AN EVALUATION OF ENERGY CONSUMPTION AND CONSERVATION OPPORTUNITIES FOR BUILDINGS AT NATIONAL RESEARCH INSTITUTE FOR CHEMICAL TECHNOLOGY ZARIA

BY

ABDULWASIU ABDULSALAM
P16EVBD8170

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Declaration

I declare that the work in this disertation entitled “AN EVALUATION OF ENERGY CONSUMPTION AND CONSERVATION OPPORTUNITIES FOR BUILDINGS OF NATIONAL RESEARCH INSTITUTE FOR CHEMICAL TECHNOLOGY ZARIA” has been performed by me in the Department of Building Ahmadu Bello University Zaria under the supervision of Prof. I. Mbamali and Dr. D. Abdussalam. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this work was previously presented for another degree at any higher institution of learning.

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Abdulwasiu Abdulsalam Date

Certification

This dissertation entitled "AN EVALUATION OF ENERGY CONSUMPTION AND CONSERVATION OPPORTUNITIES FOR BUILDINGS OF NATIONAL RESEARCH INSTITUTE FOR CHEMICAL TECHNOLOGY ZARIA" by Abulwasiu Abdulsalam meet the regulation governing the award of the degree of master of science of Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

Prof. I. Mbamali Signature ---------------------

Chairman Supervisory Committe

Dr. D. Abdulsalam Signature ---------------------

Member Supervisory Committe

Dr. D. Dahiru Signature ---------------------

Head of Department

Prof. Sadiq. Z. Abubakar Signature ---------------------

Dean, School of Postgraduate Studies

Dedication

This Dissertation is dedicated to my beloved children, wife and to the entire family members for their support.

Acknowledgement

My sincere thanks and appreciations are to my supervisory team consisting of Prof. I. Mbamali and Dr. D. Abdulsalam without whose guidance, mentoring and contributions despite their hectic schedules I would not have realized this success. It is my wish also to appreciate the enlightened guidance and concern shown on the course of this work by Engr. Jimoh Mr Yakubu all from NARICT for their contribution during the field work. My gratitude also goes to entire staff of Department of Building Ahmadu Bello University, Zaria for their guidance toward the achievement of this work.

Abstract

Understanding how energy is supplied and used in buildings is a key prerequisite to energy conservation process in the built environment. The study was aimed at evaluating energy consumption and conservation opportunities for national research institute for chemical technology (NARICT) buildings with a view to enhancing energy efficiency in the instittution. NARICT blocks of buildings constitute the population of the study with ten (10) sample blocks of buildings. The procedure adopted for achieving the set objectives were presented in three stages, energy audit using checklist, measurement of current and enviromental condition (Relative Humidity and Dry Bulb Temperture) and determing behavioral perspective through monitoring and targetting. Economical cost benefit and descriptive statistics were used in analyzing the data obtained. Results from the study shows that, Space cooling systems have the average highest energy consumption value of 5319KW (39%) followed by lighting fixtures with 1567.4KW (36%) and plug load appliances with 563KW (24%). Measured illumination level of 317 to 500lux from day lighting in the blocks of buildings were sufficient and were in accordances with ESI recommended level of 320 lux for office building and 400 to 750 lux for laboratories. Energy saving opportunities to a total of 9692 Kwh and a total cost saving opportunity of N443,028 per month were reliased. It is therefore concluded that, high usage of space cooling system, aged appliances and improper replacement of component were major factors responsible for higer energy consumption. Initiating an internal energy policy, retrofitting and establishment of an energy management system in the institute will guarantee good energy savings opportunities with enormous reduction in green house gas emission.

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IEA	International Energy Agency
TED	Total Energy Demand
TEC	Total Energy Consumption
CUE	Current Cost of a unit electricity
SW	System wattage
kWh	Kilo Watte Hour
ECL:	Energy Consumption of Lighting System
ECSC	Energy Consumption of Space Cooling
ECOE	Energy Consumption of Office Equipment
CFL	Compact Florescent Lamp
LED	Lead Emitting diode
RRF	Resistance Regulator Fanvgs,
ERF	Electronic Regulator Fans
CIBSE	Chartered Institute of Building Services Engineers

DEPARTMENT OF BUILDING

FACULTY OF ENVIRONMENTAL DESIGN

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Candidate Number : P16EVBD8170

Title: AN EVALUATION OF ENERGY CONSUMPTION AND CONSERVATION OPPORTUNITIES FOR BUILDINGS AT NATIONAL RESEARCH INSTITUTE FOR CHEMICAL TECHNOLOGY ZARIA.

S/N	Observation	General Comment	Student comment	Page Number
1	External examiner	Acknoledgment should reflect only those that contribute to the work	Corrected	V
2	External examiner	Abstract should be well written to capture all data collected	Improved	vi
	Internal examiner 1	,, ,,	,,	,,
	Internal examiner 2	,, ,,	,,	,,
3	External examiner	Include Glossary page	Corrected	xii
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	Internal examiner	Include Glossary page	,,	xii
4	External examiner	References that are cited in the work should reflect in the reference list and those in the list but not in the work should be removed	improved	
5	External examiner	Correct all grammatical error in the general work	Improved	
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6	Internal examiner	The work should read dissertation not thesis	Correctd	i
7	Internal examiner 1&2	Justify the reason why the work should be carried out in the study area	improved	4
8	Internal examiner 1&2	Divide your methodology into the different works you have carried out	Improved	40

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Energy in the form of electricity or fossil oil is commonly used in institutional buildings to operate equipment for the safety, efficiency, convenience and comfort of its occupants and users. Such equipment includes emergency systems, space cooling system, artificial lighting, vertical transportation, ventilation, office infrastructure and other appliances. Energy use in building has increase recently due to its growing demand (Cui, 2006).

Anink, Boonstra and Mak (1996) and Zhenhong (2007) observed that more than thirty percent of primary energy, mostly generated from fossil fuel is consumed by non industrial buildings, including houses, offices, schools, hospitals and so on. In recent years, the situation of electrical shortage in Nigeria and emission of greenhouse gas around the globe has become more serious which calls for immediate action to initiate another source to reduce its consumption (Hinge, 2004). Although, "this trend can partly be offset by considerable improvements of energy conservation through materials use during construction, insulation, day-lighting design and usage, and better energy management system"(Hinge, 2004).

According to the Chartered Instituted of Building Services Engineers (CIBSE, 2004) efficient energy in building is that which provides the required internal environmental and service with minimum use of energy in a cost effective and environmentally friendly manner. Also United Nations Industrial Development Organization (UNIDO, 2006), observed that energy conservation can be enhanced through improved building design, behavioral change, improved management, or initiation of new technology among others.

Unachukwu (2003) and Oyedepo (2014) posited that energy conservation also serves as the strategy for maximizing energy via systems and procedures so as to reduce energy requirements per unit of output while holding constant or reducing total cost of providing the output from these systems. Energy reduction strategies for building operation must therefore address both energy system controls executed by mechanical and electrical equipment and energy system demands, imposed by building occupants (Kinney and Piette, 2002). The role of energy conservation as a catalyst for sustainable development is realism in the industrialized countries of the world. However, in Nigeria the narrative at the moment is different as huge benefits derivable from adoption of conservation potentials by various institutional sectors remain largely untapped due largely to lack of awareness of the economic and social benefits of energy optimization (Unachukwu,2003).

Oyedepo (2012) refers sustainable energy system as a cost-efficient, reliable, and environmentally friendly system that utilizes local resources effectively. The processes of utilizing energy in higher institutions of learning are prone to wastages and the consequence of such wastage include: environmental degradation, faster depletion of energy resources, and increased cost of energy products and services. The concept of sustainable development therefore dictates that effort must be put in place to enhance energy optimization through effective conservation measures. Thus, this study sets to assess the opportunities of saving in energy consumption in NARICT blocks of buildings.

1.2 Statement of Research Problem

Energy is consumed inefficiently and most of this problem predominantly arises from building technical operation and management (Rana, 2012). The extensive inefficient use of energy has a negative impact on our environment and society at large as it amounts to increase in outdoor and indoor air pollution, greenhouse gas emissions and health related problems. This trend has contributed to increase in global energy demand, along with global warming, and is expected to rise by more than one-third over the next twenty years (International Energy Agency IEA, 2012).

A study of public buildings by Haberl, Lui, Houcek and Athar (2006) found that 50% of energy waste in building have control related problems. It was noted that various policy instruments was introduce since 1970s to support energy efficiency, despite this, the built environment is still laging behind their potential as a result of insufficient knowledge on energy performance and the occurrence of ‘mal performance (under performance) of systems (Oyedipo, 2012).

Furthermore, there are great challenges for professionals to initiate a healthy and comfortable built environment with less energy consumption and reduced negative impact on the environment through supply and demand management techniques, performance and energy matrix practices (Bernadett, 2013.)

There is need for a study that will initiate comprehensive techniques that will address energy consumption problems and proffer several conservation opportunities. Therefore, this research intends to assess energy consumption related problems in NARICT blocks of buildings with a view to addressing energy wastage and leakages.

1.3 Justification of the Study

According to International Energy Agency (IEA 2012) residential, commercial, and public buildings account for 30 to 40 percent of the world’s energy consumption. These sectors contribution to current world carbon dioxide (CO_2) emissions is about 25 to 35 percent. Rapidly growing, specifically in developing countries, the built environment offers the largest, most cost-effective opportunities for energy efficiency, with considerable co-benefits. However, to turn these opportunities into reality, efficient energy management and conservation measures must be properly put into practice through energy audit and effective management schemes (Uduma, 2010).

Kaur (2012) describe that the difference between demand and supply of energy is increasing continuously despite huge outlay of government effort towards it. Furthermore burning of fossil fuel that result to emission of gases are detrimental to the environment and this can be bridged with the help of conserving energy which can be considered as a new source of energy and environment friendly.

Hinge (2004) posited that energy management improvement in building is one of the most cost-effective ways to meet energy challenges. Also Hong, Chou and Bong (2000) observed that substantial energy savings can be achieved through conventional building designed/envelope and careful planning for energy efficiency. As noted by Rana (2012) solving control related problems and proper energy management initiatives will contribute significantly to primary energy savings.

Ensuring sustainability in all aspects of economic, social and environmental development while promoting ecological carrying capacity of the earth require more efficient resource utilization. To address these challenges, there are various approaches and roadmaps, to be adopted (Global Energy Assessment GEA, 2012). Energy efficiency or conservation and management practices are two key approaches to overcome energy challenges.

1.4 Aim and Objectives

1.4.1Aim

The aim of this study is to evaluate energy consumption and conservation opportunities for National Research Institute for Chemical Technology (NARICT) buildings, with a view to enhancing energy use efficiency in the institution.

1.4.2 Objectives

The aim of the study was achieved through the following objectives, to,

i. evaluate the consumption of energy in the blocks of buildings in NARICT

ii. assess conservation opportunities of the Institute's buildings.

iii. identify initiatives for energy efficient utilization for the institute's buildings.

1.4 Scope and Limitations

1.5.1 Scope

There were two common approaches adopted for building energy studies case study and survey. A case study is a research strategy involving in-depth investigation of a particular phenomenon, whereas a survey is systematic approach of collecting data based on a sample. Choosing one over the other is usually a decision resulted from the study objectives. For this study, the survey strategy was adopted because the objective is to have a comprehensive understanding of how energy is consumed and its available opportunities. The study covers all the ten (10) blocks of building within the study area namely Administrative Block, Entrepreneurship Center, Work, Petrol Chemical Laboratories 1,2&3 etc.

Based on the data collected and established benchmarks from literature, the main content of this thesis concentrate on analysis of data analysis to quantify the total building savings opportunities. Two approaches have been demonstrated. One is system monitoring and targeting approach while the other is retrofitting approach. However, the savings opportunities for space cooling system are developed by means of space cooling sub-systems monitoring. Building envelops, mechanical equipment, attitude of the end users and environmental conditions were analyzed by means of these two approach. Consumption of heavy machineries, equipment with higher voltage and staff quarters were left out. Blocks of building are likely to have other energy uses as well, such as diesel used for generator was not considered in the study.

1.5.2 **Limitations**

This study faces certain limitations which include:

i. Constraints of measurements, resources and access to office building have led to a small sample size selected and limited number of buildings.

ii. Information obtained from technical buildings officers may not be absolutely accurate. In addition, information such as area, equipment operation schedule is calculated manually and it is inevitably subjected to a degree of error.

CHAPTER TWO

2.0 LITERATURE REVIEW

Buildings are supposed to be equipped with some services towards meeting regulation requirement. These services include electricity (energy), water supply, waste disposal, safety and security system cabling of computer and telephone, lighting, air conditioning and refrigeration. These needs lead to evolution of a discipline known as “Building services Engineering” in order to address the demand in the building industry. It aim at improving understanding and co-operation among the user, designers, contractors, operative and maintenance staff and other Building industry personals (Sambo, 2008).

However, this chapter focuses on giving a broad idea and understanding on what is energy efficiency and what could be the possible impacts on both buildings and building regulation towards creating a sustainable environment that would last to benefit future generations and raises the awareness on the importance of sustainable building design.

2.1 Concept of Energy Studies in Building

Unachukwu (2003) highlighted that energy study as a systematic review of energy consuming installations in buildings or premises with a view of ensuring that energy is being used sensibly and efficiently. Unachukwu (2003) in his work sees energy study as ‘A study for determine the quantity and cost of each form of energy to a building, process over a given period’. An energy study usually commences through collection and analysis of data that affect the consumption of energy in a building or building premises, the area of inefficiency can be identify through reviewing and analyzing the condition and performance of various building services installations and building management techniques. However, Haberl, Lui, Houcek and David (2006) posited that lowering the consumption of energy in buildings will lead to the chain effect that less reduce fossil fuel to be burnt for electricity generation by the power generating companies and relatively less pollution of greenhouse gases will be emitted into the atmosphere, thus contributing to conserve the environment and to enhance sustainable development. However, Haberl *et al.* (2006) highlighted that the purposes of energy study is to pinpoint opportunities through conservation.

2.1.1 Efficiency of Energy in Buildings

Efficiency utilization of energy means the amount of energy use for heating, cooling, equipments and lighting, required to maintain comfort conditions in a building. Building envelop was found to be one of the factors militating against efficient utilization of energy. This includes all interior and the exterior element of the building such as: fenestration, walls, doors, roof coverings and sub-structure. All these components must work together to keep the building warm in the winter and cool in the summer (Unachukwu, 2003).

The amount of energy consumed by various building component varies depending on their design, fabrication of the systems and how they are operated (Elsadig, 2005). According to Bernadett (2002) posited that heating and space cooling systems consume high amount of energy however to control/reduce the consumption a programmable thermostats and proper energy management systems must put in place as its will reduce the amount of energy use significantly. However, Bernadett (2002) also suggest that some buildings uses zone heating and cooling systems, this enhance the reduction of heating and cooling in unused areas of the building. In commercial buildings, integrated space and water heating systems can provide the best approach to energy-efficient heating (Bernadett, 2002). In public buildings the common fule types used are natural gas and electricity. Thus Elsadig (2005) highlighted that many building can utilize another energy source form locally generated group or district form of energy in form of heat and or power. This can be applicable in big cities, university campus where building structures are sited close to each other and where it has more efficient to have a centralized space cooling or heating system which distribute energy in form of stem/or chilled water to a number of buildings.

Also Unachukwu (2003) observed that efficient energy use includes not only the physical or technical efficiency of equipment and facilities, but also the overall economic efficiency of the system. Rana (2012) idealized that, ‘all changes that result in decreasing the quantity of energy used to produce one unit of domestic activity or to meet the energy requirements for a given level of comfort’ as Energy efficiency measures. Furthermore, initiating energy efficiency measures as part of institutional energy police will cut down emission greenhouse gas from utilities since every kW/h of electricity consumed or saved is equivalent to the emission (or avoidance of the emission) of 0.44kg CO_2 (Elsadig, 2005). However, Energy efficiency programs designed and implemented as part of the overall institutional developmental policy strategy will reduce energy bills as well as enhance environmental performance (Elsadig, 2005). Etiosa (2009) highlighted that efficient energy has become the key driver to sustainable development in many economies in the world. Improving energy efficiency, i.e. obtaining more final energy services from less energy is the surest and most direct way of increasing sustainability of the use of energy resources and decreasing the negative aspects(environmental pollution) and financial costs associated with using energy and producing goods. The economic potential of even more efficient use energy will continue to grow with new technologies and with cost reduction resulting from the economy of scale (Oyedepo, 2012).

Oyedepo (2012) reported that, energy utilization in Nigeria is far from being efficient, inefficient use this energy has three major implications. These are:

a) The investment in some energy supply infrastructure is far in excess of what the energy demand

b) The environmental problems associated with energy utilization are more aggravated due to large energy consumption

c) Excessive consumption of energy will adds to the costs of goods and produced especially in energy intensive industries like cement, steel works and refineries.

With good energy management at the residential, private and public sector, there will be no need to alternate electricity supply therefore Increased energy efficiency would provide this country with significant economic, environmental, and security benefits.

2.1.2 Factors that Promote Energy Efficiency in Building

Akinbami (2013) in his work pointed out that solar architecture, solar passive systems, active systems (BIPV, energy saving bulbs, solar fridges, solar water pumping, solar fan, etc), and attitude of occupants in such buildings are factors responsible for energy efficiency in buildings. Efficient Energy in buildings are mostly achieved through bioclimatic architecture, high performance building envelope, and controlled ventilation.

i Solar Architecture/Solar Passive Systems

According to Akinbami (2013) define Solar architecture has the integrating modern building techniques with integrated photovoltaic to achieve thermal comfort within the building and reduce energy cost. Materials needed for solar architecture are those that will lead to either thermal cooling or reduction of peak cooling power demands for a building (Chwieduk, 2004). Solar passive systems is designed to make a building itself to either gain as much solar energy as possible or to lose heat depending on the season and prevailing climatic condition. Solar passive architecture enables buildings to utilize the energy of the sun for its needs without employing active devices such as BIPV, solar fans or solar water heater. To achieve this, such buildings usually incorporate materials with high thermal mass that will retain heat effectively and good insulation to prevent heat loss. Also a low surface area to volume ratio is ensured to minimize heat loss in such buildings. The indoor thermal comfort can also be improved through "passive cooling". Santamouris and Asimoukopols (1996) and Givoni (1994) in their work observed that preventive, modulation, and heat dissipation can be describe as passive cooling techniques. Furthermore, ventilation, infiltration, courtyard, wind tower, air vents and earth shelter are describe as direct cooling while indirect cooling is achived through evaporative cooling, shading, etc (Tiwari, 2006). However, Crosbie (1998) stated in his work that sun charts are used to determine shading devices of the building pattern such as wing walls and overhangs in which angular sun charts and overhangs are entered on the same plot. According to CIBSE(20204), noted that roofing, ventilation, natural lighting, window materials, building shape and orientation, colour of the wall, and trees and shrubs are classify as passive features that enhance energy efficiency in building. Proper passive design will enhance the energy balance of the exterior and interior impression of an observer (Balcomb, 1992). Bioclimatic architecture combines the use of climatic and environmental conditions to achieve visual and thermal comfort in buildings. This is achived through; proper orientation and building shapes, passive solar systems, and solar protections (Tiwari, 2006). High performance building envelope is achieved through; proper insulation, elimination of thermal bridges, through air- tight construction, and use of high performance glazing and windows. Controlled ventilation can be achieved through proper mechanical insulation and heat recovery.

ii Active Systems

Active systems refer to those energy efficient man-made appliances which are either consumed by occupants or integrated into the building envelope (Sambo, 2008). Energy efficient products do more work with less energy. Some of these products include BIPV, energy saving bulbs, solar fridges, solar water pumping, solar fan, and solar watches. According to DanShehu, Asere, and Sambo (2006) Building integrated photovoltaic is the integration of solar cell panels on roof tops, skylights or facades. BIPV is one of the fastest growing industry in solar photovoltaic because the amount of money that could have been spent on building materials and labour in constructing part of the building which the BIPV module will replace is enough to offset the initial cost. Also PV systems have energy payback time of less than 1 year (for thin film solar cells) and typically 3-4 years for silicon based solar cells (Nwofe,2013). Energy saving bulbs, solar fan and solar fridges has been proved to be more energy efficient than the conventional types.

iii Attitude of Occupants in Buildings

In Nigeria, there is wide ignorance on use of/switching off bulbs. The awareness on energy saving bulbs is limited to people in the urban areas while most rural areas are still using conventional bulbs. Also the price of the energy saving bulbs is still high. Nwofe (2013) shown that turning lights off when not in use would save a gigantic sum of £55m and 375000 tons of carbon (iv) oxide thereby preserving the environment and reducing energy cost simultaneously.

2.1.3 Impact of Non-Energy Efficient Buildings

i Human Comfort and Economy

Buildings that are not energy efficient require more mechanical/electrical devices to achieve thermal cooling in tropical areas and thermal heating for cold regions. These devices require enormous energy input and also generate green house gases. Also the cost of these devices are very exorbitant and not many people can afford it. The comfort of people in such buildings is in jeopardy. Due to the epileptic nature of power supply by the Power Holding Company of Nigeria (PHCN), most people rely on gasoline generators for power. This causes irritating noise and also increases the volume of GHGs within the vicinity. This not only lead to increase in global warming but also affect the economy through increased air-pollution related diseases. This has been highlighted in the literature (Abayomi and Bukola, 2012)

ii Environment, Global Warming and Climate Change

Human activities affect the environment in many ways. Global warming due to GHGs is an inevitable concept because of some natural phenomena such as; photosynthesis, respiration, pollution, deforestation, and production of animals for food (Abimaje and Akingbohungbe, 2013). The impact of global warming has manifested in; sea level rise and coastal flooding, longer and more damaging wildlife seasons, more frequent and intense heat wave, costly and growing health impacts, increase in extreme weather events, heavier precipitation and flooding, more severe draughts, changing seasons, melting ice, disruptions to food supplies, destruction of coral reefs, plants and animal range shifts, and the potential for abrupt climate change (Vanguard, 2014). In Nigeria, flooding was witnessed at a very large scale last year, leading to serious food shortage especially to cassava farmers. Energy efficient buildings will play a significant role in reducing these GHGs and by extension, these negative impacts (Abimaje and Akingbohungbe, 2013.,Adeaga and Olaoye, 2013) .

2.2 Methods adopted for Effective Energy Management Systems in Buildings

2.2.1Energy Targeting and Monitoring

Monitoring and targeting are management technique that uses energy information as a basis for the elimination of waste, control the level of energy use and improve on the existing operating procedures. According to Mahmoud, Muhammed and Hosen (2009) ideology "you can't manage what you don't measure". This essentially combines the principles of energy use and statistics.

Energy monitoring is essentially aimed at knowing the existing pattern of energy consumption, while targeting is the identifying the consumption level which is desirable as management goal towards conservation of energy (Mahmoud *et al*., 2009).

Furthermore these techniques can also be seen as a management technique where all plant and building utilities such as fuel, steam, refrigerator, compressed air, water, effluent, and electricity are managed as controllable resources in the same way that raw materials, finished product inventory, building occupancy, personnel and capital are managed. These involve a systematic, division of the facility into Energy Cost Centers, the utilities used in each center are closely monitored, and compared with production volume or any other suitable measure of operation. Once this information is available on a regular basis, targets can be set, variances can be spotted and interpreted, and remedial actions can be taken and implemented.

According to Mahmoud *et al*., (2009)annual energy cost of 5 to 20 percent reduction can be achieve through effective targeting and monitoring programs in various industrial sectors.

2.2.2 Energy Auditing of Buildings

An energy audit can be define as a approach that review how energy consuming installations in a building or premises are being use sensibly and efficiently (Unachukwu, 2003). Dan-Shehu (2006) define energy audit as an essential activity for any organization that control energy and utility cost. However, audit also provides information on how energy is purchased, managed and used with the aim of identifying opportunities for cost savings. According to Wah (2001) sees energy audit is a feasibility study that identifies energy use among the various services and opportunities for energy conservation, it also produce data on which supply and demand are measured, managed and evaluated. An energy audit usually commence through collection and analysis of all information that may affect the consumption of energy in the building or premises, then followed by reviewing the condition and performance of various building services installations and management (Sambo, 2008). This is aimed at identifying areas of inefficiency and suggesting means for improvement.

However, building owners can get the immediate benefits for paying less energy bills by minimizing of energy consumption in buildings and this will result to a chain effect that less fossil fuel will be burnt for the generation of electricity by the power supply companies (Nesse, 2011). Relatively less pollution of and greenhouse gases will be introduced into the atmosphere, thus contribute to environmental sustainable development.

According to Oyedepo (2012), energy audit can also seem as a concept, scope and extent to which investigations should be conducted, and which findings should be analyzed for energy efficiency and conservation improvement. In general, these may range from a simple walk- through survey at one end to that that may span several phases. The phases include a simple walk-through survey, monitoring of energy use and model analysis using simulation soft ware (Oyedepo, 2014). The complexity of energy audit is therefore directly related to the stages of the energy system, management program and the cost of the exercise.

(i) Walk-through audit: These are the simplest type of energy audit that requires minimum resource deployment to simply check for Energy Management Opportunities (EMOs) that are readily identifiable and to implement them to achieve savings (Unachuku, 2010). The audit can be conducted by walking through the building and concentrating on the major energy consuming equipment and systems, with EMOs easily identified such as over-cooled spaces and energy inefficient lamps being used.

(ii) Detailed audit: this form of audit requires adequate funding and staffing which result in more EMOs identifications and comprehensive analysis of their viabilities. All major equipment/systems are checked with systematic analysis for identification of the EMOs as many as possible (Akinbami, 2003). A typical detailed energy audit includes the following;

(a) Collection of building information: Collect information including general characteristics of the building, technical characteristics of the equipments/systems, their design and O&M records, energy consumption details and past electricity bills, maintenance and refurbishment works schedule etc.

(b) Preliminary analysis: Analyze the characteristics of energy consuming elements and compare the operational information against the design or corresponding general engineering practices, in preparation of subsequent audit activities etc.

(c) Facility inspection and measurement: Go ahead on site inspections and necessary measurements to supplement or verify the information collected and the analysis made. Close co-ordination with the O&M personnel will be important to obtain a full picture of the system operations and maintenance.

(d) Identification of EMO: Screening and spotting the parameters with values and trends that deviate from what would be anticipated or required respectively. Taking into account possible changes in operational characteristics of the systems in the building occupation stages, and identify the potential EMOs.

2.2.3 Energy Benchmarking Method

Chung, Hui and Lam(2006) describe energy benchmarking as a tool for enhancing the efficient use of energy in office buildings. Also Bloyd, Mixion and Sharp (1999) in his work shows that "benchmarking can be viewed as the first step in understanding and setting goals for energy efficiency improvements in buildings". Energy-efficiency benchmarking can be see as a tool used for monitoring changes in energy use,it also served as a bases for the design and retrofit in the budgeting for efficient energy use in efficient buildings (Lee, 1998 and 2004). However, energy benchmarking approach enable building owners understand the performance of their buildings compared to similar buildings. Filippin (2000) in his work used a sample of energy consumption data and the floor area to calculate the Energy Use Intensity (EUI), for school buildings in central Argentina. The calculated EUIs were then ranked as a benchmark table and often used for judging the energy-use performance of a commercial building (Kinney and Piette, 2002). Therefore energy saving potential by the method of benchmark can be classified as whole building metered approach or retrofit isolation approach.

i Whole Building Metered Approach

The whole building metered approach uses a main meter to measure the energy flow to the whole building (ASHRAE Guideline 14, 2002). Energy flow is usually electric, gas oil and thermal. These approaches involve the use of monthly utility bill data or data gathered more frequently from a main meter.

The “whole building metered” approach, also called “main meter” approach encompasses procedures that verify the performance of the retrofits for those projects where the whole building pre- and post-retrofit data are available to determine the savings. Utility billing data (usually monthly data) are the basis of data analysis. Continuous measurements of the whole-building energy use before the retrofit and after the retrofit on a more detailed measurement level (weekly, daily or hourly) are also required(APEC, 2001). Consumption and demand values taken from sub-Meters are acceptable for use under the whole building approach, where the meter measures energy use of a significant portion of the building area or a group of subsystems (e.g., motor control center). The data will have to meet all the requirements for a utility meter. Sub-meters are particularly useful in multiple building sites served by one utility meter (Energy Star, 2004). .

It is most appropriate to use a whole building metered approach when the total building energy performance is to be assessed, rather than the performance of specific retrofit

(Energy Star, 2004). According to Cui (2006) there are two paths for the whole building approach with the respective criteria and requirements for its applicability, namely, the whole building prescriptive path and the whole building performance path**.** The former one is most appropriate when the expected savings are greater than 10% of the measured energy use or demand and when the data are continuous and complete with no data points to be excluded, and are expected to remain this way in the post-retrofit period. Cui (2006) revel that Methodology and Calculation of whole Metered Approach can be achieved through

I. Collect data on the energy use or demand to develop the energy-efficiency indicators and conduct the benchmarking exercise; it is used as the dependent variable;

II. Collect data of the building physical and system parameters as the independent variable(s); these variables are selected based on two criteria:

They were considered as the more influential parameters affecting electricity use. In addition, Sharp (1998) i highlighted that the simple normalized EUI was not good enough for a credible energy-consumption performance rating. However, to determine the effect and factors that affect energy consumption, benchmarks were developed using a multivariate linear-regression approach to correlate other factors representing some important characteristics of buildings with EUI. Sharp’s method has been used in the Asia-Pacific Economic Cooperation Energy Benchmark System(APEC, 2005) and slightly modified as the basis of the Energy Star benchmark(Energy Star, 2004).

ii Retrofit isolation Approach

The retrofit isolation approach uses meters to isolate the energy use and/or demand of the building system/subsystems (e.g. lighting, chiller, boiler) affected by the ECM from that of the rest of the facility (ASHRAE Guideline 14, 2002).These measurements may be made once before and once after the retrofit, periodically, or continuously. Savings derived from isolated and metered systems may be used as a basis for determining savings in similar but unmetered systems within the same facility providing they are subjected to similar operating conditions throughout the baseline and post-retrofit periods. Building energy savings needs to be estimated roughly before retrofitting. The way of using simple census division averages of similar buildings as benchmarks had been investigated as a useful method to quantify the saving potential (Sharp, 1996). Furthermore, building energy saving potential can be taken as the difference between individual building EUIs and averages of similar buildings in the same climate region as a whole building level and the building system energy saving potential can be taken as the differences between individual building system EUIs and the corresponding break-down system averages separately.

According to Cui (2006) retrofit isolation approach is intended for retrofits where the end-use capacity, demand or power level can be measured or the energy use of the equipment or subsystem can be measured for a short-term period or continuously over time during the baseline period. It can also measure energy end-use affected by the retrofit or measurements for a limited period of time necessary to determine retrofit savings. In most cases, energy used is calculated by developing statistically representative analysis of the energy end-use system/subsystem capacity (e.g., the kW or Btu/h) and use (e.g., the kW or Btu/h).

Lee (2004) highlighted that using established benchmarking curves, the total energy saving potential of a building can be calculated using the total/landlord/tenant energy performance benchmarking curves. A performance target may be set for a short or long term performance of the building. If services systems' energy data are available, the savings achievable from each of the systems in a building can also be determined using system benchmarking curves. Once the saving potential in systems are established, a building's owner can prioritize energy retrofitting project according to the extent of savings each system can achieve, and the return of investment can be calculated.

2.3 Energy Conservation in Various Sectors in Nigeria

The need for energy is increasing and outstripping its supply in Nigeria. Therefore, and in view of these circumstances, primary energy conservation, rationalization, and efficient use are an immediate need (Oyeepo, 2014). Getting all the possible energy from the fuel into the working fluid is the goal of efficient equipment operations. This not only saves money and produces higher productivity, but also influences the safety and life of the equipment and reduces pollution (Sambo, 2008). Steps taken to minimize energy consumption, or to use the energy more effectively, are steps in the right direction to preserve the global environment. Energy conservation measures or recommendations are often referred to more positively as opportunities. There are two primary criteria for energy conservation opportunities: that it should be easy to implement and that its payback be short. Ease of implementation and payback period have been used to classify energy conservation opportunities into three general categories: maintenance and operation measures, process improvement projects, and large capital projects (Adeyemo and Odukwe, 2008). Although energy conservation and efficiency are not resource per se, it is acknowledged that their adoption in the country can significantly mitigate the supply challenge. It is in recognition of this that the Federal Government of Nigeria recently approved the establishment of a National Centre for Energy Efficiency and Conservation (Sambo, 2008). The Center is charged with the responsibility for organizing and conducting research and development in energy efficiency and conservation. In this regard, the Center is to carry out the following functions:

i. Develop guidelines for energy-efficient end-use products and advise on their implementation;
ii. Develop energy efficiency codes, standards, and specifications for domestic, industrial, and commercial facilities;
iii. Gather, analyze, and manage energy supply and consumption data and information;
iv. Serve as a Center for training of high-level manpower in energy efficiency and conservation;
v. Develop and execute pilot/demonstration project highlighting energy efficiency concepts;
vi. Disseminate information on energy efficiency and conservation concepts through public awareness programs such as seminars, workshops, publications,etc.; and
vii. Perform any other functions, as may be directed by the Federal Government in relation to energy efficiency and conservation in Nigeria.

2.3.1 Concept of Energy Conservation in Institutional Buildings

Conserving energy is ‘‘an attempt to reduce the amount of energy used for domestic and industrial purposes’’ (UNIDO, 2006). Also it has been described as using energy more efficiently through behavioral change, improved management, or the introduction of new technology (UNIDO, 2006). However, Unachukwu (2003) in his work sees Energy conservation as “the strategy for adjusting and optimizing energy using systems and procedures so as to reduce energy requirements per unit of output (or well-being) while holding constant or reducing total costs of providing the output from these systems”. Lee (1993) in his work made use of computer simulation to analyze energy performance of the various energy conservation measures with respect to the design of commercial buildings. The design refers to the building shape, size, texture, lighting level etc. The results revel that there was a possibility of 40% energy reduction through combination of design improvements. Thus it is important to include energy efficiency as criteria during the design stage. According to Unachukwu (2010) various energy saving measures or methods applicable to commercials building includes reducing lighting power of buildings, make use of day lighting to supplement artificial lighting and others, which are effective and yet will not affect the occupants’ thermal comfort.

However, Cui (2006) also focused on the use energy in air-conditioning system. This covered various type of air-cooling system available in markets and ways to conserve its energy. However he also highlighted the benefits of using BAS in conserving energy for air-cooling system. Nwofe (2013) focused on the lighting control techniques has a means which could help in saving energy. Thus Lighting fixtures dose not only consume energy but also generates heats in the building there by adding to cooling loads of the air conditioning system. Nwofe (2013) proposed two methods such as shorten the operation time through the application of lighting control and the introduction of infra-red occupancy sensor respectively. Through these methods, 84% to 50% energy saving were achieve respectively. Furthermore, Malgwi and Musa (2014) study the relationship between Indoor Air Quality, Energy Consumption and Ventilation. In order to achieve a good indoor air quality with efficient energy usage, the movement of the air has to be controlled within a space through ventilation and the result reveal a direct relationship between the ventilation and energy consumption. What it means is, when there is an increase in ventilation rate in a room, there would be an increase in energy consumption because more energy is required to cool down the warm ventilated air. Also Wong (2001) pointed out various factors that affect the performance of energy use in buildings. This were achieved through the comparison made on the Energy Efficiency Index (EEI) in areas like tenancy characteristics, building design, service design and management of energy usage. Wong (2001) observed that the higher the EEI, the more energy is consumed per unit area.

Oyedepo (2012) sees energy conservation as a tangible resource that competes economically with contemporary energy supply options and offers a practical means of achieving four (4) goals. Thus he observed that economic competitiveness, utilization of scarce capital for development, environmental quality, and energy security are goals that should be of high priority to any organization. Furthermore, Oyedepo (2012) also highlighted in Figure 2.1 that energy conservation is a key driver for sustainable development in many economies with a tangible resource by itself that competes economically with contemporary energy supply options. Many conservation and efficiency improvement programs have been and are being developed to reduce the present levels of energy consumption. To implement these programs in a beneficial manner, an understanding is required of the patterns of "energy carrier" consumption, such as the type of energy carrier used, factors that influence consumption, and types of end-uses (Dincer and Zamfirescu, 2011). The significant and potential benefits of conservation energy programs to the economy are proven successes in several countries, but in Nigeria conservation programs have not yet been undertaken to a significant scale (Oyedepo, 2012). The under list factors are reasons that lead to lack of conservation programs:

I. Technical (e.g., lack of availability, reliability, and knowledge of efficient technologies)
II. Institutional (e.g., lack of appropriate technical input, financial support, and proper program design and monitoring expertise)
III. Financial (e.g., lack of explicit financing mechanisms)
IV. Managerial (e.g., inappropriate program management practices and staff training)

The difference between supply and consumption of energy can be bridged with the help of conservation which may be considered as a new source of energy which is benign and environment friendly (Oyedepo, 2012). However, energy conservation is cost effective with a short payback period and modest investment. Conservation of energy enhances international competitiveness of industry in world markets by reducing the production cost of energy consuming systems and appliances. It optimizes use of capital resources by directing lesser amounts of money in conservation investment as against capital-intensive energy supply options (Unachuku, 2010). It protects the environment in the short run by reducing pollution and in the long run by reducing the scope of global climate change. It strengthens security of supply through lesser demand and lesser dependence on petroleum products imports. No energy supply option may be able to provide all these benefits. Energy conservation is a decentralized issue that largely dependent on individual, unlike supply of energy which are highly centralized. The housewife, driver, developer, client, industrial operators, and every other individual who consumes energy in some form or the other are required to participate in energy saving measures. These calls for a collective effort of professional in various field to motivate people on the important of energy conservation (Akibami, 2003).

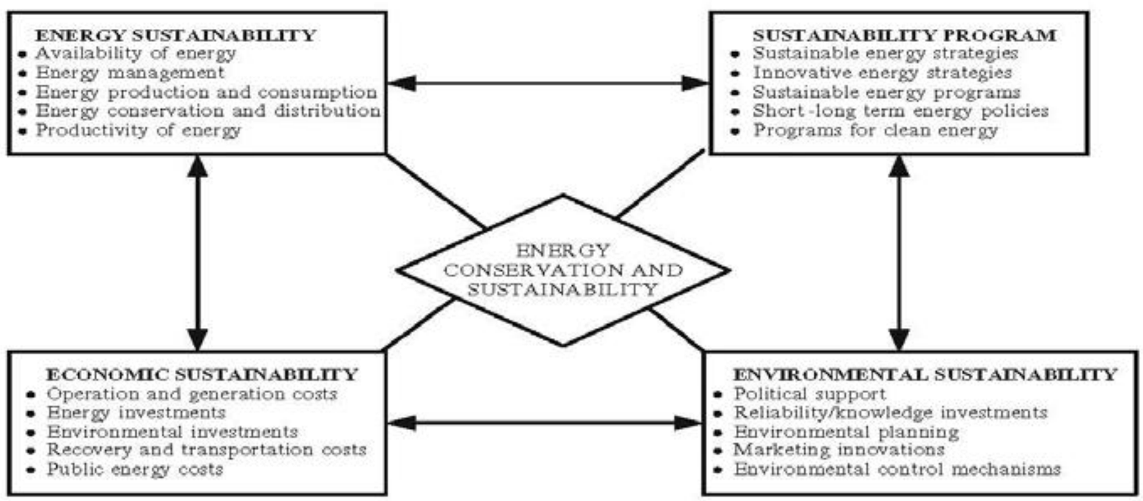

Figure 2.1:Linkages between energy conservation and sustainable development

Source: (Oyedepo, 2012)

2.3.2 Energy Conservation Opportunities in Buildings:

According to Dan-Shehu *et al.*, (2006), postulate that saving opportunities exist if the building envelope and materials were adequately considered to allow for a longer time period for day lighting, and maximum indoor space cooling, this would reduce the time needed for electrical energy for both lighting and cooling devices. Consequently, this will promote energy conservation. Apart from the building envelope, it has been established from past literature that saving opportunities also exist form lighting and cooling devices systems. Ajibola (2001) observed that weather condition of Nigeria definitely makes space cooling an essential energy service. This is provided by resistance regulator fans and air conditioning system. Resistance regulator Fans have a much higher market share than air conditioning system in Nigerian due to their lower investment costs and lower electricity consumption. However, if energy efficient lighting fixtures such as the CFL and cooling devices such as resistance regulator fans (RRF) and air conditioning systems were promoted in the country, these would lead to high saving for electric lighting and cooling energy (Ajibola, 2001). Putting all these energy savings opportunities together, it is estimated that at least 10% of total electrical energy consumed will be conserved (Tang, 2012). Based on the study form two refineries, two cement plants, one steel plant and furniture manufacturing plant revel that about 25% of energy used in these industries can be saved through good housekeeping measures (Oyedepo, 2014). It is assumed that about 10% of both total industrial and commercial sectors' electricity demand could be saved. Ultimately, these would amount to a reduction in gases emissions within the country (Oyedepo, 2014). According to Ajibola (2001) observed that Nigeria climate cannot be regard as strictly homogeneously warm/humid even though it lies within the latitude of 5^0 to 16^0N. However, he concluded that paucity of climate data and lack of energy conscious building designs are pressing issues many organization are not taken into consideration.

2.3.3 Energy Conservation Measure in Office

According to Karem, Kat and John (2010) measures that enhance conservation in residential and public buildings include:

1. Adequate building orientation and symmetry. Building design should permit most of the spaces to be day lighted. Using day lighting reduces energy consumption by replacing electric lights with natural light. Buildings designed for day lighting typically use 40-60% less electricity for lighting needs than do conventional buildings.

2. Provision of enough windows for cross ventilation. In very hot climates ventilation is very important. This will go a long way in reducing the use of air conditioners at homes and offices (Karem *et al*.2010). Although artificial lighting are free and readily accessible, however, their use without causing glare and overheating can be difficult. However from this source of light can be avoided through the use of window sills, louvers, reflective blinds and other devices that reflect light deep into the buildings. Thus fenestration with selective glazing that transmits the most visible light while reducing solar heat should be favoured and considerable saving potentials for energy in Nigerian office and residential buildings is possible through cost effective building design (Oyedepo, 2012).

i Building Envelope

The design of a building has a big influence on the energy balance. The different capabilities of the building envelope to store heat in the walls, roof or floor has a significant effect on the heating and cooling energy demand (Chung, 2006). However, for buildings which are only heated, the heat transmission factors for the different outdoor parts like outer walls, windows, roof and floor construction are enough to consider, the heat storage capacity of the different parts have to be taken into account. Thus these factors influence the cooling of the building during the night, and possibility of storing and using solar heat gain and losses during the night (ASHRAE, 2002). However, the effects on the indoor climate in the summer will highly be influenced by the storage capacity of the building. It is often possible to avoid an air conditioning system, simply by changing the construction materials of the building. The shape and orientation of a building are also influencing factors on the energy consumption (Oyedepo, 2012). However, the ratio between the volume and the outdoor surface, especially, determines the energy demand of building. For large buildings this relation can be overlapped by the bigger lighting and cooling energy demand for interior rooms; windows and solar shading have an additional impact.

ii Lighting Fixtures

The fast development of lighting technology often makes existing installations lagging behind the cutting edge. On the other hand, this offers great energy saving opportunities as presented in Table 2.1 in line with ASHRAE standard especially for buildings with intensive lighting provision. Kirk (1995), Khemiri and Hassaini (2005) identify that lighting fixtures in Forte Crest hotel in the UK were reduced by 45 per cent through regular lamp replacement. Besides, the reduction in lighting energy consumption would bring about substantial decrease of amount energy use for cooling and ventilation. Therefore, more opportunities in terms of cost saving could be reaped, and this would result in a very favorable payback period of less than one year.

Conservation measures through lighting in offices, homes, commercial centers and industries in Nigeria include:

a. Re-lamping: Re-lamping means substituting an obsolete lamp with another of high performance so as to save energy (Yukio, Tomohisa and Nishi, 2010) . New fixtures are available which produces superior energy savings, reliability and longevity compared with incandescent lamps. Compact Fluorescent Lamps (CFLs) are generally considered best for replacement of lower incandescent lamps at homes, offices, commercial and industrial outfits (Yukio *et al*. 2010). These lamps have efficacy ranging from 55-65 lumens Watt. The average rated lamp life is 10.000 h, which is 10 times longer than that of a normal incandescent. They offer excellent colour rendering properties in addition to the very high luminous efficiency. Also, they offer energy savings potential;

b. Lighting control sensor: Lighting control sensor are devices for turning lights on and off or for dimming them. This is to avoid wastage in some area such as bathroom, stores, bedrooms and other less buzzes area. Thus the following types of sensor should be available: photocells, timers, occupancy sensors and dimmers (Unachuku, 2010).

c. Security light: The control security lighting will accounts for more than 50% reduction of all electricity consumed in institutional buildings. However, form existing literature it was observed that about 50% or more waste of energy recoded were as a result of obsolete equipment, inadequate maintenance, or inefficient use of the system or appliances. To achieve effective Savings opportunities there are a need to reducing electricity consumed by the light source or reducing the length of time (Unachuku, 2010).

Table: 2.1 Lighting Power Density Using Space by Space by ANSI/ASHRAE Standard 90.1-2007

Common space type	Average light power density specified in ASHRAE standard (w/m^2)
Office- enclosed	12
Conference/meeting/Multipurpose	13
Classroom/lecture/Training	13
Laboratory	15
Workshop	15

iii Daylight Performance

The daylight performance is composed of several aspects. Building components that transmit sunlight provide building with daylight. A reasonable daylight level is desired by the occupant and saved energy for artificial lighting (Rana, 2012). The transmitted sunlight may also cause problem with glare from surfaces with high illumination levels. Building components providing building with daylight also often provide visual contact with the outdoor environment. Daylight in buildings influences the energy use for artificial lighting and thereby influences the operational cost (Sambo 2008). Part of the daylight performance associated with the distribution of daylight in the room and glare influences the comfort of the occupants. The discomforts from daylight influence the productivity. However daylight levels are often evaluated based on daylight factors, daylight factor is the fraction of the illumination on a surface in the room and the horizontal luminance outside the building. Occupant in a building wish a certain level of daylight and it is recommended that the daylight factor averaged over the floor area in the work plane is above 2% to assure a reasonable level of daylight (Christoffersen et al., 1999). Evaluating Discomfort glare can be achieved through several approaches. The British glare index on glare sensation function that describes the glare sensation from a single glare sources. The American visual comfort probability (VCP) is the probability that an observer considers a visual environment comfortable for performing a task. Guillemin et. al, (2012) in his work developed a lighting controller for both artificial and natural lighting in order to get the integrated approach for the desired illuminance level. However, he split the shading device controller into parts in relation to the user presence i.e When the user is present, preference is given to visual comfort, and when he is absent, priority is given to thermal aspects (heating/cooling energy saving). Result from further study reveal that desired illumination can be achieved based on user preferences, irrespective of the existence of external light sources (Chatterton and Wilson, 2012)

iv Heating and Ventilation System

The influence of energy consumption design is driven by: the type of the conditioning system (e.g. heating-, cooling-, air conditioning); type of system (air conditioning system with water and air or only with water); heat recovery system and energy transfer within the building; lighting system and the general appliances. These influence the household energy balance and cannot disassociated one from other. Therefore its essential to look at these parameters at a very early stage of planning a building (Darnton, 2008).

v Behavioral Opportunities for Energy Savings in Office Buildings

Darnton (2008) evaluates over sixty models of behavior and theories with a comprehensive review of potential initiatve for behavior change relating to environmental matters. However no single model was perfect, each contributes to a broader understanding of what it takes to bring about new (desirable) behavior. However, Intervention mapping (IM) as a process toward achieving a desired change is found via action plan, and continuous evaluation towards achieving the objective(s) of the intervention. Kok, Lo, Peters, and Ruiter (2011) argue that applying existing systematic approaches like intervention Mapping to energy related behavior change will more effectively address the "personal, social, and economic barriers to performing desirable behaviors" and yield behavior change. Furthermore, Steg and Vlek (2009) in their work suggest that "effectiveness of behavioral interventions generally increases when they are aimed at important antecedents of the relevant behavior and at removing barriers for change. However, Chatterton and Wilson (2012) in their work argue that interventions "need to be targeted in different ways for different groups" of people Intervention Mapping begins with a needs assessment, then moves on to identifying program objectives, methods and applications, program development, planning for program implementation, and planning for evaluation. Furthermore, Kok*et al.* (2011) posited that lasting behavior change will occur when there are Strong positive intentions, No environmental constraints, and employees possess the necessary skills to enact the change. Kok*et al*.(2011) also cite the advantage of there being "general organizational determinants (e.g. general trust in management), pro environmental policies, pro environmental management, and physical facilitation of pro environmental behavior (e.g. placing easily accessible recycling bins)". However, Nesse, Baechler, Roberts, and McDermott (2011) went further by stating that individual motivation will reduce consumption of energy in office buildings "is perhaps the most complex, requiring engagement in not only information, but translation of abstract data into meaningful information for people to use as tools that may help them to make a meaningful impact" Despite the fact that "occupant behavior is a major determinant for energy consumed in buildings, energy savings potential due to behavior are usually neglected, albeit being referred to as significant as those from technological solutions". In the work of Lopes, Antunes and Martins (2012) suggested that, focusing on energy efficient technologies alone without behavior change will likely fail in reducing overall energy use. In the work of Attari, DeKay, Davidson, and Bruin (2011) its was opined that failure to implement behavior change measures that reduce energy consumption is not unique to office buildings but rather can also be observed in households, a setting where people have an even greater (financial) incentive to adopt such measures. In the work of Bonini and Gorner (2011) result show that despite the potential value offered by sustainable organizational practices for energy reduction measures, most organizations do not actively pursue these strategies and therefore miss an opportunity to reduce costs while also addressing climate change. Opportunities for energy savings through behavior change will vary based on climate and the building size.

vi Indoor Environment Performance

The indoor environment influences the well-being and the health of its occupant, it significantly influences rate of respiration deceases, sick building symptoms and productivity. Worker salaries exceed building energy, maintenance and construction costs by a large factor and the cost-effectiveness of improvements indoor environment will be high even for small improvement in health and productivity (Chatterton and Wilson, 2012). With existing technology it is possible to improve the indoor environment and increase health and productivity. It has been claimed that improved indoor environment may increase productivity by 5% to 15% (Lorch and Abdou 1994). Investigation reveals a link between indoor environment and productivity and there is still no correlation associating factors of the indoor environment to change in productivity and cost.

Including productivity in the life cycle cost calculation would be very uncertain and would have a huge impact on the life cycle cost because the energy, maintenance and construction cost for building are much lower than the worker salaries. A number of recommendation exist that may be used to identify aspects of the building design that influences the indoor environment. Thermal comfort may be evaluated under different condition (ISO,1999; ASHRAE, 1992) and quality classes for indoor environment have been suggested (CEN, 1998). The standards as presented in table 2.3 suggest a limit on the number of hours during the year where discomfort as a result of the thermal indoor environment is allowed. For a normal office building, indoor temperature above 26^{o}C lead to thermal discomfort and the suggested performance requirement state that the indoor temperature should not exceed 26^{o}C for more than 10 hours and 27^{o}C for more than 25 hours during the year.

Table 2.2 Acceptable Operation Temperature Range Based on Comfort Zone Diagram in ASHRAE Standard

Condition	Acceptable Operation Temperature(^{o}C)
Summer	
Relative Humidity 30%	24.5 - 28
Relative Humidity 60%	23 - 25.5
Winter	
Relative Humidity 30%	20.5 – 25.5
Relative Humidity 60%	20 – 40

Source: National Research Council of Indoor Air Quality and Thermal Comfort in Office (2005)

2.4 Barriers to Energy Conservation in Buildings

Akibami,(2013) and Etiosa, Jason Muyiwa and Benoit, (2010) identify the following barriers as several factors that act as obstacles to the full realization of energy-saving opportunities in the nation’s buildings sector.

2.4.1 Manpower and Technical Know-How

There is a limited and inadequate human resource capacity to carry out energy audit studies and projects in general, and to design energy efficient buildings in particular, in Nigeria. Energy engineers are rather few in the country. Coupled with this is the fact that few professionals in the building sector have training on energy-efficient building designs. These may have been borne out of a sense of non-need for such skilled manpower due to a long persistent culture of inappropriate energy pricing in the country Akibami, (2013). However, the era of low energy pricing is gradually fading away. Provision of the required skilled manpower entails specialized training which most Nigerian tertiary institutions are not providing presently. Consequently, it is necessary to review the educational curricula in tertiary institutions to close this gap. There is a general dearth of skilled manpower and adequate technical know-how on how to carry out technical energy conservation measures in the country (Etiosa et al. 2010).

2.4.2 Lack of Legislation

A lack of legislation may imply non-availability of standards, or where such standards exist, non-compliance may result from lack of enforcement. These issues expose the Nigerian Energy Market (NEM), and hence the consumers, to sub-standard technologies which are likely to be energy inefficient and may have even been outlawed in their country of manufacture. Both non-availability of standards and lack of enforcement of standards, where they exist, discourage local manufacturers of energy technologies from investing in improving the efficiency of their products (Nwofe, 2013).

2.4.3 Policy Barrier

The lack of clear policy framework and regulations to introduce and mandate legal energy efficiency requirements is a key barrier to the development of energy efficiency in Nigeria (Etiosa, Jason Muyiwa and Benoit, 2010). Policy and legislation are two elements that can help to change human behavior as well as sending the right signals and drivers for market transformation. According to Etiosa *et al*.(2010) the absence of energy efficiency policy in Nigeria is due to the lack of understanding of Nigerian policy makers and other stakeholders of the potential for reducing energy demand through energy efficiency at the end-use sector. So there is little or no interest to develop relevant policies to transform the markets to become energy efficiency compliance.

2.4.4 Information Barrier

The concept of energy efficiency is poorly understood and developed in Nigeria even among policymakers and legislators (Etiosa *et al*. 2010). Awareness creation will go a long way to help people understand the concept and change their behavior. Little information is available at the governmental level on the potential impact and cost effectiveness of energy efficiency regulation (Etiosa *et al*. 2010). End users lack information about the availability of energy efficient equipments and the cost effectiveness of investing in efficient appliances. This poor perception of energy efficiency measures is further exacerbated by the proliferation of expensive and inferior counterfeit imports with no standards nor labels.

2.5.5 Institutional Barrier

There is lack of capacity in government ministries and institutions on how to specifically proceed the implement and enforcement of energy efficiency regulations, and how to develop and support energy efficiency schemes such as standards, codes, certification and labels thus to speed up the market transformation process. Community Research and Development Centre (CREDC) (2009) observed that the Standard Organization of Nigeria do not have any standards for electrical energy. More also, there is little or no national experience in the installations for testing household appliances according to international standards. In the relevant government institutions such as the SON, there is lack of energy efficiency quality standards.

2.6.6 Behavioral Barrier

Wasteful attitude and habits on energy use which is rampart in Nigeria is a barrier that affects consumption of energy. Community Research and Development Centre (CREDC) (2009) observed that a lot of energy been wasted in Nigeria households, public and private offices and industries were as a result of intensive use energy to fulfill their basic needs. The reason is that many end user exhibit unwholesome practices that result to energy wastage. Also according to the survey conducted by CREDC (2009), it was revealed that Nigerians do not put off their security lighting during the day. This is particularly very common in commercial and residential areas in many major cities in Nigeria. Even in public institutions such as universities, government ministries were also found to have their outdoor lighting switched on during the day.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Research Design

Research design is blueprint for conducting a study with maximum control over factors that may interfere with the validity of the findings. The research was conducted based on the flow chart given in Figure 3.0 below

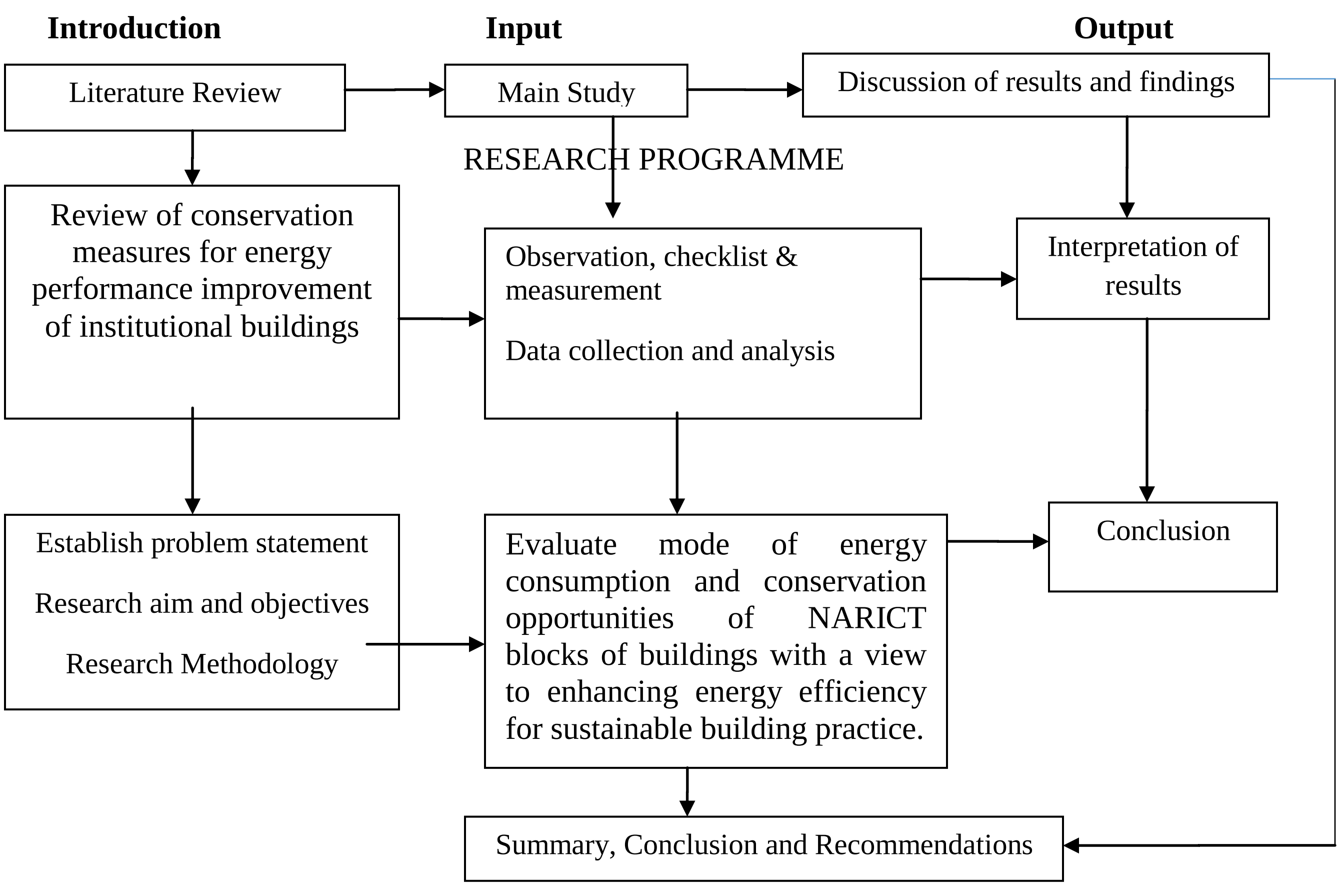

Figure 3.0 Research Design Flow Chart

Sources: Bernadett (2013)

3.2 Study Area

The study is National Research Institute for Chemical Technology (NARICT) located along old Kano road (Basawa) about 11KM form Zaria metropolis. The Institute contains various blocks forms such as Administrative block, Works and Maintenance Division, Library complex, Entrepreneurship development center, Laboratories, Clinic and multipurpose hall among others.

3.3 Population and Sample size

NARICT blocks of buildings constitute the population of the study with ten (10) blocks of buildings, the modes of energy consumption of these building are not similar. Therefore the buildings were grouped into three (3) categories of similar energy consumption as follows;

Category I: Blocks of office buildings.

Category II: Blocks of Laboratories.

Category III: Blocks of other buildings such as library, Entrepreneurship development center conference hall etc.

However, since the population is not much all blocks of buildings were adopted as the sample size.

3.4 Data Collection

The study was conducted with a carefully designed checklist and questionnaire complemented by site visit and interview with technical personnel, measurement was taken using clamp ammeter and the result were recorded using personal design templates. The procedure adopted in achieving the set objective is presented in three stages as follows;

Stage I: Interview with institute maintenance officer using data collection template.

Stage 2: Walk- through verification and preliminary assessment

Stage 3: Measurement of environmental condition and energy consumption

a. Interview with Building users

Personal interviews with the maintenance officer were arranged to obtain general information of the building such as building envelope, operation schedule, specifications of system and equipment as contain in appendix.

b. Walk-through Assessment

A preliminary Walk- through audit was conducted on system before actual measurement. The main purpose is to examine the actual condition of the investigated building, inspecting the space usage and main energy consumers, detecting the existing problems and improper operation and to determine the measuring point for environmental and energy consumption measurements.

The energy saving features from the passive system, active system and management were investigated. The possible causes of high-energy consumption (if any) or wastage inside the building were also identified and investigated. However the instruments evaluate the building physical characteristic, building services installation, building indoor environment and end-user behavior assessment. Thus, the check list is as in appendix A

c. Experimental Measurement

Two sets of measurements are involved in this section which include:

1. Measurement of environmental condition
2. Measurement of electrical energy consumption using clamp ammeter

a. Measurement of Environmental Conditions

Indoor environmental parameters were measured to establish the conditions in which various installations are working. The parameters measured include; dry-bulb temperature (°C), relative humidity (RH, %) and lighting level (Lux) were measured inside the building. The measurements were taken in the common areas on each block. The experiment setup of each measurement is as follows

I) Dry Bulb Temperature and Relative Humidity

A sling psychometer instrument used for determines relative humidity (RH) in the blocks of buildings and it was a+ccomplished with a psychrometer. In order to measure the dry bulb and wet bulb temperature the psychrometer frame- glass covering thermometer arrangement is rotated at 5m/s to get the necessary air motion

II) Lighting Level

Illuminance measuring instrument (Luxmeter) is used for measuring lighting intensity, the measurements at common areas were taken at a height of 1.2m from floor level and 1.2 m radiant distance away from the lighting source. The measurements usually include spot measurement and short-time monitoring for one week. During the same time of energy consumption measurement conducted on space cooling system.

b. Measurement of Energy Consumption and Power Demand

There are two sub-steps in this stage of the field measurements, such as data collection on energy consuming appliances/system and building energy auditing.

1. Data was collected on the following energy consuming appliances and system

I. The quantities, sizes and types of appliances and systems

II. Schedule of the operating time the energy consuming equipment is in use.

III. Location area served by these energy consuming equipment

IV. Rating power (kW) of these energy consuming equipment

V. Location of these energy consuming appliances

Thus, the instrument used for this assessment is a checklist and is presented in appendix

2. Energy Auditing

For most blocks of the buildings, measurements were conducted mostly on the components of space cooling by the use clamp ammeter, timer and experimental cable. Power measurements at a recording rate of 15 minutes time interval was adopted for all the blocks of buildings. The data was collected for a period of 7 days. However, because of the diversity within the blocks of buildings, it is very time consuming and costly to conduct the auditing on every energy consuming component. Thus, the descriptions of the appliances or systems audited were as follows:

I. Space Cooling System

The space cooling system i.e air conditioning system and resistance regulator fan are clamp on over a period of between 7 days with power measurement recorded at an interval of 15 minutes. Thus, the template for the measurement is as in appendix

II. Ventilation System

Ventilation system in the building were not audited with the energy measuring meter because the quantity of the systems in the laboratories are few in number and each with small power rating. The quantity and rated power for various exhaust system and the operating hours time pattern are recorded to estimate and audit the energy consumption of the ventilation system used in the laboratories. Power demand and operating schedule time pattern for the ventilation system are assumed to be consistent.

III. Lighting System

Similar reasons as mentioned above are also applied to the lighting system, hence, it is not audited with the energy meter. Similarly, as with the ventilation system, the quantity and rated power of the lighting system and the operating hours time pattern are recorded to estimate and audit the lighting energy consumption used in the blocks of building. Power demand and operating schedule time pattern for the lighting system are assumed to be consistent.

Plate 3.1: Simplified power meter for determining energy consumed over a typical period of operation.

3.5 Methods of Data Analysis and Presentation of Result

All data collected were analyzed using percentages and pie chart to identify area of energy wastage and its conservation opportunities, energy consumed by air conditioning system, plug loads appliances and indoor environmental condition are presented in form of charts using Microsoft excels. Thus, this allows for pictorial comparison between energy consumed and its conservation opportunities in the blocks of buildings. Energy saving opportunities were analyzed using the following formula adopted from Oyedepo (2012) as follows.

$$TED = \frac{SW}{1000}.n\ x\ Fd - - - - - - - - - - - -(1)$$

$$TEC = \frac{SW}{1000}.n\ x\ h - - - - - - - - - - - - - (2)$$

$$TECC = TEC\ x\ CUE - - - - - - - - - - - (in\ Naira) \quad (3)$$

Where

TED = Total energy demand i.e the amount of energy pulled out of the grid at any given moment in kW is given.

TEC = Total consumption in kWh

TECC = Total energy consumption cost

CUE = Current cost of a unit electricity in Nigeria

n is the number of appliances or systems,

SW is the system wattage

F_d is the demand factor. F_d is the assumed average percentage of available lighting or space cooling used at a buildings peak time and is taken as 100% for lighting and 80% for space cooling.

h = Total hour appliances or systems is used during the week.

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CHAPTER FOUR

4.0 DATA PERSENTATION, ANALYSIS AND DISCUSSION

4.1 GENERAL CHARACTERISTICS

The general characteristics of NARICT blocks of buildings are summarized in the Table 4.1. The samples are very heterogeneous in terms of size, reflected by ground floor area (GFA), number of offices and height of each blocks. The smallest block house five rooms of offices and an open space of 500m^2 GFA while the largest block has 25 rooms of offices with a total square area of 1648. In general, the sample has a good coverage of the population with regard to institute capacity.

Table 4.1 General Characteristic of the Sampled Blocks

	Minimum	Maximum	Mean	Std. deviation
Ground floor area (m^2)	500	1648	950	700
Number of offices per block	5	30	25	15
Area of each office (m^2)	12	40	20	8
Age	3	40	15	11
Height of Building	3.5	3.5	3.5	35

Source: Field Survey, (2017)

When it comes to building age, large variations are also observed. The oldest building was constructed over 35 years ago, and even its function has changed for several times. It was observed that most of old buildings were turned into a fabrication centers. In addition the thermal performances for the blocks of buildings structure were determined in order to maintain the designed door thermal comfort conditions.

4.2 Energy Consumption Analysis

4.2.1 Consumption Analysis of Building Energy Consuming Systems

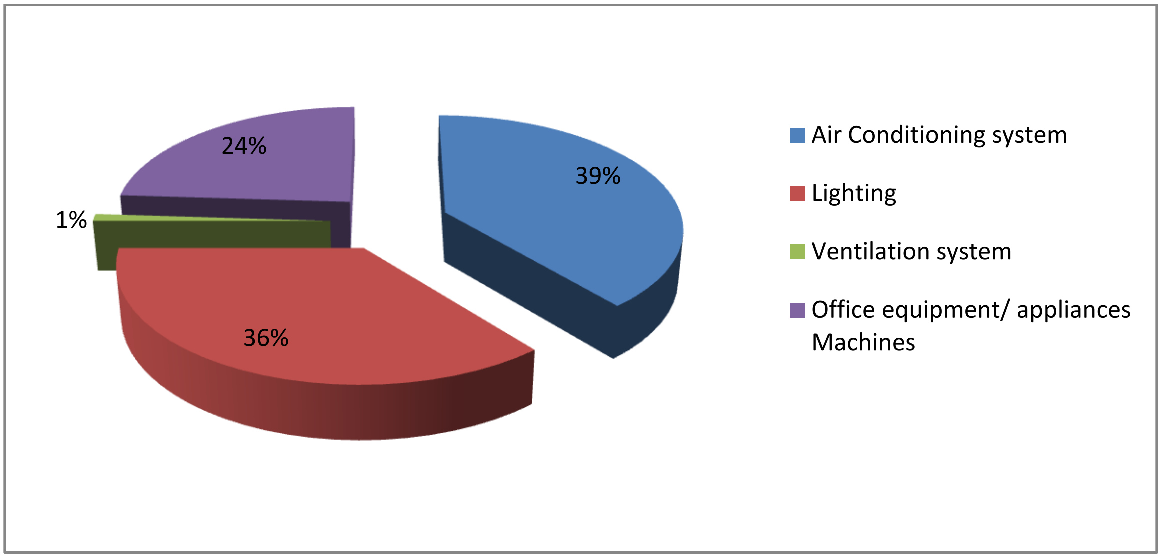
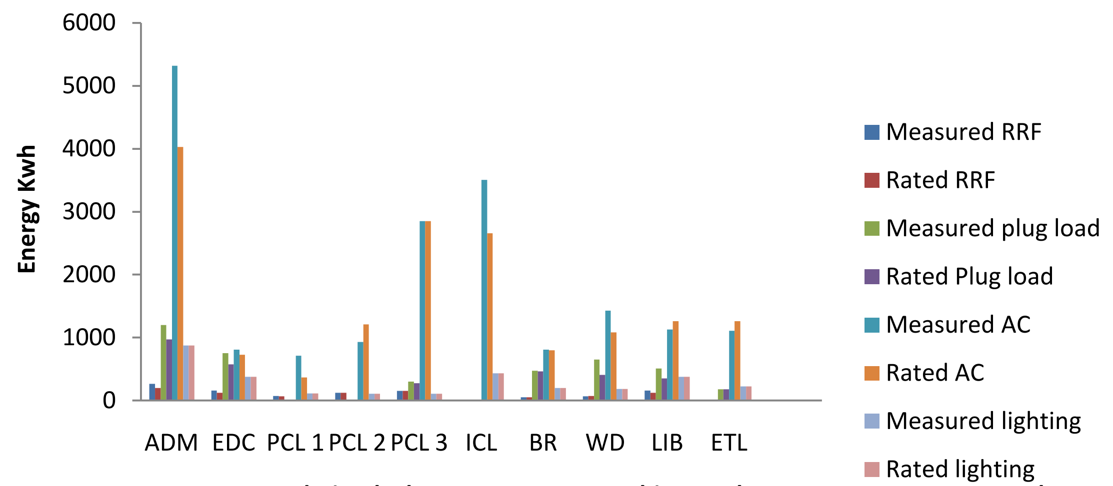


Figure: 4.1 Percentage distribution of energy consumption of building systems among the office buildings studied

The building energy consuming systems considered here consists of the four main components. They are the air conditioning system, lighting system, ventilation system, office equipment and other miscellaneous appliances (plug Load). Figure 4.1 shows the percentage distribution of the energy consumption of building systems and equipment with respect to the total building energy consumption on the basis of the average of the ten blocks of buildings studied.

Figure 4.1 shows that the air conditioning system consumed about 39%, of the total building energy consumption and this is typical of office buildings in NARICT. Office equipment and other electrical appliances consume about 24% This may be due to the extensive use of equipment such as desktop computers, servers etc which are a necessity for the modern office to function effectively and productively. On the other hand, the lighting system and ventilation system consume 37% of the total building energy consumption.

Furthermore, for the analysis on the energy consumption of the building systems of each sampled blocks in this study, the percentage distribution of energy consumption of the energy consuming components for each sampled blocks of buildings is shown in Figure 4.2. The overall relevant descriptive analysis of the four systems energy consumption of ten blocks is also presented in Table 4.2



KEY: ADM- Admin Block, EDC- Enterpreneuship Development Center, PCL- Petrol Chemical Lab, BR- Basic Research, WD- Works Department, LIB- library, ETL- Environmental Technology Lab

Figure: 4.2 Distribution of the energy consumption of building system and equipment for each sampled blocks of building

Table 4.2: Summary of statistics on energy consumption of building systems

	ECSC KWh	EC L KWh	EC OE KWh
Mean	1893	368	409
Standard Error	5396	130	93
Minimum	713	106	180
Maximum	5319	1567	1200

*ECL: Energy Consumption of lighting system **ECSC: energy consumption of space cooling

***ECOE: energy consumption of office equipment

From the table 4.2, the lighting consumption has an average of 368KWh per month with a standard error of 130KWh per month which is less than 35% of the average and plug load consumption has an average of 409KWh per month with a standard error of 93KWh per month taking up 23% of the mean. These relatively small deviation indicate that the consumption of the plug load appliances and lighting system do not vary much from one building to another.

On the other hand, the average energy consumption of space cooling was found to be 18925KWh per month with a standard error of 5396KWh per month this large deviation could be attributed to the ageing, oversize and improper replacement of space cooling part, there are some offices among the blocks mostly on the condition of natural ventilation and so the ventilation consumption is almost zero

4.3 Environmental Condition Assessment

Table 4.3 Environmental Condition Assessment

Location	Relative Humidity (%)		Dry bulb Temperature (%)	
	Measured	ASHRAE Standard	Measured	ASHRAE Standard
Admin Block	55	Not < 75	24	22.5 – 27
Entrepreneurship center	65-80	Not < 75	20	22.5 – 27
Petrol Chemical Lab1	60	Not < 75	23	22.5 – 27
Petrol Chemical Lab 2	60	Not < 75	24-25	22.5 – 27
Petrol Chemical Lab3	50	Not < 75	24.5-25	22.5 – 27
Industrial Chemical Lab	50	Not < 75	25	22.5 – 27
Basic Research Block	40	Not < 75	24	22.5 – 27
Works Division	45	Not < 75	25	22.5 – 27
Library Complex	60	Not < 75	23-25	22.5 – 27
Environmental Tech Lab	40-50	Not < 75	23-24	22.5-27

Sources; Field Survey,(2017)

4.3.1 Relative Humidity and Dry bulb Temperature

Table 4.3 shows the result of environmental condition of the study area. From the result, it turned out that Relative humidity (RH) in the blocks of buildings are in conformity with ASHRAE standard except in some general office of entrepreneurship development center (EDC) where direct air exchanges with the outside environment are frequent. However, indoor dry bulb temperature was maintained between 22.5 and 27 degree ^{o}C, with an average relative humidity not exceeding 75 per cent when the air-conditioning system is in operation. In line with this standard, it was noted that temperature settings in offices are actually adequate and is at the discretion of the occupants.

Table 4.4 Measured power density for artificial lighting

Location	Lighting Source	Average Operating Period (hrs)	Average Light Power Density (w/m^2)	
			Measured (w/m^2)	ASHRAE Standard (w/m^2)
Admin Block	**CFL**	**10**	**21**	**12**
Entrepreneurship Center	**CFL**	**10**	**20**	**12**
Petrol Chemical Lab 1	**CFL**	**10**	**12.6**	**12**
Petrol Chemical Lab 2	**CFL**	**10**	**20**	**15**
Petrol Chemical Lab 3	**CFL**	**10**	**15.5**	**15**
Industrial Chemical Lab	**CFL**	**10**	**15**	**15**
Basic research Bock	**CFL**	**10**	**15**	**12**
Works Division	**CFL**	**10**	**15**	**12**
Library Complex	**CFL**	**10**	**11.4**	**13**
Environmental Tech Lab	**CFL**	**10**	**20**	**15**

Source: Field Survey,(2017)

4.3.2 Lighting and fixtures

Table 4.4 present the result of illumination power density (IPD) for each block of buildings and it were observed that administrative block, entrepreneurship development center and environmental technology laboratories has higher IPD with a value ranging from 20 to 21w/m^2 while library complex recoded the lowest IPD with a value of 11.4w/m^2. Thus, this was as a result of improper sizing of the lighting fixtures. The maximum lighting loads for offices and laboratories were recommended to be 12W/m^2 and 15W/m^2 respectively. These requirements, measured in watts per square meter, serve to limit the installed circuit wattage of the artificial lighting system in a space. Perhaps, wider opportunities are obtainable if all installation with IPD above ASHRAE standard is replaced.

Table 4.5: Measured Illumination Level for Day Lighting Distribution

Location	Time of Measurement	Description of Source Light	Illumination Level (lux)	ESI Recommended Illumination level (lux)
Administrative Block	Afternoon	Diffused light	317- 554	320
Entrepreneurship Center	Afternoon	Diffused light	317- 554	320
Petrol Chemical Lab 1	Afternoon	Diffused light	420-500	400-750
Petrol Chemical Lab 2	Afternoon	Diffused light	415- 500	400-750
Petrol Chemical Lab 3	Afternoon	Diffused light	420- 500	400-750
Industrial Chemical Lab	Afternoon	Diffused light	420- 500	400-750
Basic Research Block	Afternoon	Diffused light	318-500	320
Works Division	Afternoon	Diffused light	289-547	320
Library Complex	Afternoon	Diffused light	300-500	320
Environmental Tech lab	Afternoon	Diffused light	400- 554	400-750

Sources: Field Survey,(2017)

4.3.3 Daylight Performance in NARICT Blocks of Buildings

Table 4.5 shows that the measured illumination levels in some locations from diffused light at day-time are quit sufficient for any type of business in offices and laboratories. Offices in administrative block, entrepreneurship development center and laboratories have the highest lux level of 317- 500 this was due to proper orientation of the building and openings. Perhaps, a lot of energy savings opportunities can be realized by keep window blinds open during the day to let in diffused light their by reducing the numbers of compact fluorescent lamps in operation during day time.

4.4 Energy Saving Opportunities in NARICT Blocks of Buildings

In today's scenario, Institutional buildings, such as NARICT is facing various challenges of saving electricity. Various electric appliances ranging from space cooling systems (e.g fans and air conditioners) to plug load appliances are over-aged, which are not energy efficient. The uses of electricity in office appliances like air conditioner, refrigerator is obvious and if these devices can be retrofitted handsome saving would be achieved in the institute. Thus retrofitting of the following were suggested as described.

Table 4.6 Energy Saving Opportunities for Replacement of Energy Consuming Air Conditioning systems

Location	Qty	Appliances Rating Before Retrofitting (W)	Energy Consumption before Retrofitting KWh	Proposed Retrofitted Appliances Rating (W)	Energy Consumption After Retrofitting KWh	Savings Opportu -nities KWh	Cost saving opportu nities N
Admin Block	20	1119	2954	746	1969	985	25610
Entrepreneurship	9	1119	1772	746	886	443	
Petro chemical lab 1&2	7	1119	1034	746	689	345	
Industrial Chemical Lab	10	1119	1477	746	985	492	
Industrial Chemical Lab	7	1491	1378	746	689	689	
Works Department	8	1119	1182	746	788	394	
Library Complex	6	1119	866	746	591	275	
Library Complex	5	1491	984	746	492	492	
Environmental Tech Lab	7	1119	1034	746	689	345	
Total	79		12681		7778	4903	

Source: Field Survey, (2017)

Table 4.6 present results of energy and cost saving opportunities for replacement of energy consuming air conditioning system with energy efficient system, the total number of energy consuming air conditioning system recorded was 79. Administrative block, Industrial Chemical laboratory and library have the highest saving opportunities of 985KWh, 689KWh and 867KWh respectively. The total monthly energy saving potentials for replacing this system is 4903KWh and the annual cost saving opportunities is N 128,949.

Table 4.7 Energy Savings Opportunities for Replacement of Resistance Regulator Fan

Location	Qty	Appliances Rating Before Retrofitting (W)	Energy Consumed Before Retrofitting KWh	Proposed Retrofitted Appliances Rating (W)	Average Consumption After Retrofitting KWh	Savings Opportunities KWh
Admin Block	**30**	**80**	**246**	**40**	**116**	**116**
Entrepreneurship Cent	**15**	**80**	**158**	**40**	**79**	**79**
Petro chemical lab 1,2&3	**29**	**80**	**306**	**40**	**153**	**153**
Industrial Chemical Lab	**10**	**80**	**106**	**40**	**52**	**52**
Works Department	**10**	**80**	**106**	**40**	**52**	**52**
Library Complex	**15**	**80**	**158**	**40**	**79**	**79**
Basic research Dept	**7**	**80**	**74**	**40**	**37**	**37**
Environmental Tech Lab	**9**	**80**	**95**	**40**	**48**	**48**
Total	**125**		**1249**		**616**	**616**

RRF* - Resistance Regulator Fans, ERF* - Electronic Regulator Fans,

Source: Field Survey, (2017)

The common types of fans available in NARICT blocks of buildings are resistance regulator with power rating 80W at full speed with a total energy consumption 1249KWh/month and total energy consumption cost of N32,936,13. Administrative block and Petrol chemical laboratories have the highest consumption with 246 and 306 KWh/month. Replacing these fans with electronic regulator having power rating 40W at full speed, a total energy consumption of 616KWh were achieved and a cost and saving opportunities of N16,201,00. The cost of replacing 125 number of 80W RRF with 40W RRF is N625,000 the capital recovery time is 39 month.

II Lighting System

Table 4.8 Energy and Cost Savings for Replacement of Compact Florescent Lamp

Location	Qty	Rating Before Retrofitting (W)	Consumption Before Retrofitting KWh	Proposed Retrofitted Bulb (W)	Consumption After Retrofitting KWh	Savings Opportunities KWh
Admin Block	25	105	346	25	149	197
Admin Block	50	85	374	25	198	179
Entrepreneurship Cent	25	85	280	25	149	131
Petro chemical lab 1&2	29	85	542	25	287	255
Industrial Chemical Lab	10	105	231	25	99	132
Works Department	15	105	231	25	99	132
Library Complex	30	85	280	25	149	131
Basic Research Dept	10	105	161	25	69	92
Environmental Tech Lab	15	85	187	25	99	88
Total	209		2632		1298	1337

Source: Field Survey, (2017)

Lighting units play a major role in the consumption of electricity in institutional buildings. However, this area offers several energy saving opportunities. Compact florescent lamps were the common types of lighting fixtures throughout the institute and their consumption was not homogenous. The total consumption by lighting fixtures and its cost savings for each location was presented in Table 4.7 petrol chemical laboratories and administrative block has the highest saving opportunities of 255KWh and 376KWh/month respectively, the total monthly energy saving potentials for the replacement of 105W and 85W CFL in offices and laboratories with 25W LED is 1337KWh and the monthly cost saving opportunities is N35163.1. The total cost of replacing 209 numbers (105 and 85W) CFL respectively with 25W LED is N94,050 while the capital recovery time is three (3) month.

III End user Behavior assessment

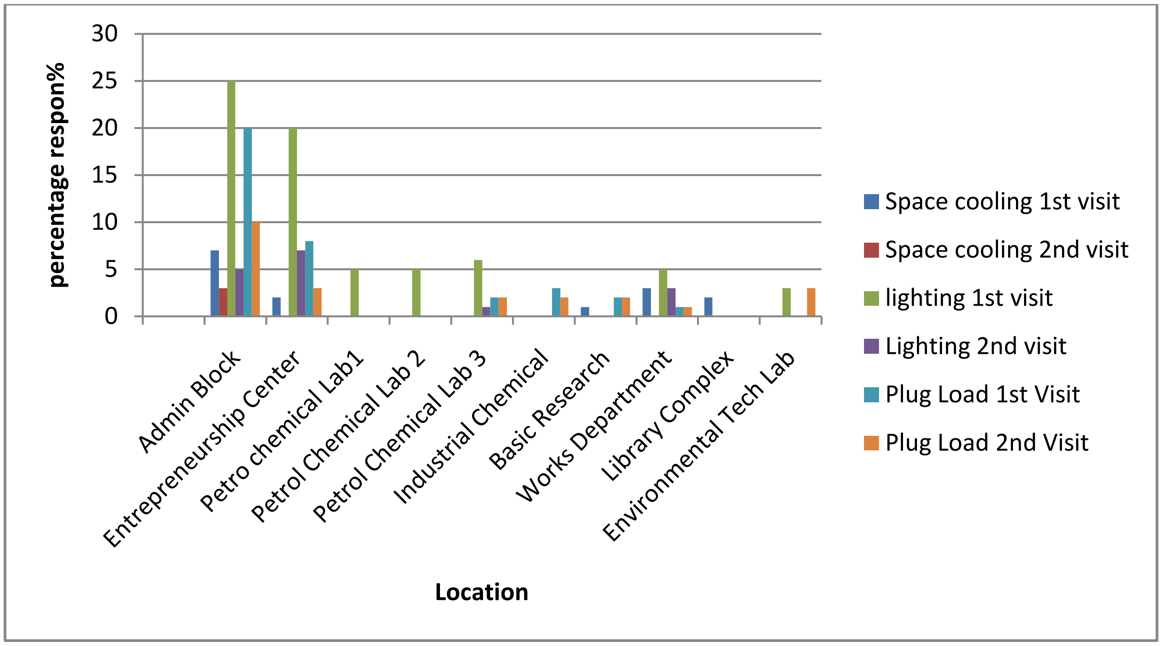
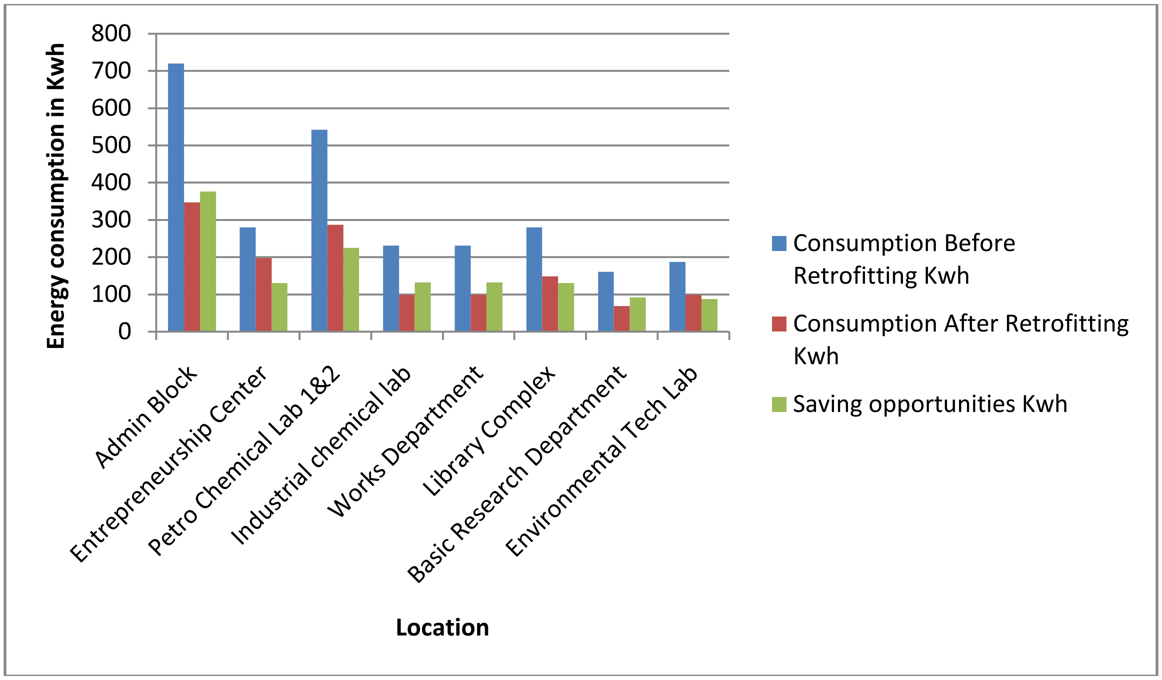


Figure 4.3: Observational analysis for energy conservation opportunities

Figure 4.3 displays the results of the observations that was collected before and after behavioral interventions were implemented. The figure indicates the proportion of the appliances/system that was turned off during non-working hours at each blocks of building. Thus it was satisfactory that the behavioral interventions were quite successful in facilitating attitude of end-user. The output indicates that there is a significant increase in the system turned off during working and non- working hours in the experimental groups between the pre and post intervention stage. Arguably, the findings demonstrate that small interventions can facilitate drastic change among employees. This suggests that other small interventions that invoke new workplace norms could be implemented to harness other sources of potential savings in blocks buildings.



4.5 Initiative for Efficient Energy Utilization and Conservation

A solid yet broad conceptual initiative for energy conservation can help advance both practice and theory by providing specific terminology, parameters, and benchmarks for planning, implementing, and measuring across the full spectrum of the conservation doctrine. These initiatives offer insight for integrating technological systems and individual behaviors, thereby enabling the development of a more organic approach that will result in enhanced energy conservation outcomes. However it can be identify form Table 4.6, 4.7 and 4.8 that effective energy management policies through monitoring and targeting, benchmarking approach and retrofit were institutionalized way to conserved energy.

CHAPTER FIVE

5.0 SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATION

5.1 Summary of Findings

i. Energy consumption in NARICT blocks of buildings

Fundamental understanding of how energy is consumed, monitored and controlled is key prerequisites for an energy conservation process in the built environment. Based on walk through audit conducted on the sample blocks of buildings, air conditioning systems and lighting were identified to be the predominant energy consuming components among the blocks of buildings with an average consumption of 39% and 36% respectively, of the total building energy consumption. These two areas are determined to be the most critical factors that directly affect the total building efficiency classification and also present significant energy savings opportunities. The rates of consumption in the blocks of building are not harmonic. High usages of space cooling, ageing appliances/systems, over sizing of appliances/systems and improper replacement of components (compressor) in most of the cooling appliances were major factors responsible for higher consumption.

ii. Conservation Opportunities in NARICT Blocks of Buildings

The total energy consumed from space cooling systems and lighting fixtures in NARICT blocks of buildings before retrofitting was measured at 12681KWh and 2632KWh respectively. It's quite clear from table 4.6, 4.7 and 4.8 that maximum power consumed after retrofitting were 7778KWh, 616KWhand 1298KWh respectively. The energy saving opportunities for space cooling systems and lighting were found to be 4903KWh, 616KWh and 1337KWh respectively. However, the cost saving opportunities after retrofitting were found to be N128,949 per month for Air condition systems, N16,201 per month for fan and N35,163 per month for lighting.

iii. Initiatives for Efficient Energy Utilization and Conservation

Several methodologies are reviewed for exploring energy consumption and conservation opportunities in NARICT blocks of buildings these include monitoring and targeting, benchmarking approach, retrofitting approach, walking through and behavioral intervention approach. However, two main approaches are identify for evaluating consumption and conservation opportunities in the study area.

Energy targeting and monitoring were established for building systems, space cooling and lighting systems. The blocks of buildings were grouped into three categories based on their energy consumption. This approach helps to identify the buildings performance as compared to general cohort of office buildings system and also help to determine the key energy inefficient areas and the areas where energy saving opportunities exists through energy audits, involving the physical inspection of facilities. The other method, retrofit approaches are presented in this study to estimate the blocks of buildings energy and cost saving opportunities with respect to gross floor area.

5.2 Conclusion

The study revels that energy and cost savings opportunities for the replacement of air conditioning systems and compact fluorescent light are about 4903KWh, N128,949 and 1337KWh at N35,163 respectively. The energy saved will enhance the performance of the environment against green gas emission and the cost saved can be use for other developmental programs in the institution. However, its can be concluded that the adoption of energy efficiency measures as part of the overall institution developmental policy strategy would not only bring about substantial reduction in peak electricity consumption but also in electricity bills, while resulting in energy conservation. Some of the identify policy option the institution can adopt to reduce energy spending include: enhancing the efficiency of electrical appliances through retrofitting, utilization of day-lighting, maximizing natural ventilation and better management practices.

5.3 Recommendations

A well articulated and vigorously pursued energy efficiency policy measures in NARICT blocks of buildings can result in an estimated annual savings in electricity consumption. The empirical evidence, however, is that many organizations are reluctant to take advantage of these opportunities, in other words there is a need for new approaches that unleash a wave in the adoption of both behavioral and technological energy savings opportunities in NARICT buildings. However, the following identify initiatives should be adopt to reduce energy consumptions and enhance conservation opportunities in blocks of buildings:

I Reduction in consumption through behavioral change would bring about decrease in actual consumption. Demand reductions involve conscious behavioral choices to reduce usage of the product or output derived from an energy resource, thus this parameter typically involves psychologically based initiatives that encourage individuals or institutions to alter consumption patterns even though doing so involves some sacrifice. The direct costs for reducing demand in this way are typically minimal.

II Maximize energy efficiency through green building policy: A policy of energy self accounting in all institutionally owned enterprises encouraged by sub-metering of such business outfits for effective energy use surveillance. However, investments in energy efficiency through proliferation of green building policies (typically using a LEED standard), energy efficiency loan funds, and institutional building retrofits, focus almost exclusively on this parameter. Investments in these technologically based efforts dominate institutional efforts and should be implemented through formal policy and programs

III Retrofitting of Systems and Appliances:

Electronic regulators are the latest type of regulators available, they are much smaller in size than the electric resistance regulators (ERR). Electronic regulators use capacitors instead of resistors to decrease the voltage. Capacitors regulate the fan speed by regulating the waveform of power supply. These do not get heated up and thus save electricity when the fan is running at lower speeds (at higher speeds electricity consumption of fan is the same with both regulators). Electronic regulator fan save up to 40% of energy consumption at speed 1 and about 30% at speed 2 compared to resistance regulators.

5.4 Contribution of the study

The outcome of this study helps to improve the energy performances of office buildings and to encourage positive management action.

i The study recorded an energy wastage of about 6856kW in the institution It describes how monitoring and targeting was use to determine the total building energy consumption,

ii Its also identify the technical and management measures that could help in reducing energy consumptions and costs through retrofitting and improve user behavior.

iii The study estimate energy and cost saving opportunities of all blocks of building, cost recovery and financing requirements

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APPENDICES A:

Data Collection form on Evaluation of Energy Consumption and Conservation Opportunities for Buildings at National Research Institute For Chemical Technology, Zaria.

Building data				
Location	Activity type (laboratory, offices, reception)	Floor square area	Number of occupants	Daily operational hour (Monday- Friday)

Plug loads					Location ------------------------		
Equipment type	Model	Total Number	Wattage	Hour of use per Day	Total KWH	How is Equipment Controlled	Description, Observation or Notes
Computer							
Printer							
Refrigerator							
Photocopy machine							
Television							

Lighting							
Location	Location Description	Lamp Type	Ballast types	wattage	Total number of lamp	Number of hour light are left on each day	Total kWh per day

Space conditioning systems					
What type of space cooling system does the building have (Window/split unit or regulator resistance Fan)	What fuel type does this system use	How is the system controlled	What are the operational set points	How old is the system	What is the capacity of the system

Building envelope				
Building Element	Condition (Excellent, Good, Poor)	Type	Observation	Possible energy Saving Opportunities
Windows				
Doors				
Roofs				
Walls				
Floors				

Operation and Management

Does the organization have an environmental policy?________________________

Does the organization have an energy policy? ______________________

Does the organization have an environmental or energy manager? __________________

Does the organization review these policies on an annual basis and establish reduction targets? _______

APPENDIX B

MEASUREMENT

Introduction

Electric energy consumption of space cooling system and plug load appliances was recorded through an experiment with the following tools/instrument: timer, clamp ammeter and experimental cable. The setting and procedure are as follow

Experimental setting: the appliances was plugged on to the experimental cable socket outlet, and a clamped ammeter was clamped on to the live cable while a digital timer by the side

Measurement procedure: The space cooling system was set to cool at 16^{o}c in which after first 15min. Electric consumption in form of current was taken from the ammeter at the end every thirty minutes hour

Template of result foam

Time (min)	0	15	30	45	60
Consumption (KW)					

Electrical energy consumption (w) at end of one hour =

Power (w) = current reading (A) X 240volt

Precaution / measures

1. Only functional equipment is consider i.e System that has no any deficiency such as pipe leakages etc

2. The entire instrument used was checked for correctness to ensure precession and accuracy

Energy Consumption of building system in various Blocks

Location	Space Cooling (Kwh/Month)				Lighting Kwh		Plug load (Kwh/Month)	
	AC		Fan					
	Measured	Rated	Measured	Rated	Measured	Rated	Measured	Rated
Admin Block	5319	4029	264	200	875	875	1200	968
Entrepreneurship	806	725	158	120	374	374	750	572
Petrol Chemical Lab 1	713	366	70	64	112	112	0	0
Petrol Chemical Lab 2	1208	930	120	120	106	106	0	0
Petrol Chemical Lab 3	2851	2851	153	153	106	106	300	275
Indus Chemical Lab	3504	2655	0	0	430	430	0	0
Basic Research Block	860	800	52	52	197	197	650	462
Works Department	1426	1080	65	70	185	185	500	500
Library complex	1128	1260	158	120	374	374	510	350
Envir Tech Lab	1110	1260	0	0	224	224	180	176

Source: Field Survey, (2017)

Behavioral Intervention Data (First visit and Second visit)

Location	First visit				Second visit			
	Space Cooling		Lightning	Plug load	Space Cooling		Lightning	Plug load
	AC	**Fan**			**AC**	**Fan**		
Admin Block	7	0	25	20	3	0	5	10
Entrepreneurship	2	0	20	8	0	0	7	3
Petro Chemical Lab 1	0	0	5	0	0	0	0	0
Petro Chemical Lab 2	0	0	5	0	0	0	0	0
Petrol Chemical Lab 3	0	0	6	2	0	0	1	2
Industrial Chemical	0	0	0	3	0	0	0	2
Basic Research	1	0	0	2	0	0	0	2
Works division	3	2	5	1	0	0	3	1
Library	2	2	0	0	0	0	0	0
EnvironmentalTechLab	0	3	3	0	0	0	0	3

Sources: Field survey, (2017)