired showed that energy consumption is fairly follows outdoor temperature variation for most of the year except for the first quarter of the year that witnessed a declining consumption as temperature was rising and in the last quarter where consumption continued its upward trend as the outdoor temperature dropped. The comparison of the actual energy consumed with the CIBSE benchmark revealed that energy consumption of the hotel is 3% worse than good practice but 39% better typical electricity consumption of hotel of its profile. Therefore, to establish the significant influencing factor, Regression analysis will be used. No linear relationship exists between the independent variable and the dependent variable. Simple regression analysis concludes that the first null hypothesis is accepted. The relationship between the independent variable and the dependent variable is not statistically significant as p-value (0.904) is above α (0.05).

However, there is a statistically significant relationship between the dependent variable (Energy consumed) and independent variable (occupancy) as the p-value (0.000) is below α (0.05). Hence, the second null hypothesis is rejected. Multiple regressions were calculated using two independent variables (Temperature and Occupancy) and the dependent variable (Energy consumed). The outcome of the multiple regressions indicates statistical significance exists between temperature, occupancy and energy consumed.

Table 6: Regression Output for Hotel B

Variable	Coefficients	Standard Error	t Stat	P-value
Intercept	145.0956852	269.0199512	0.539349162	0.602731283
Temperature(°C)	4.266017879	6.550584535	0.651242321	0.531164677
Occupancy	302.8143529	5.672433848	53.38349659	1.4276E-12

Source: Microsoft Excel Data Analysis Tool Pak

The Excel model summary for the above correlations contains the following information: R = 0.998, R Square = 0.996 and Adjusted R Square = 0.996. The only independent variable that is statistically significant is occupancy (p-value = 0.000) while the other independent variable has no statistical significance; temperature (p-value = 0.531). The influence upon the dependent variable is only by occupancy.

Case study of Hotel C

Results obtained from Hotel C is as presented in Tables (7 & 8) and Figures (7,8 & 9)

Table 7: Grid Electricity Supply

Month	Cost of Grid Supply (N)	Kwh Consumed
January	228,300.00	6517.27
February	207,250.00	5916.36
March	222,830.00	6361.12
April	241,399.17	6891.21
May	253,778.61	7244.61
June	235,209.44	6714.51
July	216,640.28	6184.42
August	198,071.11	5654.33
September	185,691.67	5300.93
October	204,260.83	5831.03
November	222,830.00	6361.12
December	222,830.00	6361.12
Total	2,639,091.11	75,338.03

Source: Fieldwork, 2015

Table 8: Generator Electricity Supply

Month	Litres of Diesel Consumed	Cost of Diesel (N)	Ideal Kwh Generated
January	3620	597,200.00	11880.30
February	4284	706,800.00	14059.45
March	5120	845,000.00	16803.07
April	5380	888,333.33	17656.35
May	4990	823,333.33	16376.43
June	4596	758,333.33	15083.38
July	4200	693,333.33	13783.77
August	3940	650,000.00	12930.49
September	4335	715,000.00	14226.82
October	4725	780,000.00	15506.74
November	4730	780,000.00	15523.15
December	4335	715,000.00	14226.82
Total	**54,255.00**	**8,952,333.33**	**178056.77**

Source: Fieldwork, 2015

The evaluation of the data acquired showed that energy consumption profile in tandem with the outdoor temperature profile change. The comparison the actual energy consumed with the CIBSE benchmark revealed that energy consumption of the hotel is 7% worse than good practice though 41% better typical electricity consumption of hotel of its profile. Therefore to establish the significant influencing factor, Regression analysis will be used. Simple regression analysis concludes that the first null hypothesis is rejected. There is a linear relationship between the independent variable and the dependent variable as p-value (0.000) is below α (0.05). Therefore, the relationship between Total energy consumed and outdoor temperature is statistically significant.

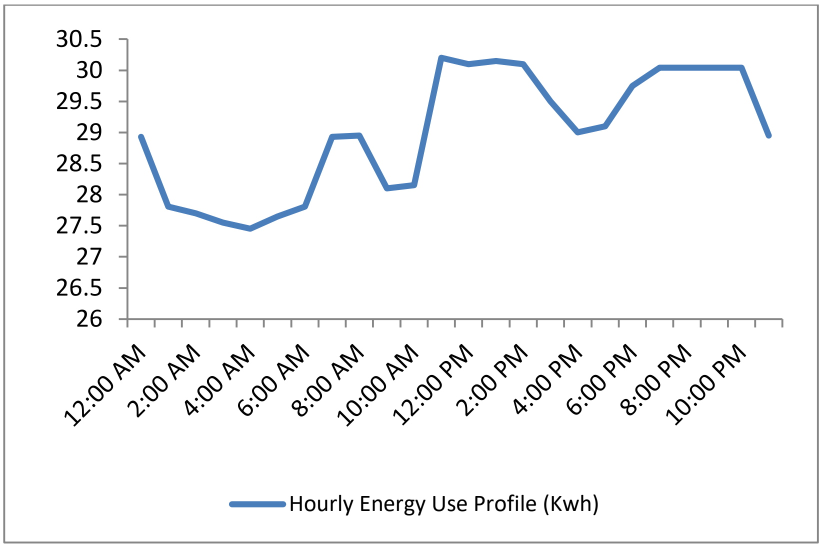


Fig.8: Hourly Energy Us

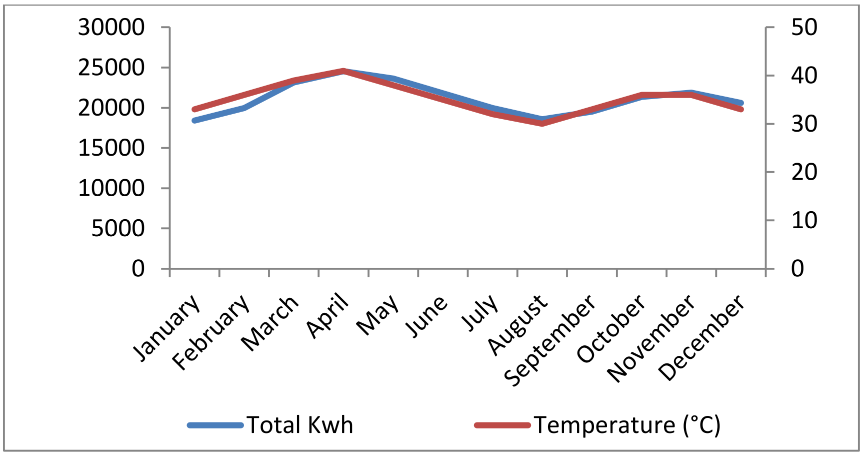


Fig.9: Total kWh and Outdoor Temperature

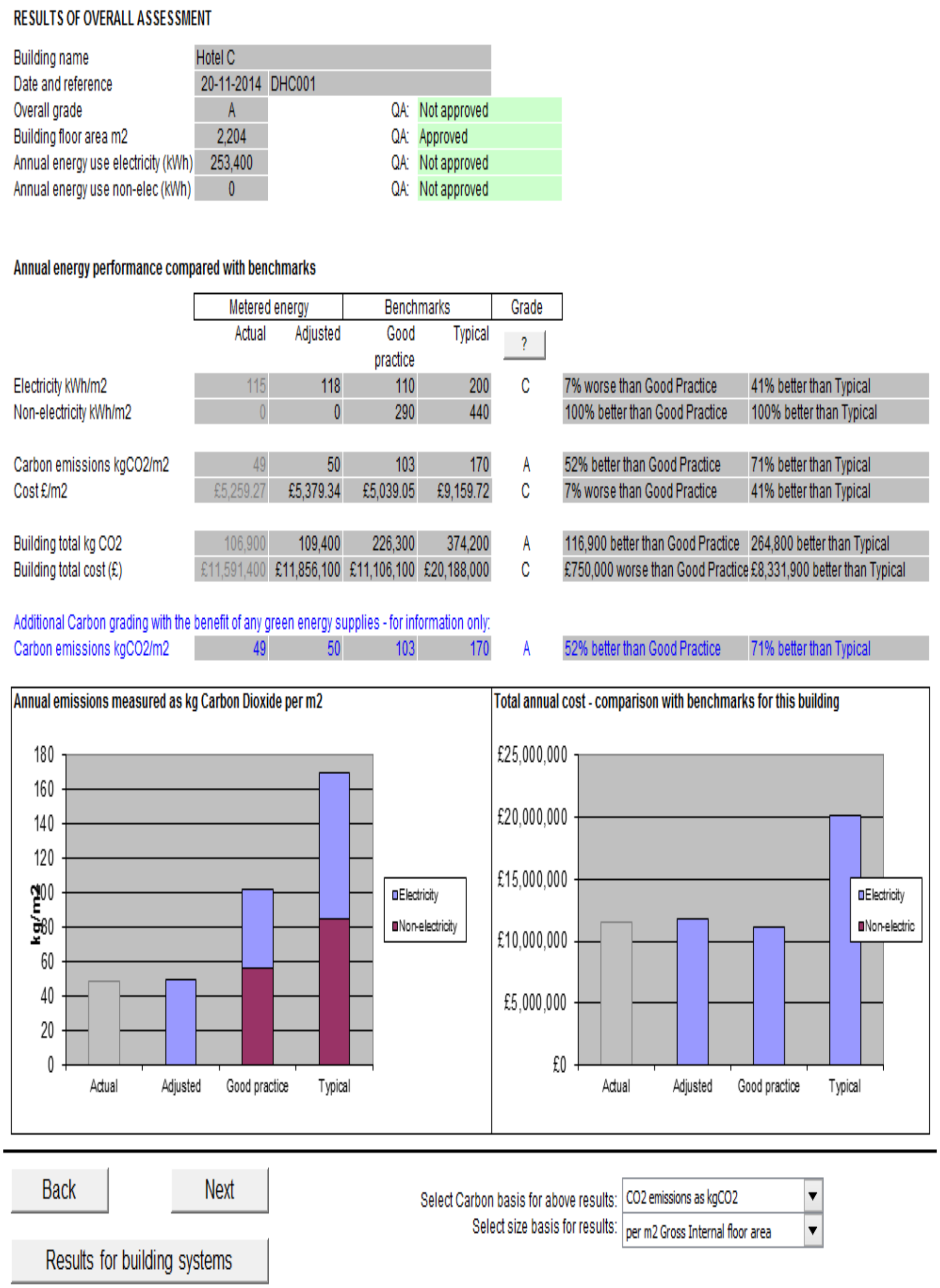


Fig.10: Assessment Result of Hotel C; Source: TM22 Excel Implementation Result Page

Similarly, there is a statistically significant relationship between the dependent variable (Energy consumed) and independent variable (occupancy) as the p-value (0.000) is below α (0.05). Hence, the second null hypothesis is rejected. Multiple regression was calculated using two independent variables (Temperature and Occupancy) and the dependent variable (Energy consumed). The outcome of the multiple regressions indicates statistical significance exists between temperature, occupancy and energy consumed.

Table 9: Regression Output for Hotel C

Variable	Coefficients	Standard Error	t Stat	P-value
Intercept	2865.682969	1573.777197	1.820894962	0.101958409
Temperature (°C)	223.229494	78.67845345	2.837237951	0.019490809
Occupancy	203.2716904	38.85507832	5.231534697	0.000540821

Source: Microsoft Excel Data Analysis Tool Pak

The Excel model summary for the above correlations contains the following information: R = 0.977, R Square = 0.955 and Adjusted R Square = 0.946. The two independent variables are statistically significant: temperature (p-value = 0.019), and occupancy (p-value = 0.000). The influence upon the dependent variable is in the order: Temperature (beta = 223.22) and Occupancy (beta = 203.27).

Cross - Case Analysis

Table 10 presents a cross-case analysis of the three Hotels

Table 10: Assessment Result of the Three Hotels

Month	Temperature	Hotel A Total Kwh	Occupancy	Hotel B Total Kwh	Occupancy	Hotel C Total Kwh	Occupancy
January	33	8328.19	40	7,774.04	25	18395.57	40
February	36	8127.74	38	5,122.77	20	19974.6	45
March	39	10855.21	45	7,242.82	23	23168.16	59
April	41	9738.55	42	7,058.07	22	24560.16	62
May	38	9231.06	43	6,371.94	21	23620.7	57
June	35	8366.7	41	6,309.09	24	21797.76	52
July	32	8526.4	44	6,311.96	20	19974.82	48
August	30	8136.73	40	6,446.42	20	18582.82	45
September	33	8248.78	41	6,630.28	21	19522.28	49
October	36	8017.98	40	7,493.37	24	21345.22	54
November	36	7465.52	37	8,251.38	26	21875.31	54
December	33	7759.7	39	9,380.70	30	20582.46	49

Source: Fieldwork, 2015

All the hotels assessed in this paper have the same climatic conditions as they are on the same latitude and fairly on the same altitude. Likewise, energy consumption for the hotels are slightly worse that the benchmark. However, the consumptions were better than the typical energy consumptions of the category of the hotels. The simple regression of the independent variable (occupancy) and the dependent variable (energy consumed), for the three hotels, showed there is a statistically significant relationship. However, simple regression for the independent variable (temperature) and the dependent variable (energy consumed) indicated that statistically significant relationship existed for two hotels. The hotel without a statistically relationship between the variables has peculiar occupancy profile where the hotel is mostly used for social gatherings. But energy consumption is also affected by other factors that are more amenable to control than the climate. These factors can be broadly grouped under building envelope, building services and human factor.

Human Factors

Internal loads in a densely populated building are usually more than the external load and vice-versa for a less populated building. The hotels considered in this paper have the same comfort requirement and occupancy regime. However, they have different activity level and controls. Furthermore, the hotels do not have an articulated energy management plan in place.

Building Envelope

Climate, culture, and available materials are the factors that underpin the choice of envelope. Consequently, the energy loads is affected by the building envelope. A major component is the thermal loads which can be internal or external. Interestingly, the thermal loads can be reduced as much as possible using passive design strategies. But, the hotels assessed in this paper were not designed with energy management in mind and this is evident in the choice of materials and massing of the envelope. Furthermore, there is marked lack of fusion and implementation of passive strategies.

Building Service

There is strong financial incentive to match and meet energy loads as efficiently as possible. To manage and optimize energy consumption and demand without sacrificing comfort and safety; user controls should be provided to address energy consumption due to human factors and automatic controls for consumption due to envelope loads. While user controls are common place in the assessed hotels, automatic controls are seldom found in the hotels. Yet, energy management control systems (EMCS) can play a key role in meeting the challenges of sustainability, high level of service and comfort while keeping energy consumption at optimum.

CONCLUSION AND RECOMMEDATIONS

Conclusion

The analysis carried out on the three selected hotels in Minna revealed in the result that even though the performance of these hotels in the metric evaluated is worse than ‘good practice’ but is better than typical performance. Comparison of the actual results was done against (CIBSE, 2005) established benchmarks. All the hotels assessed were graded worse than good practice. Furthermore, analysis of the variables indicated the energy consumption is significantly affected by outdoor temperature and occupancy.

Recommendations

The challenge of energy sufficiency and access can be reduced by designing buildings for energy efficiency. Therefore, professionals and energy design tool should be used during conceptual design of buildings to determine best energy saving strategies for each specific building. However, general recommendations can be given for Minna

i. In order to reduce energy consumption, investment in renewable energy sources is needed. For example, powering outdoor lights with solar, use of biomass for power generation.
ii. Installation of automatic controls to regulate and monitor energy use in the hotels.
iii. Fuse passive strategies into the hotels during maintenance and refurbishments
iv. Engage experts (building services professionals, architects) in the maintenance process of the hotels.

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Enhancing energy efficiency in commercial buildings in Nigeria

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ABSTRACT

Demand for electrical energy in the built environment is rapidly increasing because of the continuous rise in the standard of living, explosion in population figures and advancement in technology leading to many more electrically powered devices. At the same time, the unit cost of electrical energy consumed is escalating, so also is the increasing global concern for the environment. There is therefore an urgent need for a rational use of electrical energy in all types of buildings in Nigeria. Commercial buildings are major consumers of electrical energy and thus become a potential sector of the built environment for energy saving. Identifying the energy saving opportunities (ESOs) and evolving an action plan to implement these ESOs will reduce the financial burden on the operators of the commercial buildings and will certainly lead to efficient utilization of electrical energy in Nigerian buildings. This paper report on outcome of case studies carried out on four commercial buildings with energy audit conducted and areas of energy conservation identified for an efficient energy usage in commercial buildings in Nigeria. A detailed energy audit was conducted on three shopping malls to cover the air conditioning and lighting systems, and a Hotel building. That of the hotel also includes the water heating system and its kitchen appliances. The energy consumptions in three shopping malls and a hotel building were studied through field measurements of the electrical energy consumption with use of some building services devices and appliances. The four commercial buildings so selected for the study were those that have been occupied for at least two years. This is to ensure that early teething problems has been given good chance of being ironed out with at least 12 months of representative energy data available. Detailed electrical energy audit was performed at three shopping malls and a hotel building in the city of Minna, Niger State, Nigeria. The energy audit involved surveying the energy utilization, performing energy consumption measurement, identifying possible ESOs and seeking what could be done to make commercial buildings more sustainable. ESOs identified by the study includes: replacing the lighting fixtures magnetic ballast with light emitting diode (LED), optimizing natural ventilation, replacing manual lighting switches with appropriate automatic lighting switches, installing energy management system, self-power generation, and the use of evaporative coolers. The study submits that it will take simple payback period range of between 1 – 3 years for implementing these ESOs depending on the specific technology used.

Key Words: commercial buildings, electrical energy, energy audit, energy saving opportunities, energy efficiency.

INTRODUCTION

Commercial buildings include a wide variety of building types such as offices, hospitals, schools, police stations, warehouses, hotels, libraries, shopping mall etc. Each of these building types houses different commercial activities which have unique energy needs but, as a whole, commercial buildings use more than half their energy for cooling and lighting (EPRI: EM-4195, 2015). The use of energy in buildings has increased in recent years due to the growing demand in energy used for heating and cooling in buildings. Without energy, buildings could not be operated or inhabited. Energy efficiency means utilizing the minimum amount of energy for heating, cooling, equipment and lighting that is required to maintain comfort conditions in a building (Elsadig, 2005). An important factor impacting on energy efficiency is the building envelope. This includes all of the building elements between the interior and exterior of the building such as: walls, windows, doors, roofs and foundations. All of these components must work together to keep the building warm in the winter and cool in the summer. The amount of energy consumed varies depending on the design of the fabric of the building and its systems and how they are operated (Kjeld, 2015). The heating and cooling systems consume the most energy in a commercial building; however, controls such as programmable thermostats and building energy management systems can significantly reduce the energy use of these buildings (Kjeld, 2015). Improvements have been made in insulation, plant, lighting and controls and these are significant features that have helped towards achieving energy efficient buildings. It is easier to design energy efficient features into new buildings, however, existing building comprise approximately 99% of the building stock (EPRI: EM-4195, 2015). This sector thus provides the greater challenge for implementation of energy efficiency as well as the greater opportunity for overall energy gain. Although energy efficiency initiatives for existing buildings can be demonstrated to be cost effective, there has been limited success in convincing large organizations and building owners to undertake energy efficiency projects such as energy audits, retrofits, and retro-commissions (EPRI: EM-4195, 2015). An important factor is the use of benchmarks which stand as representative standards against which buildings can be compared and the performance monitored. Energy efficient buildings do not cost necessarily more to build than normal buildings. If they are well maintained and their energy effectively managed, they are set to be very reliable, comfortable and as productive as a normal buildings. In January 2006, the European Union (EU) Energy Performance of Building Directive (EPBD) came into force in all member states which required public buildings to display energy certificates and commercial buildings to have certificates available at the points of sale or rent. These certificates are accompanied by a list of measures that had been taken to improve the energy performance of the building. Buildings are by far, the biggest cause of CO_2 emissions in the developing nations like Nigeria and hence it is in the development of buildings that the greatest savings can be made (Productivity Commission, 1999).This paper summarizes the outcome of the energy audit carried out on some selected commercial buildings (three shopping malls and a hotel building) in the city of Minna, Niger state, Nigeria; from January to December 2015. The aim of the energy audit is to survey the energy utilization of these buildings, measuring and analysing the energy consumption pattern and balancing or accounting for the input energy as against known uses. It also seeks to identify opportunities for energy saving and institutional requirements for sector-specific energy efficiency improvement after the energy audits. The investigation focused on commercial buildings because of the large energy consumption in this sector. Hence to succeed in developing a sustainable society, buildings will always need to be improved as technology improves. The study mainly considered the lamps and lighting system, utilities, and ventilation and air-conditioning systems. However, the operation and maintenance departments of these buildings have provided the audit team with the essential data such as: the building architectural drawings, electricity line diagram showing load distribution for different floors and equipments, and the electricity consumption records. Although the number of instruments and technical resources were very limited, the results of the energy audit highlighted great potential of the energy saving opportunities in the commercial building sector in Nigeria.

LITERATURE REVIEW

Energy audit in buildings

The main objectives of an energy audit are to balance the input energy (i.e. electricity) against known uses. Energy saving can then be easily achieved through the adjustments of these uses. The auditing process, generally, includes: measurements and analysis of consumption, modifications, implementation of energy management, and energy conservative techniques. Three levels of energy audits can be classified as follows: walk-through assessment, energy survey and analysis, and detailed analysis of capital-intensive modifications. Of course, the performance of these different levels depends on the energy use characteristics of the building, and the needs and resources of the owner. These levels of energy audits, however, do not have sharp boundaries between them. They are general categories for identifying the type of information that can be expected and an indication of the level of effort and confidence in the results. Energy audits are being conducted as a useful way of determining how energy efficient the building is and what improvements can be made to enhance efficiency. Tests have been undertaken to ensure that the heating, cooling, equipment and luminaires all work together effectively and efficiently.

Electric Energy use in Buildings

There are several different uses of electric energy in buildings. The major uses are for lighting, cooling, power delivery to equipment; devices, appliances, and domestic water heating. However, the best way to determine the energy use in a particular building is to analyse its utility bills over a period of time as part of an energy audit. Today’s building industry appears to be entering another era of change which is being driven by a need to optimize and conserve resource – this includes: time, clean air, water and energy. For example, energy use for cooling is the major area of use in Minna due to its hot climate throughout the year. It is estimated that more than 30% of the total energy consumption is used in cooling (Hasnain, *et al.,* 2000). Lighting is another large area of use especially, in commercial buildings. Up to 27% of the total energy consumption is used for lighting (Abrahim, *et al.,* 1995). Thus, the opportunities for savings in these two areas of use are enormous and economically feasible.Table1 and Figure1 below show the breakdown for electric energy consumption in typical commercial buildings.

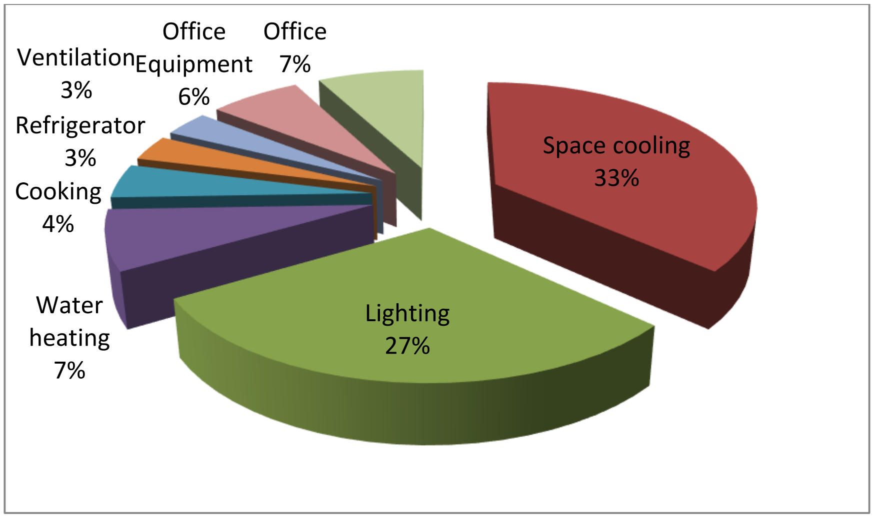

Figure 3: Energy consumption for a typical commercial building
Source: www.thecarbontrust.co.uk

Energy use in Hot Climates / Developing Countries

When it comes to the consumption of energy in tropical buildings, cooling using air conditioning consumes a higher proportion of energy compared with heating. However some tropical countries which incidentally fall within the developing countries, consume very little energy when compared to the developed countries (Diana, 2014).

Addressing the need to Conserve Energy

Addressing the issue to minimize the effects of the present crises and future energy demands, the western world and most developed countries considered responsible for the consumption of most of the world's energy, reached a conclusion with four main aspects for conserving energy resources as highlighted in Kjeld (2015):

- Reducing energy consumption in buildings, by energy management and energy efficient measures
- The urgent requirement for alternatives and renewable energy sources of lower prices.
- The design of buildings for the attainment of thermal efficiency including better insulation
- Conserving water, materials and energy sources.

In terms of energy conservation by alternative or renewable sources, solar energy and its applications tend to be more practical in terms of linking local generation (supply and demand) and hence are the most attractive for the future. The table below shows opportunities for energy conservation and renewable.

Table 5: Opportunities for Energy Conservation and Renewables

Energy Hierarchy	Domestic	Non-domestic
Reduce Demand	• Well-designed layout • Passive solar design • Life cycle analysis of materials • High levels of insulation • High NHER* (10 or Above)	• Well-designed layout • Passive solar design • Life cycle analysis of materials • Natural ventilation • High levels of insulation • BREEAM*
Energy Efficiency	• Condensing boilers • Energy efficient • white goods and lighting • Good heating controls • Influence behaviour	• Building Energy Management Systems • Energy efficient appliances and equipment • Condensing boilers • Energy efficient/Natural ventilation • Influence behaviour
Renewable Energy	• Passive solar design • Solar water/air heating • Photovoltaic • Small scale vertical axis wind turbines	• Passive solar design • Photo voltaic • Solar water/air heating • Small scale hydro • Small scale wind
CHP*/District Heating (Cooling)	• District heating/(Cooling)and CHP	• CHP with waste digestion • CHP feeding district heating

NB: BREEAM – Building Research Establishment Environmental Assessment Method; CHP – Combined Heat and Power; NHER – National Home Energy Rating

Source: Elsadig, A.K. (2005)

Energy Performance

It was not until energy use in buildings became a topic of concern that the search really began to look at establishing measures of energy performance. Energy performance indicators are measurements which provide the ability to compare different levels of energy use in the provision of a particular type of service. The objective of this is to establish an index that facilitates comparisons of buildings. There are three factors to be considered in the construction of building energy performance indices and these are: The occupancy hours, severity of the climate and the type of activities in the building. Climatic severity and occupancy hours are best allowed for by dividing annual energy use per unit area by a factor that is constructed on the basis of climate or occupancy hours (Kjeld, 2015).

Rating a building's energy performance is becoming an increasingly important factor of building operation. A highly rated building may be entitled for special recognition through a range of voluntary or compulsory programs, which increases its resale value and rental income. Energy Rating can help identify poorly operated buildings and opportunities for energy and cost savings.

A distinction can always be made between how to obtain a 'low energy building' and how to obtain an 'energy efficient building'. Energy efficient building solutions are often accomplished by selecting the lowest possible energy requirements with reasonable utilization of resources. In terms of installed equipment a strategy for identifying and rating low energy and energy efficient buildings is to define what shall be conserved and the purpose for it. Rating schemes are generally associated with certification. Certification means evaluating the building in the design stage (Kjeld, 2015).

Therefore the main aim of energy performance is to encourage the practice of specifying materials, components and systems. The particular objective of an energy performance is to specify what is required from the building in terms of target energy consumption.

Energy Audit at the Selected Commercial Facilities

Measurement and Data Analysis

Measurements conducted during energy audit include; power profile measurements of loads, power factor, and harmonic at different supply transformers and major load centres. The measurements were conducted using power profiler device, BMI 3030. Figure 2 shows the power demand and power factor profiles for one of the service transformer of Mall 1. The figure shows the double moments of peak power demand during a typical day operation at the Mall to be corresponding to the morning and evening major activity hours.

Data recorded include that of the mains, pumps, air conditioning units and lighting distribution boards, indoor and outdoor temperatures and air flow rates at supply units. For assessing the lighting performance and its electrical energy consumption, illumination levels at selected working plane locations were also recorded.

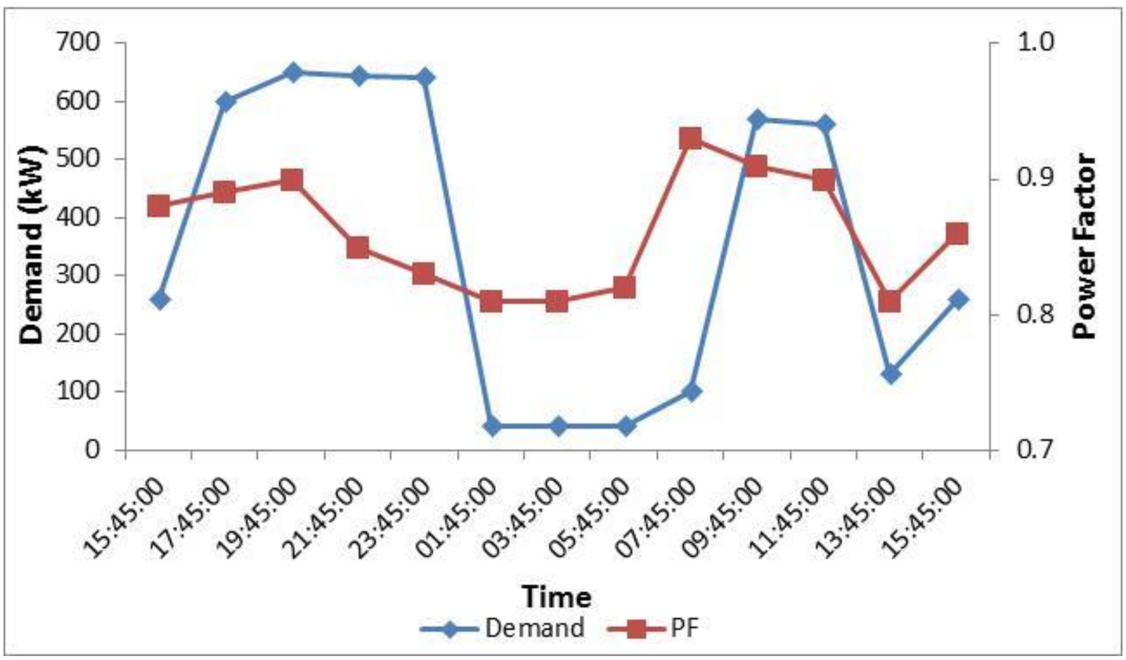

Figure 4: Electricity Demand and Power Factor at a Service Transformer of Mall 1 within 15 -16 March, 2016

Facilities Description

The study covers the energy audit performed at three major shopping malls (Mall 1, 2 & 3) and a major hotel in the town of Minna. Table 2 summarizes the facilities data including occupied area, supplied power and energy consumption. The energy consumption of the facilities is calculated based on the monthly utility bills provided by each facility manager. Mall 1 represents a large shopping mall while Mall 2 and Mall 3 represent small size malls. The average monthly energy consumption of the Malls is 1,145; 118; 161 and 745 MWH respectively. The major human activities at the Malls include shopping, storage and offices. The Facility Managers of the Malls pay the electricity bills for the common services such as general environmental and security lighting, (lobbies, corridors, parking, and water pumping.),but coordinate payments by other shop owners. The audit study focuses on the electric energy consumption for the entire facility even though each shop, store or office in the Mall has its own electricity meter and separate electricity bill, which covers its lighting power, equipment and air conditioning units. The average monthly energy consumption for the hotel is 750 MWH. For the Shopping Malls, energy consumption and HVAC capacity data are presented in Table 2.

Table 6: Facilities Description

	Mall 1	**Mall 2**	**Mall 3**	**Hotel**
Total Area (m^2)	58,790	28,930	48,168	7,345
Power supply (KVA)	5,000 (5*1000)	7,000 (7*1000)	6,000 (6*1000)	6,400 (4*1600)
Energy Consumption (MWh)				
Annual	13745	1417	N/A	9039
Monthly Avg.	1145	118	161	745
Monthly Max.	1500	165	N/A	960
AC system (Tons)	WU & SU (1140)	WU & SU (54)	WU & SU (390)	SU & PU (655)
Light system	FL (MB)	FL(MH/H)	FL(MB)	FL/IN

Key: WU – Window Unit, SU – Split Unit, PU – Packaged Unit
FL – Fluorescent, MH – Metal Halide, H – Halogen, IN – Incandescent
MB – Magnetic Ballast
N/A – Not available

Energy audit at shopping Mall 1

Air Conditioning System Audit

The eleven years old shopping complex has spaces allocated to individuals to consist of a front shop and an inner office space. The front shops all have window type air conditioners while the accompanying office spaces all have split type air conditioners. The temperature control for both shops and offices in the shopping mall is fundamentally cooling throughout the year. Summing-up the refrigeration capacity for the window units and the splits units in the whole shopping complex, amounts to 663 Tons of refrigeration (TR) capacity (I TR = 3.51kW). All the cooling facilities are working in satisfactory conditions with a nominal electrical input of 1.52kW/Ton. Each of these units uses a vapour compression refrigeration cycle. The compressors are reciprocating types, an air-cooled condenser with a fan. No by-pass control valve is provided. The space conditioning for both shops and office spaces are fundamentally cooling throughout the year in the shopping mall. Measurements carried out on the facility shows an average temperature difference across the cooler coils to be in the order of 5.5ºC and with an average supply temperature of 6ºC. The average temperature difference across the loaded cooling devices was also in the order of 15ºC. 30 to 40% of the air cooled by these units were intended to meet the ventilation requirements; then exhausted to the outdoor conditions through exhaust duct and natural convection currents.

It is estimated that, the air conditioning system alone consume more than 332561kWh/month in addition to about 10% more power for fans and other ventilating units. The total estimated HVAC monthly consumption is therefore 365,817kWhwith an assumption of 330 operating hours per month. This consumption represents about 50% of the monthly consumption on the average.

The cold potential in the exhausted air could be utilized in cooling the incoming fresh air. This can be accomplished by installing sensible wheels or closed loop heat exchangers which can be used to recover up to 80% of the cold potential, thus an equal percentage of electrical energy could be saved. For example if 50% of the cold potential in the exhaust air is recovered, savings of 33,305 kWh/month (costing about ₦123, 229/month) could be achieved. This estimate is based on the assumption of an average temperature difference of 15ºC between the outdoor and the indoor temperatures (40 – 25ºC), 330 operating hours /month and a total of 73,400 cubic metre per hour CMH of exhausted air (AHU capacities). These savings represent about 10% of the monthly average electricity consumption of the HVAC system and about 5% of the average monthly total consumption of the shopping mall. The expected simple payback period for the sensible wheel system is 4 to 6 months. The cost analysis is based on the new tariff structure in Nigeria of ₦3.665 /kWh for energy consumption above 10, 000 kWh.

To achieve greater savings in energy needed for ventilation change rate requirements especially at the lobbies, carbon-dioxide (CO_2) monitors could also be used to monitor and control the rate at which fresh air enters the air handling units. Savings of up to 70% could be achieved through this technology especially during breaks. The cost of the monitoring and control system is in the order of ₦250, 000.

Lighting System Audit

The illumination levels were measured at selected locations using the LUX meter. Most of the light fixtures contained fluorescent lamps of different sizes. However, these lamps use magnetic ballasts. Thirty percent of the electrical energy used for lighting could be saved if ballasts are replaced with energy efficient electronic ballast. Hence a saving of13,469 kWh/month (which represents 161,624 kWh/annum, costing #598,011) can be achieved. The cost of the electronic ballast is in the order of #2000. The estimated total cost of replacing the magnetic ballasts with electronic ballasts is about #2,300,000. The effect of reducing the cooling load as occasioned by the lighting load on the air conditioning load is estimated to reduce the HVAC electricity consumption by 2160kWh/month costing #47,952/year, assuming 6 months of HVAC operation per year. The total saving in energy consumption due to relighting is estimated to be about 80,000kWh, costing #296,000 annually. The simple payback period of the ballast replacement is estimated to be 3.8 years. Multiple switches and timers could also be used to reduce the lighting intensity in some sections during the noon and prayer breaks.

Energy audit at shopping mall 2

Air Conditioning System Audit

The shopping mall uses split type air conditioning units. All of the units constitute a total of 405 TR capacities. The outdoor units are air-cooled, all working in satisfactory conditions with a nominal electrical input of about 1.5 kW/ton.

Light System Audit

The lighting system represents 25 to 30% of the total electrical load on the service transformer. Different types of lamps are used; mainly compact fluorescent, metal halide, incandescent and halogen lamps. The fluorescent lamps are the high efficiency type, but they use magnetic ballasts.

The luminaires' optical performance is satisfactory. All of them distribute their lights by reflection and diffusion.

Energy audit at shopping mall 3

Air Conditioning System Audit

The air conditioning systems used in this space are window units, split system and package units of diverse capacities. In this shopping mall, the air conditioning systems provide cooling throughout the year and the area served covers some lobbies and corridors within the shopping complex. The total useful area served by the systems is 7526 square meters which is about 2509 square meters per floor. The total refrigeration capacity of these systems is 362 tons which covers about 20.8 square meters per each ton of refrigeration capacity. This refrigeration capacity is considered reasonable at peak load periods. The total electricity demand during the full load operation of the air conditioning systems in the hottest months of March and April is estimated as 597.3 kW.

Detailed electrical measurement on one of the package unit was conducted. The package unit has a refrigeration capacity of 60 tons with a power input of 1.63 kW/ton. The maximum electricity demand for this package unit, when operating at full load conditions in March and April, 2016 when ambient temperature reached 42ºC and inside design temperature of 25ºC reported as 98 kW.

Light System Audit

Most of the light fixtures contained fluorescent lamps of different size (18 and 36 Watts). However, all of these lamps are magnetic ballasts. The total electricity demand for lighting is about 298 kW. If 50% of the ballasts were replaced, savings of 14,751 kWh/month could be achieved, costing ₦53800/month. Lighting requirements are reduced during daytime because day lighting is used partially through the fixed light window. Multiple switches and timers could be used to reduce the lighting intensity in some sections during the noon and prayer breaks.

Energy audit at the hotel

Air Conditioning System Audit

The fifteen years old air conditioning plant is located at the roof of the building and is composed of five water chillers of 135 TR capacity each (for a total of 675 TR). The water chillers are of the air-cooled type with a nominal electrical input of 890 kW. The chillers are old and need to be replaced with new chillers as they are close to the end of their service life. Each chiller includes two compressors with, shell and tube chiller and an air-cooler condenser. Each chiller cools water at a rate of 20.6 l/s from about 13ºC to 7ºC. Chilled water is pumped from chillers by 3 pumps through a pipe network to different fan coil units in guest rooms, restaurants, meeting rooms, lobby as well as eleven air handling units. Fresh air is distributed to different spaces through a network of supply ducts. Air is exhausted through kitchen and toilet fans. Thus, there is little potential for recovering the cold potential of this exhaust air.

Because the water chillers are at near their service lifetime it is recommended to replace the chillers with high efficiency chillers. The efficiency high chillers can achieve energy savings of 10 to 20% of the input electrical energy or 601,425 kWh/year costing ₦156,371 /year. The incremental cost of the high efficiency chiller is in the order of ₦375/TR ($100 /TR or 675 (TR) x ₦375 =₦253, 125. the simple payback period is expected to be 1.6 years. With the tariff structure of ₦36.65/kWh, it will be worth considering partial self-generation using the standby generator for prime power generation. The cost of diesel fuel needed to run the generator is ₦240/litre. The specific fuel consumption is of the order of 220 grams/kWh. Therefore, the fuel cost needed to generate one kWh is about ₦ 51. If the depreciation and maintenance costs are added, the electrical energy cost is expected to be below ₦36.65/kWh. In addition, co-generation can be used by utilizing the waste heat from the diesel generators that can be estimated by about 60% of the fuel input energy. The waste heat could be utilized in water heating, for domestic use (200 kW) and for the laundry (96 kW). In addition to water heating, the waste heat could be utilized in operation of an absorption water chiller to cover the HVAC system needs. A two stage Lithium Bromide water absorption refrigeration system could attain a coefficient of performance of 1. Based on the total chiller refrigeration capacity of 675 TR needed, the heat input to operate one or more absorption chillers is 675 TR x 3.51 (kW/TR) = 2,369kW. If diesel generator supplies all of the electrical power, the total amount of waste heat will be in the order of 8,160 kW. If 50% of the waste heat is recovered, then 4,080 kW of heat will be available for water heating and absorption chillers. The heat required for both heating and absorption chillers is 2,668 kW. This represents only 32.7% of the generator waste heat. This energy saving opportunity is attractive specially because the water chillers in the HVAC system are not high efficiency chillers and approaching their service life (operating for 15 years) and should be replaced. A detailed techno-economic feasibility study is necessary to find the optimum electricity to heat ratio for economical operation at different load scenarios.

Insulation of chilled water piping exposed to the harsh weather conditions at the building is partially damaged and need to be repaired. This will limit the chilled water temperature rise from chillers to fan coil units or air handling units to less than 2°C. Amount of energy savings depends on the degree of damage and the length replaced.

Water Heating System Audit

Four central electrical water heaters, 50kW each, are used to heat water for guest rooms, kitchen and laundry (total 200 kW). The laundry washer also uses an electric heater, which has a capacity of 96 kW. It is recommended to replace these heaters with water boiler fired with light fuel oil with 300 kW heating capacity, especially with some of the electrical heaters undergoing maintenance problems. The cost of water heating using a water boiler is going to be significantly less than electrical heating considering that the cost of 1 litre of fuel is ₦240.

Lighting System Audit

The lamps/luminaires configuration in the hotel differs for each service area. The lamps used in guest rooms are a mix of fluorescent, halogen and incandescent fixtures. While in the lobby it is a mixture of fluorescent and incandescent lamps of different sizes. However, these lamps use magnetic ballast. Thirty percent of the electrical energy used by lighting could be saved if ballasts are replaced with electronic ballasts. The total incandescent lamp power in guestrooms is 24.75kW (90 rooms x 275 W/room). The replacement of these lamps with compact fluorescent lamps (CFL) will result in 76% energy savings or 56430kWh/ year, costing N208,791/year (assuming 3000 hours of operation/year). The cost of these lamps is in the order of N180,000 (N400/18W lamp for the CFL in comparison to N100 for the incandescent lamp). Also the CFL last about has 10,000 hours in comparison to 1000 hours for incandescent lamp. The incremental lamp cost/year is about N335 if the long lamp life is taken into consideration. The total incremental lamp cost is 335 x 5 (lamps/room) x 90 (rooms) = N150, 750/year. The simple payback period of these lamps is expected to be about nine months based on the incremental lamp cost.

Kitchen Appliances Audit

The kitchen uses liquefied Natural petroleum gas for ovens, cook-top, and other cooking appliances at an average monthly rate of 5041 gallons costing an average of N6, 167/month.

Summary of Findings

The energy conservation opportunities in the three Malls and the Hotel are summarized in Table 3 as shown below:

Table 7: Estimated Monthly Energy and Cost (in parenthesis) saving and Simple Payback (SP) in years

	Mall 1		Mall 2		Mall 3		Hotel	
ECO	KWh (SR)	SP	KWh	SP	KWh	SP	KWh	SP
SE*	55,510 (14,430)	03.-0.5	n/a	n/a	n/a	n/a	n/a	n/a
BR**	11,113 (2.889)	1.7	6,000 (1560)	2	14,751 (3,800)	2	650 (169)	2.2
CFL	n/a	n/a	n/a	n/a	n/a	n/a	9,400 (2,444)	0.75
CR	n/a	n/a	n/a	n/a	n/a	n/a	50,118 (13,030)	1.6

Key: SW – Sensible Wheel, BR – Ballast Replacement
CR – Chiller Replacement, n/a – Not Applicable.
* assuming 50% recover ** assuming 50% penetration

The findings from this study can thereby be summarised as follows:

i. The need exists for adopting more effective control measures such as carbon-dioxide monitors at lobbies of the public places such as the Hotel Building.

ii. The design and layout of buildings to make the most of the sunlight is considered as environmentally friendly and has implemented great impact on cities and towns. From an engineering point of view, it is considered of much interest with the passive solar techniques well received by occupants.

iii. There is also a great potential to use passive and active renewable energy technologies in buildings and they have the potential to be exploited in: Passive solar design, Photovoltaic cells, Solar water heating and ducted wind turbines.

Conclusion and Recommendations

The energy consumptions in the shopping malls and the hotel were studied through field measurements of the electrical energy consumption of some of the building services devices and appliances. The study, despite the limitations involved in equipment and time, indicated that a good percentage of the annual energy consumption of the malls and the hotel could be saved. In addition to the ESOs in Table 3, the following energy saving measures are expected to result in substantial savings in the facilities' energy and a detailed feasibility study should be carried out on each of the ESOs:

i. Carbon dioxide monitors can be used in lobby areas to monitor and control the amount of fresh air entering the air-handling units. Savings of up to 70% of the HVAC system could be achieved by implementing this technology.

ii. With the tariff structure of₦3.7/kWh, it will be worth considering partial self-generation using the standby generator for prime power generation.

iii. Buildings should be designed to optimise energy in use and without compromising performance in terms of, air quality and comfort conditions. Savings could be achieved with the use of energy management systems to control the HVAC operation in order to optimize chillers operation, program and control set points, optimum start/stop, fault diagnosis reporting, etc.

iv. Using evaporative coolers should be encouraged because of its relatively low specific energy consumption and suitability of this technology to the dry weather in Minna.

v. The design and layout of buildings should make the most of the sunlight as this is considered environmentally friendly and has implemented great impact on cities and towns. Passive solar techniques if adopted will be well received by occupants.

vi. Use of passive and active renewable energy technologies in buildings should be encouraged in Buildings. Passive solar design, Photovoltaic cells, Solar water heating and ducted wind turbines are hereby recommended.

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Note to Contributors

Introduction

The West African Journal of Building and Road Research (WAJBRR) is an International Journal published bi-annually (in May and November of every year) in English for scientists, research scholars and professionals in the fields of Engineering, Building Technology, Architecture, Geosciences, Construction Technology and Management, Town Planning, Quantity Surveying, Land Surveying and Estate Surveying and other fields related to the built environment, road and traffic and the construction industry. It is a refereed journal which provides a multidisciplinary outlet for the publication needs of those involved in the construction sector; with particular emphasis on the publication of a balanced mix of articles in fields of building and road research and related areas in construction industry.

Requirements

Preparation of material

All manuscripts should be submitted electronically as attachment via:
chukaosadebe@yahoo.com; brriadmin@gmail.com; editorwajbrr@yahoo.com. Text of every article submitted to WAJBRR electronically should be prepared as a Microsoft Word document with the specified WAJBRR double column format unless otherwise agreed. English is the standard language. Manuscripts are prepared in Times New Roman font using a font size of 12, single-spaced. There shall not be any decorative borders anywhere in the text including the title page.

All research manuscript should be typed single spaced and should have the following sections: Title page, Abstract, Key words, Introduction, Materials and Methods, Results, Discussion, Conclusion, Acknowledgement (if any) and References, a list of figure captions, the figures, and any tables (tables in Excel or Word). All abbreviations should be clearly explained in a footnote.

Manuscript Format

After acceptance, all manuscript must be submitted in prescribed WAJBRR Format

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The title page contains the title of the paper, name(s) and affiliation(s)/contact(s) of the author(s), and an e-mail address for the corresponding author to whom proofs will be sent. An asterisk (*) must be placed after the corresponding authors name as superscript whose email id, fax, telephone number can be given at the bottom left corner of the title.

Keywords

Author(s) must give about 4-6 key words which can identify the most important subjects covered by the paper. They must be placed at the end of the abstract.

Abstracts

Abstract should be a summary of the content that contains the essential information in the article. The abstract must clearly outline the essential contents of the paper without citing of references. This page should be vividly informative and adequate for separate publication in abstracted outlets. Avoid abbreviation, diagram and references in the abstract. It should be single – spaced and should not exceed 250 words for full papers.

Text

The general format for the text should comprise the following: Introduction, Description of study area, Methods/Techniques, Result/Discussion, Conclusions and Acknowledgement (where applicable)

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References should be listed alphabetically at the end of the manuscript and must be complete, including names and initials of all authors, year of publication, title of paper referred to, journal name in full, volume, and first and last page numbers. It is necessary to give the issue number in parentheses after the volume. Citation of references in the text should be as follows: 'Atiemo and Osadebe (2005)'. When reference is made to a work by three or more authors, the first name followed by 'et al.' should be used (Matawal et al. 2005)'. Published abstracts should be cited in the same way as published papers, but denoted as abstracts in the reference list. References to unpublished papers are not permitted in the list but may be given in the text (as 'unpubl. results' or 'pers. comm.'). The list of references should follow the following format.

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Adesuwa, C. and Dotun, C.A. (2000), Review of hydrocarbon exploration and production in Niger Delta, Nigeria. Journal of Geology and Mining, **8**, pp.155-165.

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