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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.

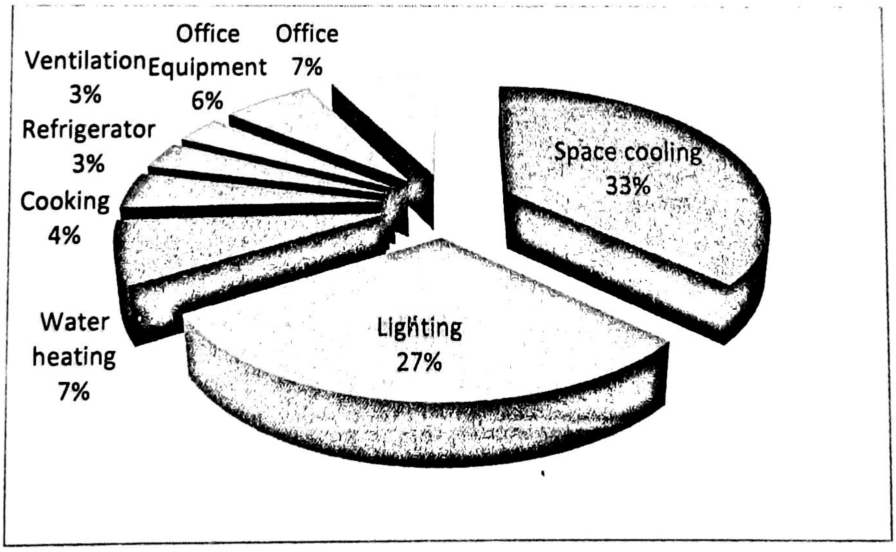
LITERATURE REVIEW

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 10: 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 9: 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).

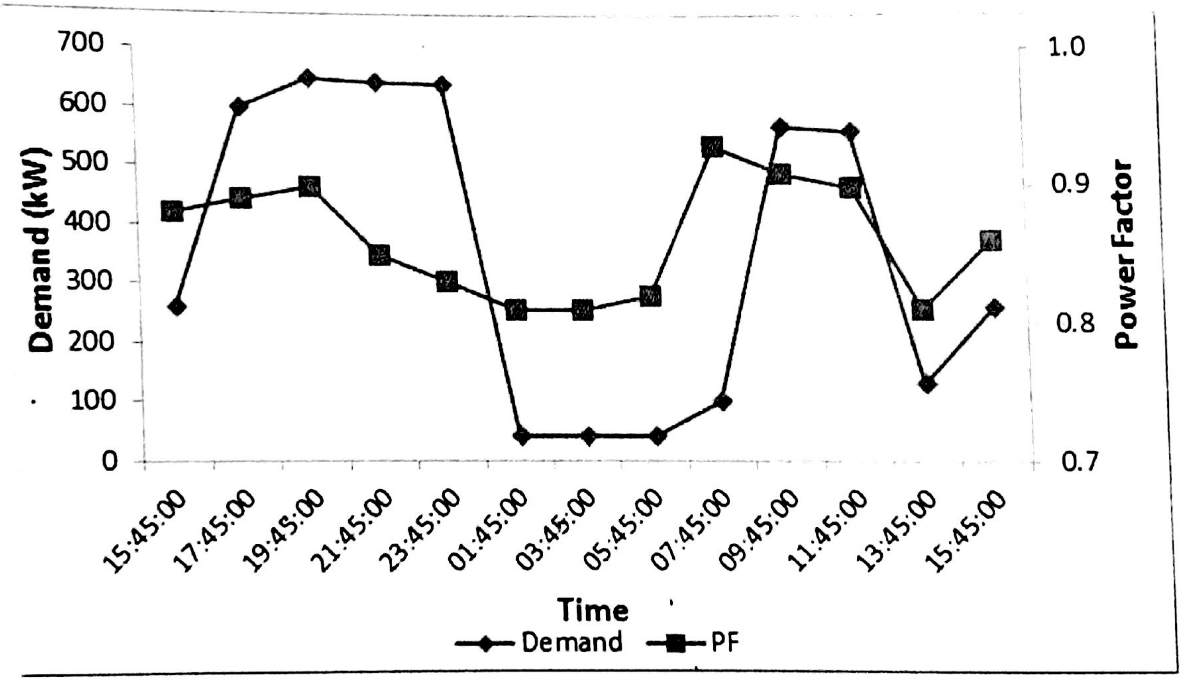
Therefore the main aim of energy performance is to encourage the practice of specifying materials, components and systems. The particular objective of an energy performance is to specify what is required from the building in terms of target energy consumption.

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 11: 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

	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

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 5.5°C and with an average supply temperature of 6°C. The average temperature difference across the loaded cooling devices was also in the order of 15°C. 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 15°C between the outdoor and the indoor temperatures (40 – 25°C), 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 re-lighting 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 42°C and inside design temperature of 25°C 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 13°C to 7°C. 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 11: Estimated Monthly Energy and Cost (in parenthesis) saving and Simple Payback (SP) in years

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,