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Simulating an Integrated Smart Lighting Control of Ahmadu Bello Stadium, Kaduna Nigeria, with a View of Optimizing Energy Consumption

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Abstract
The reductions of unnecessary energy used in buildings have continuously been a global concern. The amounts of energy consumed in lighting a stadium main bowl have posed great challenge on as to how this waste could be drastically reduced. Also, there is a dart of information or data in Nigeria as regards aspects of minimizing lighting energy consumption in a stadium using simulation. This study has employed the use of energy meter and light lux portable device to gather field data on lighting energy consumption as well as the illuminances levels around the stadium. The study also uses a state-of-art lighting simulation software known as DialuxEvo software in modelling the stadium main bowl lighting to optimize energy use. The study discovered that an average of about 400 litres of diesel is consumed on each match when the generator is fully loaded with an average of about 4339.2Kw consumed by the 240 numbers of 2000Kw lamps each within 3 ½ hours match play. The existing lamps provides an average illuminance of 1703lux with a uniformity ratio of U1 (Emin/Emav) as 0.56 while U2 (Emin/Emav) as 0.82 using a 100 watts lamp with a SON gear luminaire. The result therefore showed that the existing lighting design for the stadium main bowl was inadequate and inefficient with lots of opportunity for energy savings. Hence, the lighting fittings should be retrofitted. The revamped lighting fittings should be installed at optimum angle in other to properly illuminate the stadium. Therefore, a proper consideration of the provided guide by The Society for Light and Lighting in the Chartered Institute of Building Services Engineering should be parameter and adhered to.

INTRODUCTION

More of a global priority as regards sustainability is the harnessing and reduction of unnecessary building energy. Energy is the heart of any functional building (Hanafy, (2012). The need to create an enabling environment requires higher energy consumption so as to improve the space and these growth over the years can be traced according to Kim and Schubert (2008), to energy used for lighting, heating and cooling in buildings. The stadium is not left out in the provision of a comfortable environment which is expected to meet the satisfaction of large number of players, officials, spectators and televisions. It is expected that a good sports lighting scheme will have a major influence on the overall ambience of the playing space and should therefore provide an adequate illuminance suitable brightness, contrast uniformity of light distribution and satisfactory control of glare for the activities of sport (Sport England, 2012).

25 to 40% of the total energy consumption been clamoured for is imputable to the built sector and out of these percentage, Mady, Boubakeur and Provan (2011) indicated that lighting alone can waste up to 30% of the total energy waste found in some retail and public buildings and offices. This shows that lighting is a major source of energy inefficiency. Energy problem all over the world is a major challenging and controversial issue that demands great attention so as to tackle it. Dietrich and Melville (2011) identified the professional sport stadium to consume between 5mw to 10mw of electricity during an event which is equivalent to about 5000 to 8000 homes in America. According to Dietrich and Melville (2011) accepts that stadiums is perceived as mini cities with an approximately served 1 million square foot facilities and are by no means a typical users of energy which makes energy efficiency a more complex one. Even since the discovery of this great potential savings envisaged in a stadium, several stadium managements have tried to minimise energy use by employing experts to look into this issues as it was done at St. Louis Cardinal Busch stadium and Imtech Arena Germany.

Philips (2014) spotted lighting as a key player among the comfort parameters in creating exactly the right setting for sporting events as well as live music and many other forms of entertainment on the pitch, yet a major contributor to energy consumption within the stadium main bowl. The present sport world today is been revolutionised by the entertainment industry and this possess a great demand for energy to operate properly (Chuah, 2013). Giebler, Wei, Dengi, Liu, Claridge and Turner (2000) established that there have been significant changes in the design and operation of modern sports facilities. These facilities have been attributed with poor ventilation and bad lighting with such buildings consisting of little more than the spectators seated, main playing floor and the team locker rooms. As the interest on sustainability increase by the public a push ongoing green by sport organisation have continue to pave way immensely. The struggle to optimizing energy in this field by energy experts have continue to be of great task as researchers have identified that there exists a high potential savings in lighting consumption and cost in today's practice. However, there will be an existence of substantial savings and cost savings if lighting is controlled rightly by complimenting available daylight where necessary. According to SEI lighting guide (2008), approximately 40 – 60% of the installed load could be saved with appropriate use of lighting controls systems. However, even the most efficient lighting controls system is wasteful if lighting is in use when it's not required or light beyond the required illuminance.

In recent times most researchers are taking a painstaking effort to addressing the building control and monitoring of energy use. By adopting the recent technology in integrating a building simulation practice, building integration according to Wang (2013), would develop an effective building energy management system whose major task is to minimize the consumption without occupants comfort compromised and creating a balance.

There are several reasons for installing smart lighting controls such as reducing your buildings energy consumption, providing a healthy environment for users and reducing greenhouse gas emissions (GHG) (IPCC, 2007). Various studies on lighting controls in Nigeria and other part of the world are aimed at delivering a sustainable energy efficient future. Further, it was hypothesized that there exists a large potential for energy savings and optimization. Clarke (2009) advocated that there could be a number of reasons stadium should consider intelligent lighting and integration to include; (a) cost savings and profitability; (b) performance improvement; (c) alignment with internal sustainability initiatives. Smart lighting controls can integrate day lighting with artificial lighting to provide flexibility, energy and cost savings and also provide the functions of turning lights 'on/off'. It is possible to find many public buildings where one measure or another has been undertaken by management to decrease electricity consumption.

STUDY AREA

Brief description of the Stadium

The Ahmadu Bello Stadium known as ABS is a multi-use stadium in Kaduna, Kaduna State Nigeria. It was designed in 2nd August, 1964 by the English architects Jane Drew and Maxwell Fry. The stadium is classified as a large Stadium and comprises a main section for track and field events as well as football and two indoor sports centers. The Pitch is made up of a natural turf. The stadium has a seating capacity of 20,000 inclusive of the VIP section. The 20,000 seaters stadium is a multi-purpose sport complex which serves as a center for various social, cultural and religious events. The 20,000 seaters stadium consist of only one tier seating arrangement with a VIP section. All functional secondary areas are accommodated also occupying a gross area of approximately 25,000m^2. This building also provides several kiosks, banks, first aid stations and toilet buildings, one scoreboard and four tower floodlights.

LITERATURE REVIEW

Energy Use

Energy is a crucial aspect in the existence of man and must therefore be harnessed so as to be sustained; this is so as it is an important fact for a country for both its socio-economic development and economic growth (Ekren and Ekren, 2009). The increasing rate of technology and design has continued to raise the demand of energy use. In the US according to Wen, Granderson and Agogino (2006), buildings accounts for 1/3 of primary energy and 2/3 of the electricity generated in the US. Most human outdoor activities have continued to gain interest in revolutionising into an indoor activity. This has therefore, raised the request for a more comfortable indoor space. Elliot, Molina and Trombley (2012) identified energy efficiency as the major contributor to meeting demands of a country energy system.

Challenges of energy and its need for optimization

Protecting the climate is one of the greatest challenges of our time and one which will affect the existence of future generations (ABB, 2009). The threat of global warming is closely related to energy use. The world's largest growth in greenhouse gas (GHG) emissions originates from the use of energy (IPCC, 2007). Clarke (2009) spotted in a research that in the course to fight the war on climate, so many designers and managers have decided to embrace sustainability system. Smulders (2012) stressed that meeting the world's global energy demand requires more attention and active changes as problem of energy all over the world is a major challenging and controversial issues which needs to be tackled. Hence, optimization of energy is a great potential for energy savings as a way to tackle this issue.

Need for Optimization of Energy

According to Ekren and Ekren (2009), several researchers have carried out a great deal of research on hybrid energy system with respect to performance and optimization. The global emphasis on the hike in fuel price and energy efficiency is a major player in the reduction of excess energy cost. This push also applies to the sporting facilities, player in the reduction of unnecessary energy costs. While Giebler *et al* (2000) identified this excess energy costs as unnecessary. It is pertinent that this energy is been optimized in the built sector in other to reduce the threat its emission has to the environment and hence save cost.

Environmental Comfort Associated with Stadium

The view has been expressed by Philips (2014) that more often than not people search for lighting that support the architecture of building and less often the types of comfort needed within the space. While Quantum (2013) had stated that for large venues such as stadiums which often host multiple events at one time or throughout a day, central control is extremely important and went further to propose an intelligent lighting solutions to help preserve views, eliminate glare and reduce heat gain. Hanafy (2012) has emphasised that energy efficient management and optimization strategies in office buildings can be established by implementing simulation-based optimization control.

Importance of Installing Lighting Controls

In almost all the technical literature, constant lighting control is frequently accredited with a high level of potential savings for electrical energy (ABB, 2008). Lighting controls therefore have been one of the numerous ways of reducing overall energy consumptions in a building and a major act of energy reduction in commercial building. According to Di Louie (2006) as cited in Clarke (2009), lighting controls overall purpose is to eliminate waste while supporting a productive visual environment. Edwards and Torcellini (2002) was able to show that lighting controls can increase the value of commercial buildings by making them more comfortable, productive and energy efficient. It simply despatches its service by either keeping the lights switched off when not needed or by dimming the light output so that no more light than necessary is produced. Pisello, Bobker and Cotana (2012) concluded by saying building energy efficiency is strongly linked to the operations and control systems together with the integrated performance of passive and active system. Lu, Birru and Whitehouse (2010) added that light control systems aim to illuminate a space that provides sufficient ambient lighting for the needed tasks to be performed. Wei (2011) concluded that modular intelligent control system can be used to obtain an energy savings and autonomous operation in a lecture hall.

Lighting in a Stadium

Lighting in a stadium is a subject area with a high degree of technical complexity that can be difficult to understand. According to Sport England (2012), the design considerations for lighting installations for sport need to balance certain issues such as levels of illuminance, uniformity of illuminance, contrast, glare control, colour rendering, compliance with statutory regulations within an integrated design. It is very important that at outset of a project, lighting requirements for each sport are clearly understood and designed for. Aside the need for a sport area to be well lit so that those taking part and those spectating can clearly see all that is going on.

Plate 1: View of a well-lighted Stadium. Source: Philips lighting (2014)

Building Simulation and Intelligent System

A comprehensive documentation by Sport England (2012) is that the creation of an appropriate visual environment is a fundamental requirement in sports design and the effective integration of the artificial lighting system should be considered as a standard part of a modern sports facility. Philips (2006) explained that in reality, sometimes the lighting is not given proper consideration and an inadequate lighting system is thereby installed. Simulation of smart lighting should provide a flawless lighting effect creating a smart balance that would offer increased energy efficiency, compact and clean design that blends with the environment and improved health and physiological being of man.

Wen, Granderson and Agogino (2006) explained smart lighting as a novel of wireless sensing and actuating technology with the potential to solve many of the problems associated with commercial daylighting systems. Dynalite (2012) indicated that intelligent lighting would allow easy control of light from a single interface and the savings are in running cost, maintenance cost and operational cost. The integration should maximise natural lighting and reduce the need for artificial lighting so as to optimize energy.

Building Integration

Building energy efficiency is linked strongly to the building control system and operations with the integrated performance and active systems. Pisello, Bobker and Cotana (2012) emphasized that even the post occupancy assessment at the service light of the building after implementation of integrated performance must be considered to reduce whole energy.

Integration would involve the harmonization of natural lighting with artificial lighting so as to create an energy efficient stadium. While trying to control the light intensity within a building space, Selkowitz and Lee (2004) adopted an automated integrated façade and lighting system so as to obtain an optimized lighting system using smart control system. Reubinstein, Treada and Pettler were able to improve building performance, increase energy efficiency and enhance occupant comfort and satisfaction in the built sector significantly by integrating lighting controls. Lee, DiBartolomeo, Vine and Selkowitz (1998) also integrated the performance of an automated venetian blind and electric lighting system to reduce perimeter zone energy use and increase comfort in offices.

MATERIALS AND METHODS

The research employed the use of energy monitoring Data logger to get an average energy consumed within a particular space of time. A light lux portable device was used to measure the lighting intensity on the viewers' visible region. Energy bills for a duration of 3 ½ hours were retrieved for analytical press. Interviews on the officials and managements during the walkthrough survey to obtain relevant information on energy use pattern were carried out.

Description of Research materials

To obtain hourly electricity use profile of the stadium main bowl, an electronic instrument consisting of Mini CT sensor, Transmitter and Wireless energy monitor was used. See plate 2 and 3.

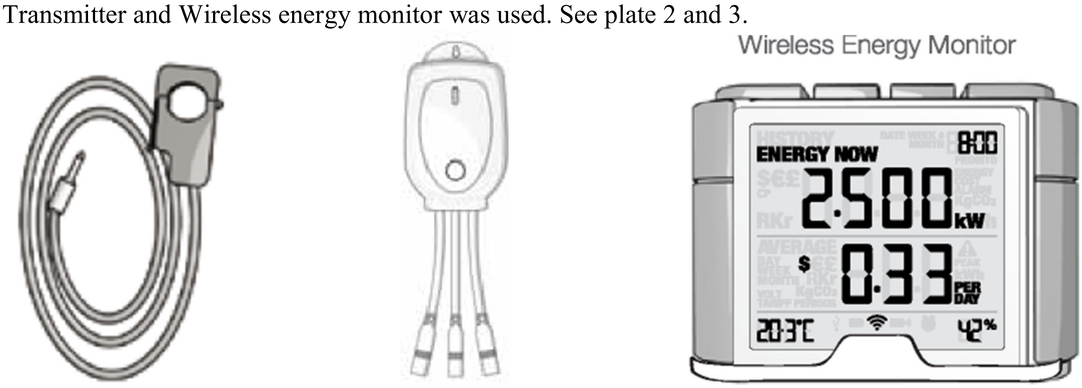

Plate 1: Electronic Instrumentations. Source: www.efergy.com

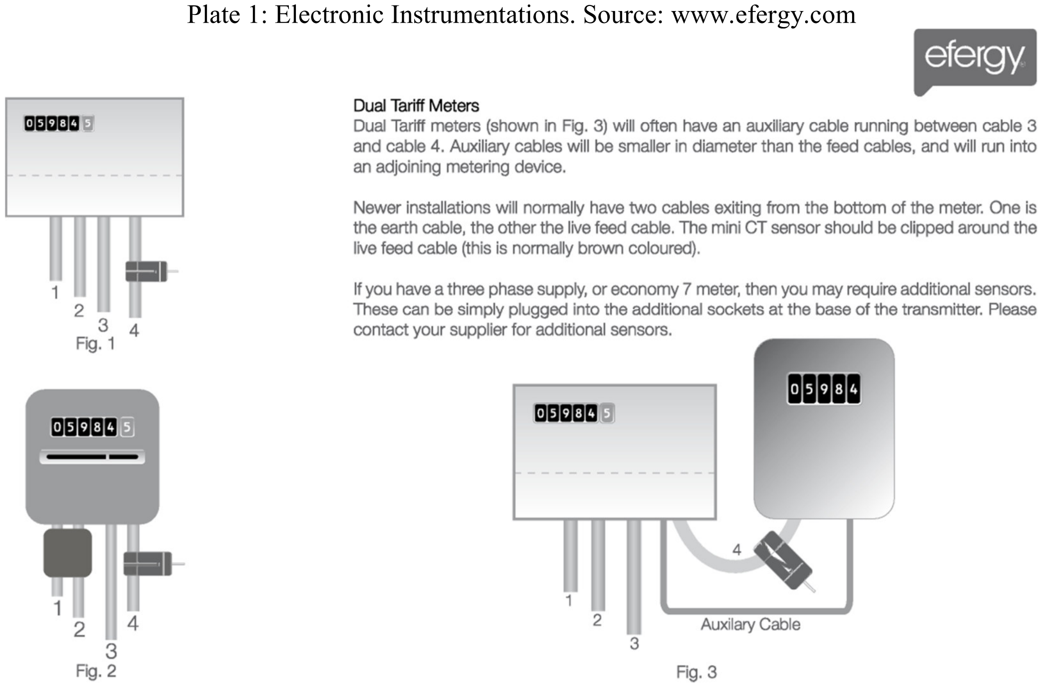

Plate 2: Installation of Wireless Energy Monitor. Source: www.efergy.com

The Portable light lux meter which can measure between from 0.01 – 50,000 lux and has a resolution of 0.1lux/fc was employed as the tool for taking the measurement of light illuminance within the stadium main bowl. The portable light lux meter is comprised of two main features as the sensor and the display and these two parts are connected together with the aid of a cable. See plate 3.

Plate 3: Light Lux meter

Research Procedures

The following procedures were adopted for the research success;

A. Walkthrough process and Interview with the officials provided information on:
   i. such as quality, quantity, wattage and types of lamps
   ii. the capacity, frequency of use and size of the stadium
   iii. specific characteristics and energy use pattern in the stadium
   iv. existing energy efficiency measures and strategies

B. Measuring process using lux meter and wireless energy monitor provided information on:
   i. Data required for the specific energy use by the flood lamps sport stadium is determined using portable device and documented.
   ii. Light flux is measured using portable light lux meter and documented properly. To obtain the light illuminance a portable light lux device was used with precision and obtained at various points at 10m X 10m on the 105 X 68m field 1m above the natural turf and would be read at intervals of 10secs on the turf of the field been the focus point (work plane)

C. Data Analysis
   i. The data obtained was compared with the design standard required by such space using charts.
   ii. The data was hence, simulated using Dialux 4.12.1 software to determine the level of energy required for such space
   iii. Comparison of efficient practice from simulation was made against obtained practice on ground.

RESULTS

Installed Electrical Lighting Facilities

The followings are the electrical facilities supporting the lighting of the mainbowl of the stadium.

Table 1: List of Lighting Facilities for the Main Bowl

S/no.	Description of facility	Quantity	Condition/Remarks
1.	Towers	4	Good
2.	500 KVA generator set	2	✓
3.	850 KVA generator set	2	✓
4.	Fuel Storage tank 200litres	4	✓
5.	Control panels	2	✓
6.	Seaters Capacity	20,000	✓
7.	Tiers available	1	✓
8.	Track lamp	72	✓
11.	Field lamps (2000watts of metal halide)	168	✓

Source: Fieldwork, 2015. **Key** –Good condition

Illuminance measure using light lux meter

Table 2: Illuminance Measurement taken as at when no Lights were Switched On

Section (pm)	Illuminance (lux)	Remarks
3:00	54500	Little overcast due to initial partial rainfall
3:30	46600	✓
4:00	43700	✓
4:30	39400	✓
5:00	23500	✓
5:30	5660	✓
6:00	5080	✓
6:30	3850	Longer day experienced
7:00	1760	✓
7:30	650	✓

Source: Fieldwork, 2015

Although, with little overcast as a result of partial rainfall at 3pm and without artificial lights on the illuminance recorded yet a higher lux value and this high lux recorded can be seen till 5pm after which there is a drastic drop in illumination with a difference of about 17,840 lux of which therefore an additional artificial lighting compliment would be required.

Table 3: Illuminance measurement conducted when lights were switched on

Section (pm)	Illuminance (lux)	Remarks
3:00	63000	On-going match as at the time of readings
3:30	50100	✓
4:00	49400	✓
4:30	42800	✓
5:00	28390	✓
5:30	7570	✓
6:00	6480	✓
6:30	5490	✓
7:00	2700	✓
7:30	2020	✓

Source: Fieldwork, 2015

The light illuminance in Table 3 recorded an adverse reduction as the clock whines down into the night due to the shift in sunrise and sunset. From the hours of 3pm to the hours of 5pm there wouldn't be any need for artificial lighting as the lux value reads far more than expected as 63,000 lux and 28,390 lux while between 5:30pm down the night hours a highly sequential addition of artificial lighting would be necessary for compliments especially for a televised event due to camera capture.

Table 4: Light illuminance from the towers measured on the play field

Baselines	1	2	3	4	5	6	7	8	9	10	11
1	1584	1446	1226	1330	1269	1507	1443	1509	1497	1838	1970
2	1873	1508	1829	1370	1408	1531	1460	1545	1867	2120	1970
3	1575	1780	2084	1394	1905	1519	1810	1541	1880	1983	2026
4	1353	1817	2089	2166	2113	1587	1889	1517	1678	1906	1730
5	1288	1404	1970	2140	2145	1835	1717	1637	1607	1827	1520
6	1382	1488	1570	1845	1875	1754	1717	1780	1804	2028	1630
7	1470	1573	1750	1881	1921	1782	1791	1919	1830	1696	1412
8	1538	1750	1860	1887	1834	1571	1828	1419	1820	1370	1529

Source: Fieldwork, 2015

Table 4 indicated the tabulated form of the measured light illuminance. For Uniformity purpose from the above measurements, the average illuminance incident on the stadium field from the use of flood lights was calculated as 1703 lux and the information on the table shows each point on the field measured has different illumination level varying from point to points and with high concentrations at the middle. The least illuminance was 1226 lux while the maximum illuminance was 2166 lux. The uniformity ratio was calculated as U1 for E_{min}/E_{av} to be 0.57 while the U2 for E_{min}/E_{ave} to be 0.720. This therefore, shows there was no uniformity of illuminance on the field. The average lux per metre square as 21lux/m^2.

Existing Efficiency Practice for the Stadium

The stadia electrical design was done by ABB and as at the time of its design, certain efficiency measures were ensured to avoid excess waste as in terms of operations. All the flood lamps numbered 60 on each mast are done to create a two way control of the lamps. These flood lamps grouped in two places sections the first seven rows (42 nos. lamps) to be switched separately and the last three (3) rows (18 lamps) to be switched also separately. These first 42 lamps are considered the field lamps which extends to the middle of the pitch and the rest 18 lamps considered as track lights which concentrates on the track area and these zoning makes a whole tower flood lights to illuminate 1/4th of the entire field. The track lights or light events while the field lamps are used during an international or large event going on. There are no emergency lamps provided for illumination on the main bowl except for the emergency exit. As long as an international competition is on-going and would lapse into the night or experience dark weather, once the cost is met the lights needed for that evens are switched on not minding its cost implication or timing as the aim would be to satisfy the international body responsible for the event. One generator set is been used at a time and another on a standby as a back-up.

Diesel Consumption Rate

Diesels are used to power the generating sets and these are often during an international match or an important event which would require energy to power the electrical device. Although a public supply from the main grid is provided to power only the offices and other street lights. The floodlights because of their huge energy consumption and demand and in other to avoid interruption which could affect the visibility and aim of the activity are not connected to the main grid. The stadium is provided with 2nos. X 500 KVA generating set and a 2nos. X 850 KVA power generating set. Because of the operating nature of generators to obtain an optimum efficiency the generators are loaded to a capacity of 80% efficiency and not below 65% so as not to cause a circuit failure. The following is a consumption rate of diesel when operated for both full load and low loads

Table 5: Average Diesel consumed during a Match

Generator (KVA)	Quantity of generator Set	Hours used per game (hours)	Diesel quantity (Litres)	Remarks
500	2	6 ½	200	Not fully loaded
		6 ½	400	When fully loaded
850	2	4	200	Not fully loaded
		4	400	When fully loaded

Source: Fieldwork, 2015

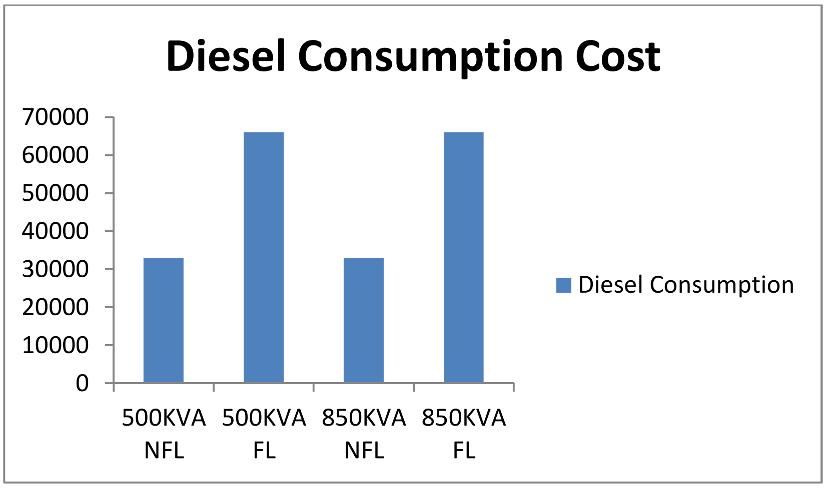

Plate 4: Diesel Consumption per match. Source: Fieldwork, 2015

The cost of a litre of diesel as at May, 2015 was 165 naira averagely. When checked upon the quantity of diesel consumed per match in the absence of public grid supply as shown in Plate 5 above. For every 200 litres diesel consumed, the cost amounts to ₦33, 000. Although, these cost are for when not fully loaded with other spaces. This amount would only serve for 6½ hours for a 500 KVA generator set and 4½ hours for an 800KVA generator set. When the generators are fully loaded with other facility spaces other than the floodlights like offices, changing room and others would amount to ₦ 66,000 for same hours as earlier scheduled.

Table 6: Consumption Rate (Kw) per Metal Halide Lamp as Measured

S/no.	Timing	Energy used(Kw)
3	6:00	3.90
4	6:30	3.11
5	7:00	2.53
6	7:30	2.12
7	8:00	2.12
8	8:30	2.14
9	9:00	2.16

Source: Fieldwork, 2015

The energy metre was used to measure the energy consumed by the metal halide lamp. One metal halide lamp out of the 240 lamps installed was selected since all lamps are separately installed and have same consumption rate as expected. The measurement was done between the hours of 6pm to 9pm considering the used periods of lamps. The consumption rate in Kw per lamps revealed that the lamps when measured at the early switched on hours consumed more energy than the expected rating of the lamps for as much as 3.90kw at the first 30mins as more energy is needed for the initial lamp powering and thus, drops down after a while an d when the lamps have worked for a while then the consumption rate starts increasing because it needs more energy to work effectively due to weakness of elements due to long use and age. Hence, within a span of 3 ½ hours a total of 18.08kw was consumed by just one lamp.

Pattern of the Maintenance Practice Adopted

It is very important that installed electrical facilities are always checked regularly in other to avert any fault, great damage or grounding of the entire system and also because of the huge resources put on ground to have such an edifice. Investigation into the pattern of usage and operational practice put in place in piloting the running of these masts shows that because the stadium in a bowl is not an all-time use as identified in Dietrich and Melville (2011), the maintenance practice therefore is carried out periodically every six months which is twice in a year as a Protective maintenance. Also, due to the level of matches played which requires to be broadcasted live internationally and for the optimum performance of the players, the world Football body FIFA usually carry out a light lux test to ensure the lamps provides accepted light intensity as recommended as a standard for the soccer game. A minimum standard of 1000lux is always ensured. When any lamp gets bad, it affects the illuminance intensity and could lead to poor performance and poor video quality for the camera transmittance.

Benchmarking the Baseline Light Illuminance with Standard

The guide provided by The Society for Light and Lighting (2006) under the authority of Chartered Institute for Building Services Engineering for televised events in a stadium main bowl if between 1000lux and 1400lux. This benchmark is juxtaposed against the measured illuminance as obtained from the field and the below Tables 9 and 10 showed the differences between the expected (benchmark) and the actual (as measured).

Table 7: Differences between Benchmark Light Lux for Televised International Matches and Baseline Illuminance from the Flood Lights.

Base	1	2	3	4	5	6	7	8	9	10	11
1	184	46	-174	-70	-131	107	43	109	97	438	570
2	473	108	429	-30	08	131	60	145	467	720	570
3	175	380	684	-6	505	119	410	141	480	583	626
4	-47	417	689	766	713	187	489	117	278	506	330
5	-112	04	570	740	745	435	317	237	207	427	120
6	-18	88	170	445	475	354	317	380	404	628	230
7	70	173	350	481	521	382	391	519	430	296	12
8	138	350	460	487	434	171	428	19	420	-30	129

Source: Fieldwork, 2015

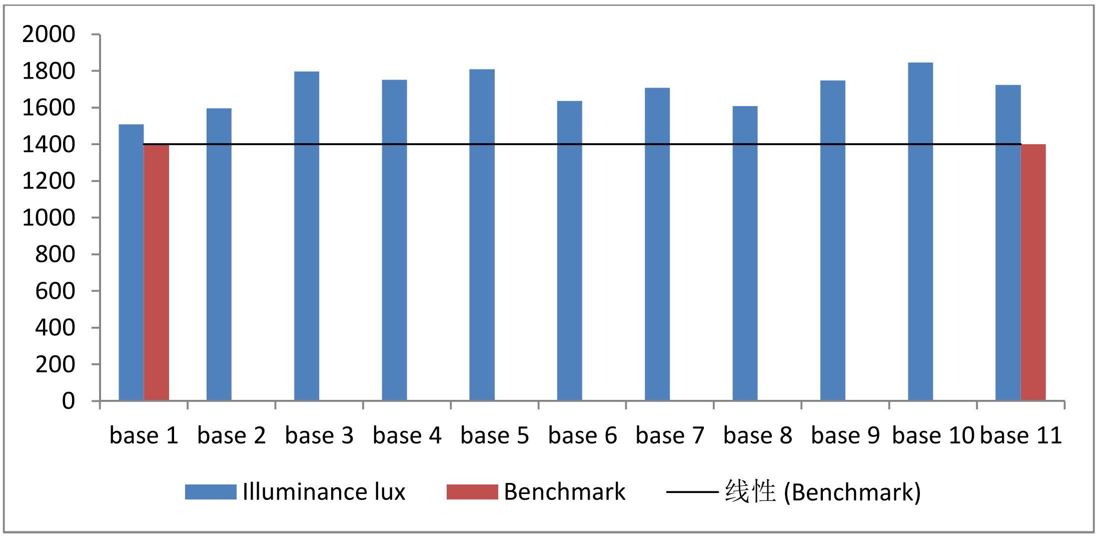

Plate 5: Benchmarking the base line average illuminance with the expected standard illuminance for internationally televised event (1400 lux).

Table 8: Differences between Benchmarked Light Lux for Televised National Matches and Base line Illuminance from the Flood Lights

Base	1	2	3	4	5	6	7	8	9	10	11
1	584	446	226	330	269	507	443	509	497	838	970
2	873	508	829	370	408	531	460	545	867	1120	970
3	575	780	1084	394	905	519	810	541	880	983	1026
4	353	817	1089	1166	1113	587	889	517	678	906	730
5	288	404	970	1140	1145	835	717	637	607	827	520
6	382	488	570	845	875	754	717	780	804	1028	630
7	472	573	750	881	921	782	791	919	830	696	412
8	538	750	860	887	834	571	828	419	820	370	529

Source: Fieldwork, 2015

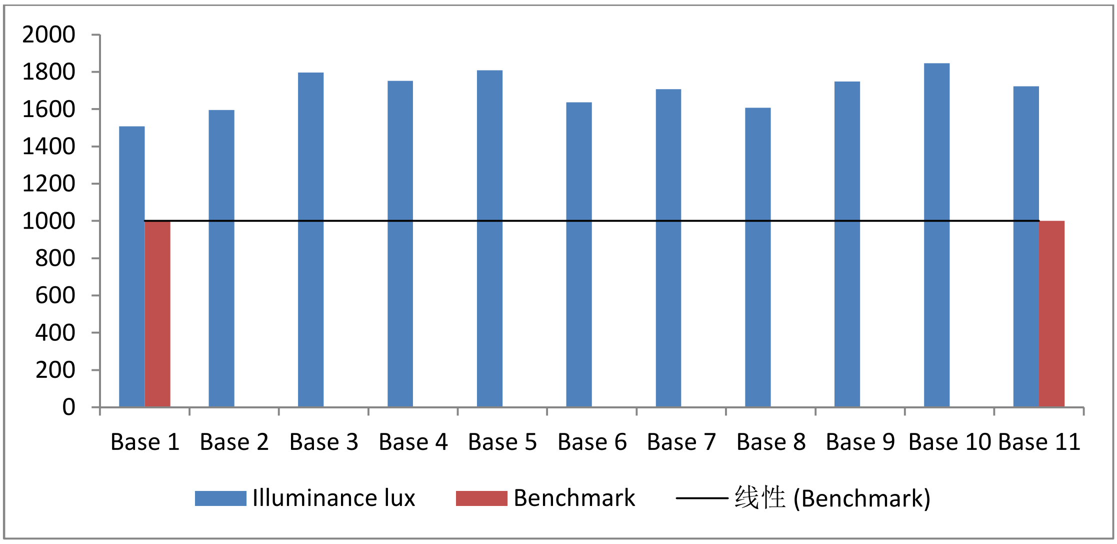

Plate 6: Benchmarking the baseline average illuminance with the expected standard illuminance for national televised event (1000 lux).

Hence, using the actual lamps 2000 watts installed would consume as much energy as 120,000 watts which is about 120 Kw per mast with a total of 480 Kw for the four masts while the use of an energy efficient lamp of 1000 watts with a better efficacy would only amount to 60,000 watts which is about 60 Kw per mast and a total of 240 Kw. This invariably would amount to a difference of about 240 Kw with a saving energy of about 22%. The aiming of the floodlights was not well projected thereby causing excess spill.

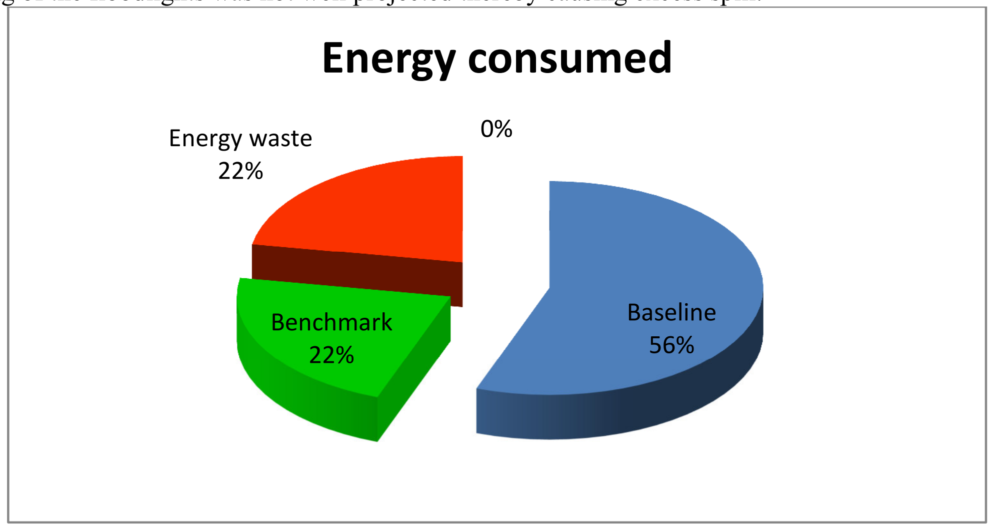

Plate 7: Estimated rate of Energy Consumed
Source: Fieldwork, 2015

Although, going by the equation provided for the approximate determination of illuminance for normal events is calculated and determined below;

E = 324{ln[2.1(D+S)]}-1530 1
E = 324{ln[2.1(100+20000)]} – 1530
E = 324{ln(42210)] – 1530
E = 324(10.56) – 1530
E = 3450.6 – 1530
E = 1921lux

The value showed that though the illuminance for normal event in stadium (1921 lux) using the approximate value could be achieved at some points in the field but it's not uniform as some values recorded are lesser (1226 lux) with a difference of about 695 lux and some points much higher than expected (2166 lux) with a difference of about 245 lux.

Simulation of the Stadium Main Bowl

The lighting system of the stadium was considered with focus on only the flood lights of the stadium main bowl. Referencing the flood lighting system with its baseline illuminance on the main bowl, lighting simulation software known as dialux 4.12.1 was thus used in simulating a more energy efficient system required of in the flood lighting installations against the baseline measured. The following were obtained in the simulation;

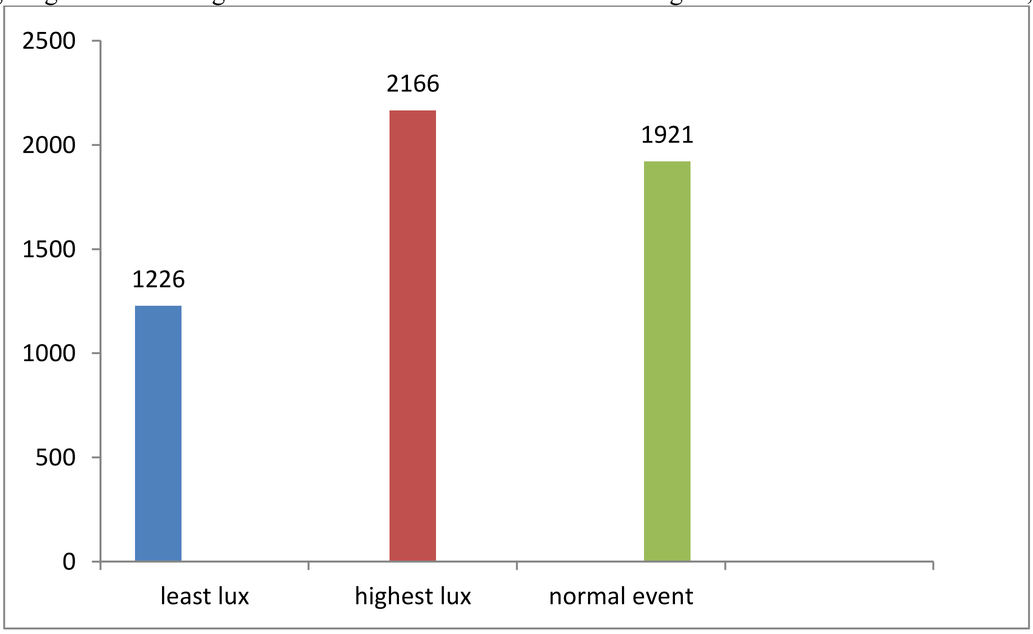

Plate 8: Compared illuminance lux values of measured and expected for a normal event
Source: Fieldwork, 2015

Table 9: Luminaire Parts

Description	Baseline	Designed
Name	Philips HNF207 1xHPI-T2000W/220V WB	Philips MVF024C 1xSON-T1000W SGR MB
Total lamp flux	189000lm	130000lm
Light output ratio	0.59	0.80
System flux	111510lm	104000lm
System power	2035w	1020w
Dimension	HXD-7.0x0.65m	LxBxH-0.6x0.48x0.23m
Ballast	HPL/HPI gear	SON gear
Luminous efficacy	93 lm/w	128 lm/w
Maintenance period	Twice yearly	Annually

Source: Dialux 4.12.1 Simulation CA

Table 10: Estimated Rate of Consumption and Cost

Description	Numbers of lamps	Power per lamp (Watts)	Total lamp energy consumed (KW)
Baseline	240	2000	480
Designed	200	1000	200
Energy waste			280

Source: Fieldwork, 2015

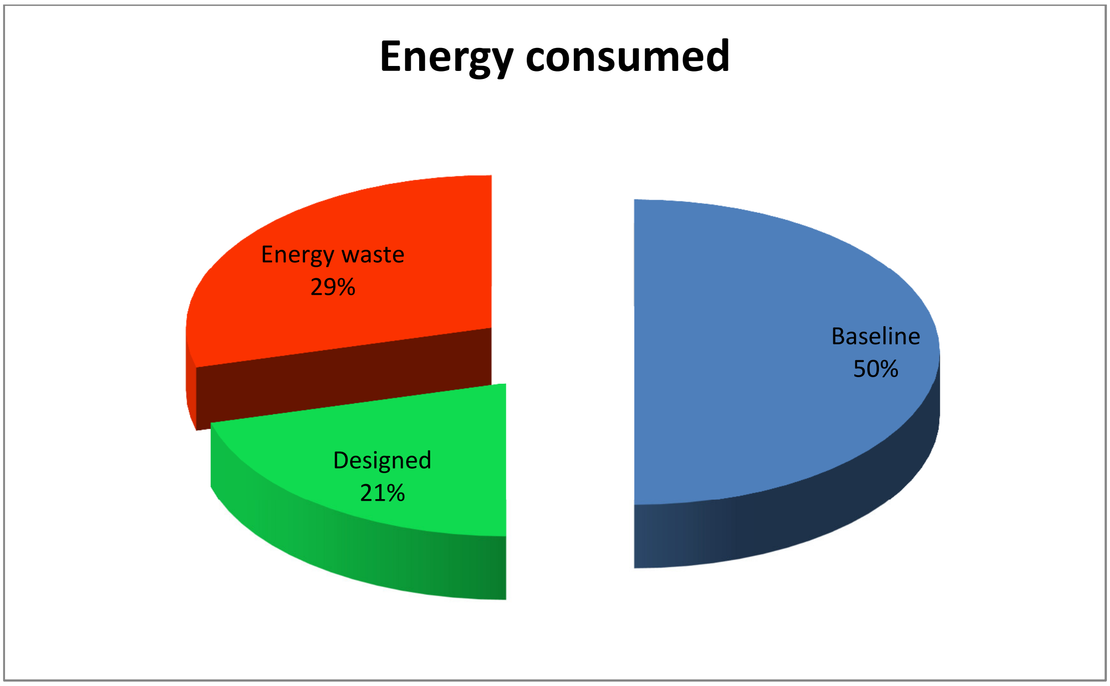

Figure 9: Calculated rate of Energy Consumed
Source: Fieldwork, 2015

Table 11: Capital Cost of lamps and luminaire (Relamping)

Description	Cost of luminaire ($) (A)	Cost of lamp ($) (B)	Total cost of luminaire and lamp ($) (C= A+B)	Numbers of luminaires and lamps (D)	Total Cost of lamps and Luminaires ($) (E=CxD)
Baseline	420	60	480	240	115,200
Design	390	36	426	200	85,200
Total Waste					30,000

Source: Fieldwork, 2015

The simulation thus revealed that using a 200 numbers 1000 watts lamps would yield the required output expected of the floodlights if the aiming are well projected to the main bowl. The output met with the requirements by The Society of light and Lighting with U_1 0.56 and U_2 0.82. A total of about 200 kw would be required when going to be fully used rather than the baseline 480 kw which records a waste of about 280 kw as shown in Table 9 above with a percentage waste of about 29% also shown in Plate 10. This similarity in waste is almost the same as that estimated in the benchmarking in Plate 8 above. The cost as obtained from the above Table 11 revealed that the cost of using the SON gear luminaire and a 1000 watts lamp would yield a savings of about $ 30,000 as against the HNF gear luminaire with a 2000 watts lamp. Hence the implication of adopting the design would be of a great cost benefit for both installation and in maintenance and with integration of sensors and ballast dimmers a more energy savings would be enhanced as well as providing good efficiency.

CONCLUSION

From the result presented, it can be seen in the data presented that the management's concern was just to provide the light output required during matches and meeting the FIFA or IAAF standard regardless of the cost and what it takes to meet the requirement. Hence, there is very poor or no energy efficient practices as regards the facility's lighting systems and their operation. When results obtained was benchmarked against best practices, there exists an energy waste as much as 240 Kw equivalent to 29 % in percentage on lighting use for the stadium main bowl as a result of excess wattage from the Metal halide lamp been used rather than using a more efficacy lamps with a less wattage consumption. The simulated lighting environment also shows that, it would be appropriate using the 200 numbers 1000 watts lamps and a SON gear luminaire as this would cut off the excessive waste based on the current practice by 29%. Therefore, an efficient energy practice is needed to ensure a better cost effective and management of the lighting facilities using an integrated smart lighting control and relamping using a more energy efficient lamps.

RECOMMENDATIONS

With respect to the set out standards for lighting a stadium, the conclusion has shown that there is a great need for improvement on the lighting system to achieve an energy efficient system rather than unnecessary waste. The following suggestions are recommended;

1. The use of track lighting system should be encouraged as these would be helpful in the aspect of uniform distribution of light in and around the main bowl.
2. The luminaires should be positioned in layers or tiers to be able to regulate the light incident at each and every giving time on the main field of play when required.
3. The environmental and climate considerations should be well studied before the design stage and as such a well calculated lighting design should be adhered to.
4. Standards and guides regarding such space should be strictly complied to and maintained.
5. Huge savings are better achieved at the design stage as a lot of factors affecting energy efficient would be inherent and as such lamps and luminaires must be carefully selected at this stage.
6. In the case of retrofitting the use of led luminaires that are robust and made of cast aluminium heat sink should be encouraged when designing for a high environments.
7. Reduction in lighting fixtures and lamp types is with great consideration when trying to reduce energy consumption and as such a high efficacy lamp should be encouraged.
8. Due to the nature of the use of such space and the energy required to light it, it would be wasteful to light the entire field of play fully when match is been played during bright day with enough daylight available. To these effect smart technology will automatically take care of these aspect and dim lights when necessary.
9. Also, it is wise to ensure a good switching and control arrangements are such that only the necessary illuminance levels are provided over relevant areas and only during the periods required.
10. The guide provided by Chartered Institute of Building Services Engineering in The Society for Light and Lighting (2006) should be emphasized in the cause of floodlighting design or retrofitting in a Stadium.

Hence, all these are adhered to strictly, the benefits of minimising energy use and its associated costs are the obvious overall operating costs are reduced and the environmental impact minimised as well as the use of a less capacity alternative power supply (Generator set) which would consume lesser quantity of diesel to power.

Contribution to Knowledge

The study as intensely conducted would create feedback to the management concerned that there is so much energy wasted in the practice resulting to unnecessary cot and could be minimised and monitored as these efficiency practice would attract a huge savings from lighting alone since lighting accounts to 30 - 40% of the total waste of energy in a built environment.

Further areas for Study

The following areas could further be assessed to delineate the gaps experienced within the field;

1. Integrating renewable energy system into the design of stadiums
2. Optimization of energy in a stadium by simulating a building energy management system.

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