ASSESSMENT OF ELECTRICAL ENERGY USAGE IN RESIDENTIAL BUILDINGS IN MINNA NIGER STATE

BY

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2016/1/63780TI

DEPARTMENT OF INDUSTRIAL AND TECHNOLOGY EDUCATION

FEDERAL UNIVERSITY OF TECHNOLOGY MINNA

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A PROJECT SUBMITTED TO THE DEPARTMENT OF SCIENCE EDUCATION, SCHOOL OF SCIENCE AND TECHNOLOGY EDUCATION, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA, IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF TECHNOLOGY (B.Tech) IN SCIENCE EDUCATION

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CERTIFICATION

This project has been read and approved as meeting the requirements for the award of B. Tech degree in Industrial and Technology Education, School of science and Technology Education, Federal University of Technology, Minna

Dr. Hon G. A Usman ____________________
Project Supervisor Signature & Date

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Head of Department Signature & Date

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____
External Examiner Signature & Date

DEDICATION

This project is dedicated to Almighty Allah, the most merciful, the most beneficent, the most gracious, the omnipresent and omniscient.

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All thanks and adoration is due to almighty Allah (SWT) who gave me health, strength, wisdom and ability to carry out this research work successfully, may peace and blessing of Allah be upon the Prophet (S.A.W).

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

Globally, the increased rate of energy use has raised concerns over problem of energy supply and exhaustion of energy resources. This has resulted in severe environmental problems such as high energy demand, global warming, ozone layer depletion, air pollution and acid rain. (Janda & Busch, 2013). The International Energy Agency (IEA) data on energy consumption in the past decades has been upsetting, given that energy use by emerging economies has projected to grow at an annual rate of 3.2%. If this annual rate should continue it will exceed the energy use of developed countries of the world by 2040 (Lombard *et al*., 2018).

In most developing countries, particularly in Nigeria, energy consumption has been growing rapidly due to recent economic growth and development in infrastructures. The number of new buildings is increasing rapidly in developing countries. This increase in new buildings is accompanied with high energy prices and a market which most often do not encourage the use of efficient technology (Hui, 2016). According to Lomabrd *et al*. (2017) IEA annual energy consumption rate prediction stated that energy consumption will increase rapidly, if all buildings are given immediate approval for construction. The household consumers in the Organisation of European Development Communities (OECD, 2014) noted that worldwide, residential buildings consume about one third of all energy end use. This submission also predicts that energy demand will grow in a reference scenario to a level above 40% higher than the situation in 2007 by 2030. This increase will arise mainly from non-OECD countries, mostly in Asia and Africa in which Nigeria is significant with her population projection of about 200 million. Energy management is the means to controlling and reducing buildings energy consumption, which enables building owners to:

i. Reduce costs – this is becoming increasingly important as energy costs rise.

ii. Reduce carbon emissions and the environmental damage that they cause - as well as the cost-related implications of carbon taxes, every organization may be keen to reduce its carbon footprint to promote a green, sustainable image. Not least because promoting such an image is often good for the bottom line, especially for educational organizations.

iii. Reduce risk – the more energy some building consumes, the greater the risk that energy price increases or supply shortages could seriously affect its functionality. With energy management every organization can reduce this risk by reducing demand for energy and by controlling it so as to make it more predictable.

In order to monitor and control energy consumption, adequate collecting data is primer issue. The old school approach to energy-data collection is to manually read meters once a week or once a month. This is quite a chore, and weekly or monthly data is not nearly as good the data that comes easily and automatically from the modern approach. The modern approach to energy-data collection is to fit interval-metering systems that automatically measure and record energy consumption at short, regular intervals such as every 15-minutes, half-hour or hour. At the global scale, the contributions of energy consumption of residential and commercial buildings are between 20% and 40% in developed countries (Hassan, 2018; Lombard *et al.*, 2017). Unfortunately cities in Africa in general and Nigeria in particular have no documented data to back up this claim because of her non-OECD membership status (Hassan, 2018, Lombard *et al.*, 2017; Geoffrey, 2018). This is highly required for analytical purposes towards the development of energy standard and government policy guidelines. On the strength of this, energy consumption especially in cities like Minna with rapid increase in population growth rate constitutes the case study of this research. However, the issues of population growth, nature of urban and rural migration in emerging mega cities, increased comfort level demands of occupants, together with the rise in time spent in buildings have been identified to have raised the trend in energy demand.

It is therefore essential to assess the electrical energy usage in residential buildings in Minna Niger State for many reasons such as global climate change, carbon emission, global temperature increases, comfortable living and other sustainable issues.

1.2 Statement of the Research Problem

The population of Nigeria continues to increase in accordance with the projections made by the United Nations that Nigeria will become the most populous in the world by 2050. With residential area occupying about 60% of land, the implication of this for housing stocks is immense on energy consumption. Hence, the density pattern with socio economic and climatic requirements for sustainable living condition becomes a major challenge for the provision of adequate energy for future housing development.

The traditional housing design goals of providing basic shelter and reliable security for occupants of residential buildings in Minna and Nigeria in general. However, the essential comfort required by most occupants continues to remain a major challenge in most buildings, without the much reliance on adequate active energy supply. Moreover, the thermal insensitivity nature of most residential building designs, as identified by research, which impacted much on indoor living conditions, is likely to make issue relating to energy consumption worse. This may have propelled the reliance on fossil fuel energy supply by most occupants that may result in emission, despite ICPC global potential to reducing approximately 29% and 31 % baseline projected emission from residential and commercial buildings by 2030 and 2040 respectively.

The prevalence of this thermally insensitive nature of residential buildings in Minna may be as a result of failure to employ the right tropical bioclimatic passive design principles, thereby necessitating high energy consumptions for their operations. At the same time, the typical problems high population density, overcrowding, high traffic congestion and urban heat associated with a place with a megacity status are also issues to contend with in Minna. These are usually responsible for the air and noise pollution of the city environment that necessitate high intensity of energy consumption in Minna households.

The paradigm shift in the living condition of most residential occupants due to their upward comfort requirement and increased economic level of income, make indoor comfort a significant problem of high energy consumption. The resulting effect of this paradigm may be seen in the new culture of residential buildings and architectural trends of inadequate solar control with attendant high energy consumption consequences. This concern, alongside occupants' reluctance to window opening in preference to sealed up building envelope often results in the use of air conditioners for indoor cooling, as dictated by prevalent building mode. This may be linked with the high level of air and noise pollution in Minna, which is likely to have enormous impacts on the amount of energy consumed. Based on this insight the study assess the electrical energy usage in residential buildings in Minna, Niger State.

1.3 Purpose of the Study

The purpose of the study is to assess the electrical energy usage in residential buildings in Minna Niger State. The specific objectives of the study is to;

1. Examine the characteristics of selected residential buildings, with respect to their energy consumption in Minna Metropolis
2. Identify energy consumption indicators of residential buildings in Minna Metropolis
3. Investigate the impact of environmental factors on energy consumption in residential buildings in Minna Metropolis

1.4 Research Questions

The following research questions were raised to guide the study

1. what are the characteristics of selected residential buildings, with respect to their energy consumption in Minna Metropolis ?
2. what are the energy consumption indicators of residential buildings in Minna Metropolis?
3. what is the impact of environmental factors on energy consumption in residential buildings in Minna Metropolis?

1.5 Significance of the Study

The study will be beneficial to the students, government, Nigerian Electricity Regulation Commission (NERC), building professionals, Distribution companies (DISCOs) and Generation Companies (GENCOs) and the society.

The study will be beneficial to Students to understand the importance of energy as an essential ingredient in economic growth of all nations and as well improve the quality of life.

The study will be beneficial to the government to determine how effectively and efficiently a country uses her natural resources. It is also relevant for the identification and application of energy conservation opportunities, as well as dictating the energy strategies and directions of a country or society towards solving this problem.

The Nigerian Electricity Regulation Commission (NERC) will benefit in which the study therefore serves as a platform for data collection and analysis of energy consumption in order to formulate a standard for the development of a building energy consumption code and policy in the country.

The study will also benefits building professionals to develop designs for residential buildings potential to reduce the projected base line emission. The professionals client will be better educated and guided on building energy performances.

The study will also be beneficial to the Distribution companies (DISCOs) and Generation Companies (GENCOs) to improve energy supply and generation, it will provide the basis for an effective evaluation and determination of the total and actual energy requirement for sectorial generation.

The society will also benefit from the study by being better informed on effective energy consumption indicators and energy generation.

1.6 Scope of the Study

The study is limited to the assessment electrical energy usage in residential buildings in Minna, Niger State. The study is limited to residential buildings in Minna due to their level of energy consumption. The study will examine the characteristics of selected residential buildings, identify the energy consumption indicators and the impact of environmental factors on energy consumption in residential buildings in Minna Metropolis. The study will compare the responses between the civil servant building owners and private building owners. The study will be carried within the duration of eight weeks. The study did not cover Chanchaga due to financial implication.

1.7 Hypotheses

The formulated hypothesis will be tested at the level of significance of 0.05

HO_1: There is no significant difference between the mean score of civil servant building owners and private building owners on the characteristics of selected residential buildings, with respect to their energy consumption in Minna Metropolis.

HO_2: There is no significant difference between the mean score of civil servant building owners and private building owners on the energy consumption indicators of residential buildings in Minna Metropolis.

HO_3: There is no significant difference between the mean score of civil servant building owners and private building owners on the impact of environmental factors on energy consumption in residential buildings in Minna Metropolis.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Conceptual Framework

2.1.1 Building Characteristics and Energy

The building characteristics play a significant role on energy consumption since energy and building relationship are dynamic in nature. This can be clearly explained with the principle of thermodynamic, in which the built environment is formed by the building and other objects constructed in the natural environment. This assertion can be explained further through an extensive literature review drawn from textbooks, scholarly journal articles, and researches undertaken to establish the basic principles for designing energy efficient buildings. The understandings of these principles constitute the essence of energy consumption. The residential building types and their characteristics vary in accordance with their regional climatic condition and cultural setting. But for purposes of energy consumption studies, residential building types are basically determined by two major characteristics:

1. Building characteristics in term of occupancy affects energy consumption with respect to the number of occupants at a given period of the day (Weekdays and Weekends)
2. The Building ventilation mode, on the other hand, play a major role in determining the energy consumption rate of households. However, for the purpose of this study and the climatic setting, known to be warm and humid, have the following major modes.

a) Natural ventilation Mode

b) Mixed mode ventilation

c) Mechanical ventilation mode

Nicol *et al*. (2015) study of occupants control of temperature in mixed -mode buildings seems to provide a design solution in the inevitability scenario of air-conditioning and end energy use control in the study area. A building that is heated in winter, free-running in mid• season and has cooling available in summer, as required, is called a 'MIXED-MODE' building. They are usually characterised as likely to consume less energy than a fully air conditioned building. Their energy consumption as well depends greatly on how occupants use the available control, such as windows, fans, heating and cooling technology. The aim of mixed mode building is to maximise energy consumption by good design and judicious control, throughout the proportion of the year that free- running mode is applicable. Mixed mode operation can save energy compared to conventional air-conditioned buildings, as it may also improve air quality, if well designed.

2.1.2 Energy Consumption in Residential Buildings

In developing countries, energy consumption has been increasing rapidly due to economic growth and development of infrastructures, Building Energy Standard (B E S, 2016; Jarda and Bush 2017). This can be attributed to the number of new buildings, rapid growth, un-encouraging energy prices and market for the use of efficient technology Hui. (2016). The International Energy Agency (IEA 2018) report pointed out that worldwide, households consume about 1/3 of the total end use energy. Most of the projected growth in energy consumption is said to occur in Asia and Africa where climate change impact is leading to decrease in energy demand in the coldest region and increase in the warmest regions.

As prior studies point out, energy consumption in buildings worldwide accounts for as much as 45% of primary energy resources. This makes building the biggest single contribution of total energy consumption according to Chow, (2019); Publish Group, (2018);Yang *et al*, (2018); Radhi, (2018); Lombard *et al*.(2018); Omar aid and Yan *et al.* (2006) and Mohammed (2018).

The studies of Hassan 2018, EC, 2017, Geoffrey & Yan kelvin, (2015), note that global contribution of buildings towards energy consumption, both residential and commercial have steadily reached figures between 20% and 40% in developing countries.

Sureh *et al*. (2019) study indicated that US residential buildings account for more than 20% of total energy consumption. But European and Asian countries" consumption is up to 30%. It is noted that the energy consumption of African countries cannot be adequately accounted for. This is mainly due to the absence of data, a fact confirmed by IEA, (2018) report. Pleongeham *et al*, (2016) study reveals that residential buildings in South Korea consume more than 55% of energy use. According to research publications on households energy use by end-use survey among 19 countries of IEA (2018), it is now generally agreed that buildings use energy for heating and cooling, lighting, Ventilation, Water heating, and for operating equipment and appliances.

This pattern of consumption is said to be however strongly influenced by the activities that occur within several building types, energy cost and economics. Fundamental as well is the energy use pattern that characterizes the regional prevailing climates, available technology and sources of supply. This study is mainly focused on a regional climatic setting characterized by its warmness and humidity and the three major uses of energy consumption considered include: cooling lighting and ventilation.

Lang, (2014) refers to building energy consumption as the energy consumed within buildings, including the energy consumed through heating, ventilation, air -conditioning, illumination, electrical equipment, hot water supply and cooking. According to Lang, this energy consumption is related to the quality of life. As standards of living improve, Lang concludes that energy consumption in building will increase.

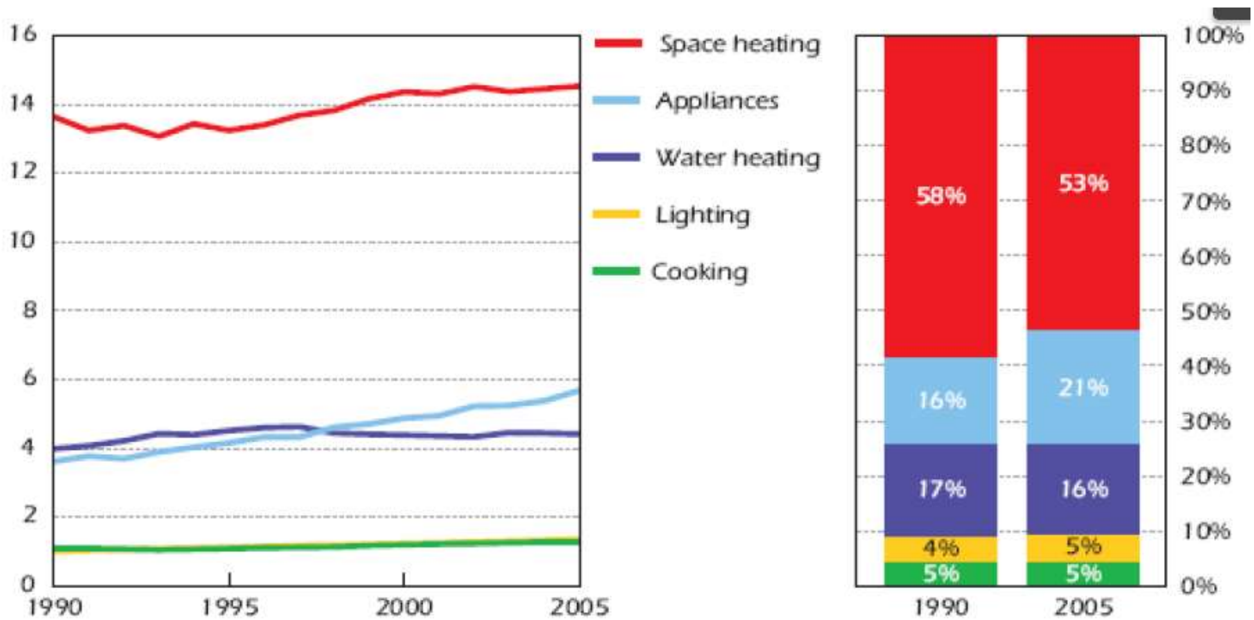

Figure 2.1: Household energy use by end-use, among the surveyed countries of IEA 19. Source: IEA, (2018).

2.1.3 Cooling Energy Consumption

In most tropical buildings, air-conditioning system is found to be essential in maintaining good thermal environment. It is often regarded as the largest consumer of energy in which about 30%-60% of the energy is used for cooling and dehumidification purposes.

Moma *et.al*, (2018) wrote on modelling global residential sector energy demand for air• conditioning and heating in the context of climate change and energy efficiency. Their study noted that residential heating and cooling (air-conditioning) potential development of energy use in global energy demand are projected to increase until 2030 and then stabilized. In the same way, energy demand for air-conditioning is projected to increase rapidly in the period between 2016-2100, as driven by income growth. The impact on cooling (air-conditioning) energy demand is found to increase by72%. Morna *et.al.* (2018) also found out that cooling increases with statistic collected by (IEA) for U.S and Europe. The US department of energy data book (2016) reported energy consumption through air conditioning for residential buildings to be only 10.4kw/m2 nationwide. Similarly, that of residential buildings in Japan is less than 3.8kwh/m in the same year.

Godwin, (2014) maintained that generally the study area of Kwara in Southern Nigeria enjoys good climate and may be described as moderate, having no extremes of heat and cold. In this area, the designs could be passively cooled without the need of active energy. However, Sangowawa *et al* (2016) in their study concluded that the use of air conditioning in Minna is inevitable. They noted clearly that attempt can only be made to reduce the energy consumed by the system.

At the same time, Adebamowo *et al* (2017), in their study of low energy design in the study area, justified the use of air conditioning in Kwara. They also identified the problem of dust• Laden atmosphere of Kwara and the prevailing noise and vehicular pollution in the high density city for use of air-conditioning. This is in addition to high humidity reaching over 80% in the morning, and rarely dropping below 65% in the afternoon. While minimum temperature occurs in the evening and early morning, the afternoon comes with high temperature and consequently requiring high demand of energy to ameliorate the condition. They further put the typical heating calculated for residential building in Kwara as corresponding to a cooling load between the ranges of 100-175W/m.

Homer (2013), in his study according to Voss *et al* (2017),revealed that building technology accounts for up to 20-30% of investment cost, with lower usable spaces and uses the largest part of energy consumption. Aligning with this, Pathen*et.al*, (2018), study on UK domestic home air-conditioning reveal that different type of air conditioner units affect energy consumption, depending on the average indoor temperature setting. The study show that an overall Energy Efficiency Ratio (EER) of 5-10% was revealed by single split units, while less than 1 % was found for portable units tested. This could mean that the type of air conditioner, temperature setting, and average operation duration are responsible for cooling load and consequently energy consumption in buildings. The work of Hwang *et al*; (2018), suggested that the temperature setting for air conditioning system can be raised to 2°c higher than conventional setting for reduction in energy consumption, where every 1 °c increase in the most start setting may lead to a reduction of 6% in energy consumption according to Ayinsley, (2017) study.

2.1.4 Lighting Energy Consumption

End use energy for lighting in buildings can either be active driven or passive as the case may be. Passive energy for lighting in buildings usually refers to a day lighting system which is nature-driven. A day lighting system has a number of elements, most of which must be incorporated into the building design at an early stage. This can usually be achieved when considerations are given in relation to the incidence of day lighting on the building

These may include:

1. The orientation, space organisation and geometry of spaces requiring Lighting.
2. The location, form and dimensions of the opening through which daylight will pass.
3. The location and surface properties of the building's internal partitions which may reflect the daylight and play a part in its distribution.
4. The location, form and dimensions of movable or permanent devices which may provide protection from too much light and glare.
5. The light and thermal characteristics of glazing material used in the building.

These considerations were based on a study of an office room carried out in Athens, London and Copenhagen. The finding indicated that artificial lighting almost represents about 35% of the total lighting, cooling and heating cost throughout a year. In essence, it implies that correct day lighting will reduce energy consumption in relation to artificial lighting. This could diminish the possibilities of having to use mechanical devices to cool rooms that may be overheated by low efficiency lighting fittings and appliances. Achieving good day lighting to minimize energy consumption will require designing of the building opening and glazing for a correct balance between the heat gain and loss that may result from the transmission of thermal radiation in and out of the building and the light entering into the building. Careful considerations are therefore required in maximizing natural lighting through good orientation and geometry of spaces as well as location, form and opening dimensions in buildings.

The active energy lighting in buildings usually refers to as artificial lighting which is as a result of bad designs. Many researchers have carried out studies in this respect for energy efficiency. Haas (2017), considering energy efficiency indicators in residential sector, identifies lighting and appliances as fourth in the use of energy consumption in residential building sector. He further identified dwelling areas as an important explanatory variable for lighting, despite highly efficient Compact Fluorescence Lamp (CFLs) as a better indicator for measuring the intensity of energy consumption. This is simply an application of the product of the usage, efficiency and service level. The importance and application of artificial lighting in contributing to the increase in energy consumption is further stressed in Lam *et al*. (2015), study which revealed that lighting accounts for 20-35% of the total energy consumption in tropical buildings. The study concludes that for purposes of energy efficiency, the use of free natural lighting (day lighting) as a source to provide sufficient illumination level should be encouraged between the hours of 8.30am - 5.00pm, when solar intensity is able to provide sufficient daylight luminance of about 100 LUX. Zafer and Arif (2018), study estimating the energy and energy utilization efficiency for residential and commercial sector in Turkey energy consumption is noted that electrical energy use for lighting range first to other uses. This further corroborates other views on the importance of artificial lighting in energy consumption.

However, according to a study carried out by World Business Council for Sustainable Development (WBSCD) (2017), on the indicators of energy efficiency, lightning is found to consume about 18% of energy use in buildings. This improvement may not be unconnected with development of high energy efficient lighting fittings. A further study by Li and Tsang (2018) on facade engineering design to aid artificial lighting improvement showed that good building facade design utilizing day lighting can reduce over 25% of total electric lighting energy consumption. While recommending that attention should be given to issues of glare and solar heat gain in building, Yang *et al*; (2010)'s study on major factors on energy consumption in Chinese residential building identifies difference in lifestyle as one of the key factors that affects lighting energy consumption. It was also noted in the study that the luminosity of a Lamp is measured by the size of a room, as key determinant to the service level as a service demand indicator for lighting consumption.

Further study by Rahamatabadi and Tomshimalani (2019), on energy efficiency concluded that utilized energy in building by electrical appliances and equipment including lighting consumed about 35% of energy consumption. This is in reference to IEA and OCOED countries indices. Yao *et al.*.(2012), in an holistic method to assess energy efficiency, categorises lighting as a weighted indicator for energy efficiency indicators for residential building facilities assessment, as ranking second to Air conditioning in energy consumption rate. This agrees with the works of Yang *et al* (2010), which confirmed the importance of lighting issue on energy efficiency towards designing of residential buildings.

However, it is pertinent to note that Eti-osa *et al*; (2015), report on energy efficiency survey in six major cities in Nigeria and noted that major challenges had been experienced in formulating a viable energy policy for the country. This has undermined the importance and gain of energy efficiency on environment and economic growth. The report also noted that a lot of energy is wasted in Nigeria, because both private and public households, offices and industries, use old and inefficient equipment and production process. Other findings include the dominant use of incandescent light bulbs, while people living in low voltage supply area use between 1 00w and 200w in order to get a good level of luminance for tasks.

The tendency to use artificial lighting for advert purposes for goods and switching them on during the day and night was also identified as one of the areas of inefficient energy consumption. Similarly, the outdoor lighting during the day is a usual occurrence; despite the finding of experts that day lighting utilization is effective at the same period. According to available statistical data, as revealed in the 2016 national survey, more than 50% of regular households in Kwara use electricity as their main source of lighting fuel. This figure represents about 1,891,540 households, and may also be significant in considering energy consumption in the study area. At present only about 10,323,427 households in Nigeria use electricity for lighting purposes (federal bureau of statistic 2012). Lighting, therefore, constitutes an important factor in considering a design for energy efficiency in the residential building sector for the control of energy consumption.

2.1.5 Ventilation Energy Consumption

Ventilation usually refers to the rate of air movement m and around buildings. In architectural design, it is used to drive effective cooling for the comfort of the occupant. This cooling could be achieved in building design through passive and active energy means. Natural cooling in building is achieved by air movement through wind pressure differential and temperature gradient effect. The stack design effect can be put to effective use in order to release unwanted heat from a building via court yard or atrium. This does not involve any energy consumption in buildings. This creation of natural air movement phenomena gives rise to the intake of air from the building into the sun space, thereby leading to a cross ventilation for cooling. In other words, mechanical system driven or powered by electrical energy are sometimes used at homes in occupied spaces including heat generating spaces such as living room and kitchen.

The energy consumption of the mechanical systems employed for ventilation purposes could sometimes be enormous. The energy consumption of devices such as fans, and extractors can only be controlled by manufacturers of the products through their ratings for efficiency. These products of energy efficiency controls are absolutely unavailable in the Nigerian market.
The effect of ventilation cooling in building is however determined by the thermal condition of the building and occupants responses to temperature ranges at the same time. This response varies from different climatic regions and is controlled by outdoor and indoor temperatures in and around buildings most of the time.

According to studies, Sawachi (2016) identifies the possibilities of reducing the use of air• conditioning by supplementing it with passive measure for enhancing thermal comfort. In this regard, he suggested the use of window opening and turning on of fans (adaptive measure), since fans are seldom use alone. Macarthney and Nicol, (2016) study, shows that more Adaptive Approach towards temperature control might be beneficial both in terms of energy consumption and in occupant's comfort, especially during summer. It realized that thermal comfort in real life is more dynamic of the indoor temperature (momentary), while outside temperature obviously results in some energy saving.

Ventilated cooling, on the other hand could, be achieved through the opening elements in buildings, usually the windows. Various studies undertaken in this area revealed that, the level of success of ventilation depends on the rate of air movement, window glazing, window sizes, their position and orientation. Also of importance to occupants to achieve good ventilation cooling are the available control means. The building form, shape and orientation also play a significant role for its attainment.

Asimakopoulus and .Santamouris (2015), in their study conclude the shapes of the building can affect natural ventilation, since area of low and high pressure has an influence on it. However, further study by Stelios *et al*. (2012), observed that the buildings shape does not affect performance concerning natural ventilation. This is because air speed and air flow around studied model do not show any significant measure at the level of openings. However ventilation cooling is only applicable to naturally ventilated and mixed-mode buildings.

2.1.6 Energy Consumption Indicators

One of the most effective means of reducing building energy consumption is the assessment of building energy efficiency. However, this cannot be achieved without identifying those factors and indicators that encourage intensive energy consumption. This section identifies these indicators, as they may affect energy consumption in the residential buildings. Many researches have been carried out on the indicators of energy consumption. Adebamowo (2017); Olaonipekun (2012); Burbery (2017); and Lutzenhenzer (2014) identified dwelling characteristics such as orientation, shape and size, site location, use of buildings, design Layout and building envelope as important factors which influence energy consumption pattern. However continuous researches on this have led to different categorisation of factors with various identified indicators weighting. Yang *et al*. (2010) categorises the factors that influence energy consumption into five different areas viz:

1. Building Design with three indicators involving orientation, shape and outdoor environment of building.
2. Building Envelope performance with indicators including insulation, air tightness and shading.

3. Building energy efficiency facilities with indicators encompassing HAVC, lighting and water facilities.
4. Building operation and Management. Involving indicators as facilities operation, qualification and energy efficiency consumption statistic awareness.
5. Comfort and Health with indicators capturing indoor thermal environment, lighting, acoustic and indoor air quality.

Yang *et al*. (2010) and Yao et, al. (2015) list of identified indicators agree and cover such as have been proposed by Cong *et al*.207 Wang, 2016, and Lin et, al. 2016. These were derived from four rules that include: Feasibilities, Completeness, Effectiveness and Multi-attribute decision making rules.

A critical assessment of these indicators reflects a purely technical submission as the human behavioural control is conspicuously absent. However, the need for energy consumption indicators in the residential sector is further strengthened through understanding the components of change in household energy use, which provide the key to strategic planning for future energy use, This, according to Bass's, (2015) study, is therefore more important to show which aspect of housing population, dwellings, equipment stock and other structural parameters influence energy consumption by end use. The study however identifies structure, climatic demography behaviour, technical and economic factors as some of the driving parameters for energy consumption. Understanding these parameters easily lead us to variables explaining household energy demand such as household population, energy prices, individual attitude, life style with regard to time spent at home or work. The dwelling area in respect of structure, efficiency in terms of technology of home equipment, while climate specifically signify differences in heating and cooling degree days as policy address issues of taxes and demand side management.

2.1.6 Environmental Factors and Energy Consumption

This section examines the impact of environmental factors on energy consumption and their relationship with residential household's internal condition in the built environment, emphasizing their effect on occupant's behavioural actions. The built environment is formed by the buildings and other objects constructed in the natural environment. According to Mason and Hughes, (2016), modem buildings have various purposes, but all provides an internal environment different from the external. At the same time, a climate of the natural environment, the shelter of the built environment and human activities are linked by physical process and an outline of independent relationship. It is therefore the environmental factors which drive this relationship that explain energy demand. This factors is referred to as environmental variables. This section therefore identifies and examines their influence on energy consumption.

However, a building's first mam function is to protect occupants against harsh outdoor climate and provide a comfortable and healthy environment for them at the same time. In providing for this comfortable and healthy environment some factors have been identified through research that determines it. These factors are referred to as Thermal Comfort determinants. The technical aspects of these factors are responsible for occupant's behavioural action which determines the energy consumption of households. This has been identified as environmental variables in energy study. They include: Air Temperature, Mean radiant Temperature (MRT), Air movement (Velocity), Relative Humidity (RH) However for the purpose of energy study, the environmental variables directly responsible for energy consumption in most researches have been emphasized. They are:

1. Indoor and outdoor temperature
2. Indoor and outdoor relative humidity

This is founded on the premised that the Air and Mean Radiant Temperature determine the indoor temperature hence the thermal comfort temperature that drives the energy consumption.

2.1.6.1 Air Temperature

The air temperature of an internal space (room) in a building varies from spot to spot. Humphrey (2016) found out that the temperature measured near ceiling level in a school classroom with warm air convector heating can be as much as 10°k higher than the temperature experienced by the children on the floor. In this study area, daily maximum temperature is usually between 29°c and 31"c which usually occurs during the day in the hottest month of February and March. However measurements for both outdoor and indoor DBT, the diurnal range was between 1"e-3"c which is significant to energy consumption.

However Adebamowo' s (2017) study in Kwara found out that occupants still express satisfaction with 27°c indoor temperature in most residential buildings. The implication of this to energy consumption is that occupant's available control of operating fan or au conditioner could be made depending on the building mode of the household. Kwara minimum temperature usually occurring between the evening and the early morning, and the day temperature is usually high. This usually has a significant effect on energy consumption, as the city is noted for hybrid of day activities. Going by the indication of the IPCC report, the surface temperature for Kwara increased by about 1 °c in the period between 1970 and 2018, and prediction that the last decade of the century (2090-2099), that the temperature would increase by 3'c03.5c. The effect on energy consumption is better imagined, as suggested by Nicol et, al. (2015) in the three reasons why thermal comfort is important. The temperature which people try to achieve in their house is an important factor which determines the amount of energy it will use. The influence of the air temperature is therefore such that it determines the indoor comfort temperature of the internal building environment, and consequently the indoor air quality in a naturally ventilated building. This is also true for the cooling temperatures in mixed mode and mechanical ventilated buildings.

2.1.6.2 Relative Humidity

The changes in the amount of precipitation and variation in humidity (both outdoor and indoor), to a great extent, affect both consumption and production of energy. This study demonstrates that significant impact on energy demand is due to higher indoor temperature and humidity which could consequently raise demand for air condition during the day in the study area. Kwara has a warm humid climate with humidity reaching over 80% in the morning, but rarely dropping below 65% in the afternoon. This is the major cause of discomfort in households. This dehumification process has strengthened the choice of air conditioning in Kwara which has become highly necessary for indoor environment. Sangowawa and Adebamowo's (2010), study makes relative humidity significant to energy consumption in the study area. The impact, according to most researches, is responsible for up to 60% of energy consumption in tropical buildings. High values of RH were generally observed in most households where measurement were taken, the study recorded indoor RH mean value of 64.7% as the outdoor mean RH value stood at 66.7% respectively, during the period of field measurement in the study area.

2.1.6.3 Air Velocity

This is the rate of air exchange in buildings which aids occupant's ventilation comfort. It is usually achieved by air movement through buildings, which can be induced by stack effect, wind pressure differential, or mechanical means such as fans, evaporative coolers and air conditioners. External features which include, numbers, size and position of openings components are some of the factors that affect air flow through buildings, hence air velocity. Air velocity which is responsible for air flow around building is therefore determined by the shape, height, orientation and planning of building (Givoni, 2016).

Energy consumption in relationship to air velocity can be seen from both passive and active consumption. The passive energy is determined by the wind pressure differential which is responsible for air flow around buildings and is driven nature. This is majorly relied on in natural ventilation building mode and aided by building opening characteristics. The active energy consumption is usually depended on in both mixed and mechanical mode buildings, to aid indoor climatic condition for ventilation and cooling. This is through electrical appliances such as fans and air conditioners in the study area. The warm humid climate of the study area makes the use of mechanical aids employable to aid air movement due to the high rate of presence in the air. However, a recommended standard of wind velocity in the city centre by IHVE guide is 3m/s which are rarely attainable, thereby necessitating the use of these electrical appliances for occupants cooling comfort.

2.1.7 Occupants' Behavioural Actions and Energy Consumption

Energy consumption in buildings and residential buildings uses a greater percentage of energy end use in the attainment of indoor comfort, specifically thermal comfort. Research findings show that in most tropical buildings, air conditioning system accounts for 30%-60% of energy use for cooling and dehumification purposes (Yao *et al*.; 2012, Rahadmatabadi 2019 and Momal*et.al* 2018).This is essentially used in maintaining good thermal environment through the use of various available control mechanisms, as provided by design for occupants.

In view of the above, this section explores the impact of thermal comfort attainment on energy consumption in the study area. Thermal comfort is a psychological phenomenon defined by the American Society of Heating, Refrigeration and Air conditioning Engineers (ASHRAE) as "that state of mind which expresses satisfaction with thermal environment". Most researchers identified and agreed that air temperature, relative humidity, solar radiation, air movement, clothing, metabolic activity comprise the six factors that determine thermal comfort. While the first four factors are identified as being climatic, the other two can be classified as personal. It is vital to note that both have an impact on the amount of energy consumption in residential building. Adebamowo's (2017) study on this in Kwara found that occupant is comfortable in the range of 27c indoor temperature and 70% relative humidity. This is however slightly higher than (ASHRAE 55-2018) recommendation, which makes adaptation of occupants very vital to both thermal comfort attainment and energy consumption implications.

Many researches on occupants' behaviours show interesting finding. Dick *et al*, (1951) for instance, found out that United Kingdom field study demonstrated that there is a correlation between the ratio of open window and outer temperature. While extensive studies on the relationships between occupants' adaptive behaviours and thermal environment, with respect to regions and survey attributes as well as types of adaptive behaviours are found to include: opening windows, turning fans and air condition on and off and changing clothing, (Raja *et al*, 2016, Nicol *et al*, 2018, Rijal *et al*, 2017a, 2017b, Carli *et al*, 2017, Yun *et al*, 2017, Herhel *et al*, 2018 and Robinson *et al*, (2018). It is however noted that occupants of dwelling houses have greater freedom to control their environment than occupants of offices.

As Nicol *et al* (2018) pointed out the necessity of examining a combination of behaviours, stating that the use of one control may change the use of another. This could, to a greater extent, determine the intensity of energy consumption of the households. However, Sawachi (2016) on the possibility of reducing the use of AC by supplementing it with passive measures for enhancing thermal comfort found out that the methods will be limited to when temperature exceeds 30°c in temperate region. This inversely implies its limitation to adaptive temperature not exceeding 27c in the study area.

Adebamowo (2017) and Takashi *et al* (2018) observe that in all cases, occupants' behaviour, with respect to opening/closing windows, turning fans and AC on and off are significantly described by the indoor and outdoor temperatures, than other variables. The study therefore concludes that passive behaviours by occupants such as opening windows and using fans reduce temperature at which AC was switched on for temperatures as from 25'c to 30'c.They however, cautioned that it had little effect in the reduction of the temperature at which AC was switched on in high temperate environment, such as the study area.

Rijal *et al* (2018), deducing reasons for the use of building control, highlighted the tendency for people to open windows and use fans more often, if they would like to feel cooler and to use heating more often if they would like to feel warmer. Exploring the interaction between window opening and other control found out that the likelihood of window opening is higher when the fans are not switched on for all building types. While the proportion of window opening is low when the air-conditioning is running (AC on), except in Europe, as the proportion of window is less when heating is on. The study therefore concludes that window opening behaviour is consistent with energy saving. This is with the exception of window opening in some buildings when the cooling is on.

Occupants' adaptation strategy to thermal comfort on the other hand, necessitates their dependants on the available design social and physical characteristics of the building opportunity to attenuate their thermal environment. This ability of occupants to change their behavioural attitude also goes a long way to determine the amount of energy consumption of households. This is however premised on the building design ventilation mode of the household. Natural ventilated household's mode provides control tendency to window opening, which contributes to reduce energy and passive in nature. This is however applicable when the weather outside is not very hot. This accords with (Kolokotrom *et al*., 2016) assertion that naturally ventilated buildings consume less than half as much as energy those with air conditioning. Reliance on the provision of mechanical systems to alleviate the more extreme condition is however energy intensive.

Again, the choice of air conditioning has also been strengthened by the problem of dust-laden atmosphere of Kwara and the prevalent noise and vehicular pollution in high density communities and commercial capital of Nigeria (Sangowawa, and Adebamowo 2010). This makes mechanical ventilation and air conditioning a necessity for occupants thermal comfort satisfaction in the study area. This does not encourage energy conservation and efficiency. While changes in the amount of precipitation and variation in humidity, wind pattern and number of sunning days per year could also affect energy consumption and production, understanding the tropical bioclimatic architectural concept could be the first step to optimizing energy consumption in the warm humid climate zone of Kwara. This is further confirmed in Steven et, al.(2017) on ASHRAE 55-2018 adaptive method examination and review which identify limitation on its application to mix-mode design, though coupled with unfamiliar calculation and compliance. The mix• mode is a hybrid approach to space conditioning that uses a combination of natural ventilation from openable windows (either manually or automatically controlled) and mechanical system that provides air distribution and some form of cooling (air conditioning, radiant cooling etc.). This is with the realization that by utilizing mechanical cooling only when and where it is necessary to supplement the natural ventilation, a well-designed mixed• mode building offers the potential to improve the indoor environment air quality, while minimizing the significant energy consumption.

2.1.8 Energy Consumption Control in Buildings

Until recently, energy research in architecture has focused on individual building component and characteristics, rather than the whole building system for optimal design. It is therefore necessary for designers to understand the building as a dynamic energy system. This is explained in the interrelationship between passive and active energy system. According to Busch (2017), in passive and low energy cooling of building, the physical processes have been characterised and understood since the last century. The recent concern is on the identification of how these processes interact to affect energy consumption pattern for the building as a whole. The role of buildings in energy consumption will therefore include and not limited to the following:

1. Energy consumption process and Interactions patterns
2. Identification of sources of Energy for consumption
3. Energy Consumption Optimization
4. Energy Conservation and Efficiency

Previous studies made by Givoni *et al.* (2016) and Robert agreed that buildings use energy for heating, cooling, lighting, ventilation, cooking and for operating equipment and appliances for the comfort occupants of building. As it relates to the warm humid climate of Kwara, the concern will be on cooling, lighting and ventilation for a sustainable living condition. However, pattern of energy use is strongly influenced by architectural designs and the activities that occur within several building types, the energy cost and economics. Added to this is the issue of building materials used for construction and consideration for environmental architectural design factors. The prevailing climate change scenario as they affects energy usage is an important consideration as well. Great architects and their works in the past greatly rely on passive energy and as such were deeply influenced by climatic principles. Markus and Moris (2018), Adebamowo's (2017) studies affirmed that before necessary measurements and theoretical method were developed, the application of climatic knowledge to building designs was based on the architect's knowledge in classical theories of elements, personal observation and, to some extent, the living vernacular tradition which they observed. Such were reflected in the works of great designers like Vitruvius, Alberti, Paladio, Frank Llyod Wright, Le Corbusier, Gropius and host of others. The departure from this knowledge base caused the energy crisis in the late 70s which witnessed climate change scenario and global warming effect. This, alongside the works of scholars such as of Peter (2016), makes sustainable (low energy) designs a serious issue of concern in the built environment. The main aim of low energy designs is to maximise comfort for building occupants, while minimising and ultimately eliminating fossil based energy use. Movement for this innovation identified six performance indicators as a condition for the attainment of a sustainable design. While three are design based, three are mainly infrastructural in nature. This research is however concerned with the Design based indicators such as Operational Energy, Embodied Energy and Biodiversity.

Operational Energy: Energy consumed during the in-use phase of a building life. In relation to sustainable construction, the operational energy use of a building is its biggest environmental impact. Therefore, reducing the operational energy use and increasing durability should be the prime concerns of Architect who wish to design and build "green buildings"

Embodied Energy: This refers to the energy consumed by the processes associated with the production of a building from the mining and processing of natural resources to manufacturing, transportation and product delivery.

Biodiversity: This is the variety of different types of life found on earth and the variations within species. It is a measure of the variety of organism present in different ecosystem: Biodiversity conservation is about saving life on earth and keeping the natural ecosystems functioning and healthy.

As it relates to energy, it is the source of energy with particular relevance to carbon emission and the impact on ecosystem and environmental impact, having direct relevance to global warming effect and occupants' health and general condition.

The environmental consideration in building designs is therefore primarily aimed at maximising passive system so as to reduce reliance on active system that uses energy. This makes operational and embodied energy a great concern to designers. Both determine, to a great extent, the active energy consumption of any building. However, of concern is the fact that, the integrated planning needed for most of the passive cooling and natural ventilation concept is rarely realised at the building design stage. This is because of the lateness in the consideration of energy issue, such as detailed building technology at a stage when all decisions concerning building characteristics had already been taken. But for Pears (2013), the issue is hinged on the sustained growth in the household income over the last couple of decades, with falling real prices of air conditioners equipment and electricity tariff. Extending this view, Pareto (2015) noted that energy used in air conditioned building is about twice that of naturally ventilated buildings. This accord with previous views noted by researchers. This aggregated view therefore suggests a hybrid design situation for possible conservation and efficient energy consumption in form of a mixed mode buildings, most especially in a warm and humid climatic situation of Kwara. To this end, bioclimatic tropical architecture needs to be generally encouraged and adopted in the residential built environment.

Some research suggestions have also been given. For instance, Ashok and Ruchi (2017), proposed that the first level of energy economy in building is an informed assessment of needs and standard for climatic zone of concentrated urban development. Also, there is the suggestion that traditional passive strategy for climatic comfort display new exigencies of city living. It is also suggested that new material and technology of construction are responsible for poor thermal performance of most construction. This, as a consequence, results in poor energy use in buildings. It could be understood from most studies in energy efficiency, that our traditional passive strategies could not be completely abandoned for new construction materials. At the same time, the peculiarity of our climatic zone should be well understood and applied to design so as to achieve optimal energy use through good thermal building performance and occupant's thermal comfort satisfaction.

Jacob (2017) also identified new trends in architectural designs, of a better insulated and more air tight envelopes, resulting in modem buildings being less able to lose heat naturally. What results is a more reliance on effective ventilation for passive cooling. The study justified this through the social trend of occupants' reluctance to leave window open, particularly in urban areas, because of noise, air quality (pollution) and security issue. Also is the fact that modem homes have more number of electrical appliances and lighting fittings, which further raise internal heating. The result is a high energy use. In summary, the dynamic interrelationship of energy and architecture in the built environment in recent time is the resultant sustainable issue of energy optimization and efficiency issues in design towards behaviour of occupant and the nature of specific climate differ on basis of regional, national and international locations.

2.2 Related Empirical Studies

Ali (2012) carried out a research on Electrical Energy Efficiency Improvement in Commercial Buildings: A Case Study of Selected Bank Buildings in Zaria. The study used energy audit to determine where, when, why and how electrical energy is being used in selected bank buildings in Zaria. The information was used to identify opportunities to improve efficiency, decrease energy cost and reduce greenhouse gas emissions that contribute to climate change. The study employed both primary and secondary sources of data. Questionnaires were the instruments of the primary data collection while information from manufacturers' manuals, catalogues and maintenance records of the banks constituted the secondary data. The findings indicated that the average electrical energy consumption and cost for the four (4) bank buildings are 7,412.26 kWh/month and N63,004 14/month before retrofitting. The actual energy consumed (estimated wattage Rating on nameplate of appliances/equipment) was also calculated and compared to the consumed energy using One-way ANOVA. It was concluded that energy usage in the bank buildings involved much wastage especially in the area of lighting, cooling and plug loads. An energy efficiency programme which covers lighting, cooling and the plug loads was recommended.

The above study is related to the present study because both studies discussed electrical energy efficiency, they tend to differ in the instruments for data collection where this study employed both the use of questionnaires and interview to collect data, the present study used questionnaire alone.

Saba *et al*., (2016) (a) conducted a research on Level of Electrical Energy Management Practice Awareness Among Residents in Niger State, Nigeria. The study investigated the level of electrical energy management practices awareness among residents in Niger State, Nigeria. The study adopted Cross Sectional Survey Research Design. The population of the study was made up of 191,416 heads of household in residential buildings that are connected to the distribution network in 25 Local Government Areas of Niger State. The sample of the study consisted of 1,290 heads of house hold in residential buildings, drawn through Multi-stage Sampling Techniques. Three research questions were formulated to guide the study. The instrument used for data collection was a structured questionnaire. Statistical Package for Social Sciences (SPSS Version 19) was used for data analysis. Mean and Standard Deviation were used to answer the research questions. The finding of the study shows that, residents in Niger State were somehow aware of electrical energy management practices in lighting, cooling and heating systems and the use of electric motors. Base on these findings, the following recommendations were made: Electricity Management Board in collaboration with Energy Commission of Nigeria and Center for Energy Efficiency and Conservation should jointly organize public enlightenment campaigns to promote awareness on electrical energy management practices in lighting, cooling and heating systems and the use of electric motors.

The above study is related to the present study because both studies discuss electrical energy savings/management, while this study is carried out in residential buildings.

Saba *et al.,* (2016) (b) carried out a research on Behavioural Approaches to Electrical Energy Management in Residential Buildings in Niger State, Nigeria. The study adopted Cross Sectional Survey Research Design. The population of the study was made up of 191,416 heads of household in residential buildings that are connected to the distribution network in 25 Local Government Areas of Niger State. The sample of the study consisted of 1,290 heads of house hold in residential buildings, drawn through Multi-stage Sampling Techniques. Two research questions were formulated to guide the study. The instrument used for data collection was a structured questionnaire. Statistical Package for Social Sciences (SPSS Version 19) was used for data analysis. Mean and Standard Deviation were used to answer the research questions. The findings of the study shows that, consumers in Niger state rarely adopted the following human behavioural practices; utilization of low wattage lamp to provide required light, usage of appropriate colour for walls and ceilings for better illuminations, switching off light when not in used and they also practiced electrical load management habits at very high extent; ironing of cloth at the peak period and utilization of incandescent and halogen bulbs during peak period. It was recommended among others that; Policy and law makers with a sense of urgency should formulate policies and laws that will help in changing human behaviour and there should be more awareness on electrical load management habits among residents in order to cultivate positive practices towards energy usage during the peak period of electricity usage.

The above study is related to the present study because both studies discuss electrical energy savings/management, both study is carried out in residential buildings. This study is carried out in Niger State.

Maytham *et al*., (2017) carried out a research on Awareness on Energy Management in Residential Buildings; A case study in Kajang and Putrajaya. Two research objectives were used, two research questions and two research hypotheses were used. A survey research was used in the research work. Questionnaires were developed with 37 questions grouped in 5 different sections related to home appliance information. Data was collected from a sample size of 384 respondents with confidence level of 95%. The accuracy of the percentage energy usage data were analysed by applying the SPSS software. Actual residential electric power consumption was measured by using a power quality analyzer to determine the total power consumption at weekday and weekend and power consumption of each electrical appliance. The measurement results showed that the average energy consumption is 25.8 kWh/day during weekend and 21.9 kWh/day during weekdays with 11.5 kWh/day for the air conditioner only. The survey results revealed that 89.06% of the respondents expressed awareness toward household power consumption and that they are willing to install home automation system to reducing their electricity bill.

Both studies, are related because they are both dealing with electrical energy management, though this study is carried on residential buildings.

Hammad, (2018) carried out a research on comparative study of energy consumption between various hospitals in Malaysia. The buildings' sector consumes about 15% of the total energy consumption in Malaysia. Of the biggest contributors to this figure are hospitals, which usually use energy above average due to their operation hours, occupants, and complex services. A survey study was conducted during various energy management system audits to Malaysian hospitals where important data for energy, load apportioning, and significant energy users are collected and comparatively analyzed. The data spans the period of three years from 2015 up till 2017 and the hospitals are categorized by their number of resident specialties and subspecialties. From the study, it was estimated that in 2015, district hospitals consume in average 2,237,776 kWh having a BEI of 148.92kWh/m2.year; minor specialist hospitals consume in average 6,155,092 kWh having a BEI of 216.62 kWh/m2.year; major specialist hospitals consume in average 17,848,413kWh having a BEI of 241.89 kWh/m2.year; general hospitals consume in average 28,224,856 kWh having a BEI of 240.96 kWh/m2.year. The load apportioning for 5 different hospitals were also analyzed and it was found that HVAC contributes to about 69% of the total load in hospitals. The study also found in 2016 that, the impacts of El Niño Southern Oscillation event to hospitals' energy consumption increased the energy consumption up to 13.6% depending on the types of hospitals. The study concluded with ways that could improve energy performance in hospitals from various angles that include technical, management and system improvement.

Both studies are analysis of electrical energy and are both survey researches. This study was carried out in Malaysia with three main objectives, while the present study was carried out in Niger State.

Oyeleke (2018) carried out a research on Comparative Analysis of Household Energy Consumption in Ibadan Region; A Spatio-quantitative Approach. Understanding locational variations in household energy consumption is critical to ascertaining dichotomies of energy use, need and wellbeing. In recognition of this, the study compares quantities of household energy consumption among urban, peri-urban and rural areas in Ibadan region, Nigeria using Net Heating Value (NHV). It employs a stratified random sampling of 166 households across the three zones. Results show that electricity, majorly used for appliances is dominant in the urban in contrast to fuel wood at the peri-urban and rural areas where cooking is the major end use. Though the quantities of total household energy consumption do not vary significantly at $p < .05$, electricity consumption is however significantly higher in urban households than in peri-urban and rural households. The Multiple Regression Analysis (MRA) and Analysis of Variance (ANOVA) indicate that socioeconomic characteristics significantly influenced quantity of household energy consumption at the urban area only. Major variations between locations appear to be in energy types and end uses rather than quantity consumed.

2.3 Summary of Literature Reviewed

The study assess electrical energy usage in residential buildings in Minna Niger State. The study reviewed on the building characteristics which plays a significant role on energy consumption since energy and building relationship are dynamic in nature. The residential building types and their characteristics vary in accordance with their regional climatic condition and cultural setting. It also reviewed the energy consumption in residential buildings. Residential buildings account for more than 20% of total energy consumption. The residential building uses energy for heating and cooling, lighting, Ventilation, Water heating, and for operating equipment and appliances. Also few related empirical studies were also highlighted in the study. The study intend to fill the gap on energy minimization in residential buildings in Minna, Niger State.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Research Design

This study employed a descriptive survey method because it involves the use of questionnaire to help in determining the opinion of the respondents. Udogu (2014) stated that a survey research as a descriptive study are plans, strategies and structured employed towards obtaining answers to research questions and hypothesis. He further added that it covers the outline of what the researcher intends to do up till the final analysis. In the same angle, this study seeks the opinion of respondents on assessment of electrical energy usage in residential buildings in Minna, Niger State.

3.2 Area of the Study

Niger State is a state in Central Nigeria and the largest state in the country. Niger State between Longitude 6° 32’ 51.94” and Latitude 9 ° 331 and 9 ° 40 North and 6 ° 351 East. It is in the North Central Zone and occupies an area of approximately 29,484 square area in the present political zoning system. It's cover the distance 76,363 km^2 from Jebba to Abuja, Nigeria's federal capital.. The state capital is Minna, and other major cities are Bida, Kontagora, and Suleja. It was formed in 1976 when the then North-Western State was bifurcated into Niger State and Sokoto State. It is home to Ibrahim Babangida and Abdulsalami Abubakar, two of Nigeria's former military rulers. The Nupe, Gbagyi, Kamuku, Kambari, Dukawa, Hausa and Koro form the majority of numerous indigenous tribes of Niger State (United Nation, 2010).

3.3 Population of the Study

The population of the study comprises of three hundred (300) residential buildings in which one hundred and fifty (150) residential building is for private owners and one hundred and fifty (150) residential building is for civil servant owners. The population of the study is classified as shown in table 3.1 below.

Table 3.1: Population distribution of the study

Respondents	**Number**
Private owners	150
Civil servant owners	150
Total	300

3.4 Sample and Sampling Techniques

A purposive sampling technique was used for the study. Purposive sampling is a non-probability sampling method and it occurs when “elements selected for the sample are chosen by the judgment of the researcher. Researchers often believe that they can obtain a representative sample by using a sound judgment, which was result in saving time and money. Three hundred respondents were used.

3.5 Instrument for Data Collection

A structured questionnaire titled; Assessment of Electrical Energy Usage in Residential Buildings in Minna Niger State. This was developed by the researcher and will be used for data collection.. Each part of the questionnaire is divided into section A and section B. Section A sought for information on personal data while section B sought for information on the research questions. A four point rating scale of measurement will be used for section B. Section B consist of research question one with seven (7) items which sought for information on the characteristics of selected residential buildings, with respect to their energy consumption in Minna Metropolis, research question two consist of fifteen (15) items which sought for information on the energy consumption indicators of residential buildings in Minna Metropolis while research question three consist of eleven (11) items which sought for information on the impact of environmental factors on energy consumption in residential buildings in Minna Metropolis

3.6 Validation of the Instrument

Copies of the drafted instruments was subjected to face and content validation by three lecturers in Department of Industrial and Technology Education, Federal University of Technology Minna. The experts wias requested to suggest modifications on the structure of items, organization and assess appropriateness of the study. Their suggestions and corrections for improvement on the language level, technical terms and content of the instrument will be used to refine the items before the final copy of the instrument will be produced.

3.7 Reliability of the Instrument

A pilot study was conducted to test the internal consistency of the instruments by administering the questionnaire to building owners in Paikoro L.G.A. The generated data was analyze using the Cronbach's alpha to test the reliability and value calculated was 0.76.

3.8 Method of Data Collection

The method of data collection was through administration and collection of the questionnaire from the respondents by the researcher and two research assistants. The questionnaire was administered to the respondent and was collected after a week interval from the date of administration. The total questionnaire that was distributed is hundred (300).

3.9 Method of Data Analysis

Data collected for this study was analyzed by computing the mean and t-test statistics. Mean will be used to answer the research questions while Independent t-test was used to test the hypotheses at 0.05 level of significance. A four-point Likert rating scale was used for research questions one to three. Decision on the research questions was based on the resulting mean scores. Standard deviation will be use to decide on the closeness of the respondents to the mean of their responses.

Any item with a mean of 2.5 and above was consider required while item with a mean below 2.5 was considered not required. Independent t-test was used to test the hypothesis at 0.05 level of significance.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Results

4.1.1 Research Question One

What are the characteristics of selected residential buildings, with respect to their energy consumption in Minna Metropolis ?

The results is presented in Table 4.1 .

Table 4.1: Mean and standard deviation of respondents on the characteristics of selected residential buildings, with respect to their energy consumption in Minna Metropolis.

S/N	Items	$\bar{X}_1$ n_1=120	$\bar{X}_2$ n_2=125	$\bar{X}_T$ N=225	SD	Decision
1	Detached house	3.5	3.05	3.27	0.98	Agreed
2	Terrace house	3.00	2.55	2.78	0.83	Agreed
3	Semi-detached house	3.30	2.38	2.84	1.04	Agreed
4	Block of 6 flats	3.30	2.77	3.03	1.34	Agreed
5	Bungalow	3.40	2.97	3.18	1.05	Agreed
6	Rooming house	2.90	3.26	3.08	0.97	Agreed
7	Face to Face House	3.60	3.12	3.36	0.98	Agreed

Key: $\bar{X}_1$ = Mean response of Private owners, $\bar{X}_2$ = Mean response of Civil servant owners, n_1 = No of Private Owners, n_2 = No of Civil Servant owners, $\bar{X}_T$ = Average mean response, SD= Standard Deviation

Table 4.1 shows the responses of respondents on the characteristics of selected residential buildings, with respect to their energy consumption in Minna Metropolis. The result revealed that all the items agreed with the mean range from 2.78-3.36 on the characteristics of selected residential buildings, with respect to their energy consumption in Minna Metropolis. The result also revealed that the standard deviations (SD) of all items are within the ranges from 0.83 to 1.34, each of these values was less than 1.96 which indicated that respondents were not too far from the mean and from one another in their responses on the characteristics of selected residential buildings, with respect to their energy consumption in Minna Metropolis. This indicated agreed that most of the residential buildings consumes energy.

4.1.2 Research Question Two

What are the energy consumption indicators of residential buildings in Minna Metropolis? The results is presented in Table 4.2

Table 4.2: Mean and standard deviation of respondents on the energy consumption indicators of residential buildings in Minna Metropolis.

S/N	Items	$\bar{X}_1$ n_1=120	$\bar{X}_2$ n_2=125	$\bar{X}_T$ N=225	SD	Decision
1	Indoor thermal Environment	3.40	3.34	3.37	0.97	Needed
2	Lighting of the building	3.40	3.08	3.24	0.97	Needed
3	Acoustic of the building	2.90	3.28	3.09	0.91	Needed
4	Indoor air quality	3.50	3.20	3.35	0.89	Needed
5	Lighting and water facilities	2.90	3.05	2.97	1.07	Needed
6	Insulation of the building	2.60	3.37	2.98	0.91	Needed
7	Air tightness and shading of the building	3.70	3.14	3.42	1.06	Needed
8	Facilities operators qualification	3.20	3.14	3.17	1.00	Needed
9	Energy efficiency consumption statistic awareness	3.50	3.26	3.38	0.87	Needed
10	Outdoor environment of the building	3.40	3.06	3.23	1.04	Needed
	Heat, Air, Ventilation and Cooling (HAVC)	3.40	3.06	3.23	1.09	Needed
11	Indoor thermal humid environment	3.40	3.29	3.35	1.01	Needed
12	Occupancy Rate	3.60	3.22	3.41	1.04	Needed
13	Outdoor thermal temperature	3.50	3.38	3.44	0.86	Needed
14	Size of Building	3.80	3.31	3.55	0.90	Needed
15	Indoor thermal Environment	3.40	3.31	3.35	0.95	Needed

Key: $\bar{X}_1$ = Mean response of Private owners, $\bar{X}_2$ = Mean response of Civil servant owners, n_1 = No of Private Owners, n_2 = No of Civil Servant owners, $\bar{X}_T$ = Average mean response, SD= Standard Deviation

Table 4.2 shows the responses of respondents on the energy consumption indicators of residential buildings in Minna Metropolis. The result revealed that all the items agreed with the mean range from 2.97-3.55 on the energy consumption indicators of residential buildings in Minna Metropolis based on the decision. The result also revealed that the standard deviations (SD) of all items are within the ranges from 0.82 to 1.07, each of these values was less than 1.96 which indicated that respondents were not too far from the mean and from one another in their responses on the the energy consumption indicators of residential buildings in Minna Metropolis This indicated most of the respondents agreed on the energy consumption indicators of residential buildings in Minna Metropolis.

4.1.3 Research Question Three

What is the impact of environmental factors on energy consumption in residential buildings in Minna Metropolis? The results is presented in Table 4.3

Table 4.3: Mean and standard deviation of respondents on the impact of environmental factors on energy consumption in residential buildings in Minna Metropolis.

S/N	Items	$\bar{X}_1$ n_1=120	$\bar{X}_2$ n_2=125	$\bar{X}_T$ N=225	SD	Decision
1	Take bath more often	3.50	3.25	3.37	0.97	Needed
2	Change cloth to light clothing	3.30	3.40	3.35	1.06	Needed
3	Get more cold drink	3.40	3.26	3.33	1.07	Needed
4	Open windows and doors wide	3.80	3.25	3.52	0.63	Needed
5	Switch on fan	3.30	3.25	3.27	1.06	Needed
6	Switch on Air-conditioner	3.90	3.28	3.59	0.32	Needed
7	Go outside for fresh air or to the cooler places	3.80	3.22	3.51	0.42	Needed
8	Change cloth to heavy clothing Closing the windows	3.60	3.23	3.42	0.70	Needed
9	Turn up some lighting fixtures	3.90	2.80	3.51	0.82	Needed
10	Lighting a heater	2.30	2.94	2.55	1.05	Needed
11	Take bath more often	3.00	2.35	2.97	0.48	Needed

Key: $\bar{X}_1$ = Mean response of Private owners, $\bar{X}_2$ = Mean response of Civil servant owners, n_1 = No of Private Owners, n_2 = No of Civil Servant owners, $\bar{X}_T$ = Average mean response, SD= Standard Deviation

Table 4.3 shows the responses of respondents on the impact of environmental factors on energy consumption in residential buildings in Minna Metropolis. The result revealed that all the items agreed with the mean range from 2.58-3.59 on the impact of environmental factors on energy consumption in residential buildings in Minna Metropolis based on the decision. The result also revealed that the standard deviations (SD) of all items are within the ranges from 0.12 to 1.26, each of these values was less than 1.96 which indicated that respondents were not too far from the mean and from one another in their responses on the impact of environmental factors on energy consumption in residential buildings in Minna Metropolis. This indicated most of the respondents agreed on the impact of environmental factors on energy consumption in residential buildings in Minna Metropolis

4.2 TESTING OF HYPOTHESES

4.2.1 Hypothesis one

There is no significant difference between the mean score of civil servant building owners and private building owners on the characteristics of selected residential buildings, with respect to their energy consumption in Minna Metropolis.

Table 4.4: t-test analysis on the characteristics of selected residential buildings, with respect to their energy consumption in Minna Metropolis.

Variables	N	Mean	SD	Df	T	p-value
Private owners	120	3.32	0.46	223	1.37	0.175
Public Owners	125	3.13	0.39			

Table 4.4 shows the comparison of t-test of the mean rating of the responses of the respondents on the characteristics of selected residential buildings, with respect to their energy consumption in Minna Metropolis. The results revealed that the mean and standard deviation of private owner are 3.32 and 0.46 while the mean and standard deviation of public owners are 3.13 and 0.39 respectively. Since the p-value (0.175) is greater than 0.05, the result revealed that there was no significant difference between the mean ratings of private owners and public owners on the characteristics of selected residential buildings, with respect to their energy consumption in Minna Metropolis Therefore, the null hypothesis was accepted.

4.2.2 Hypothesis two

There is no significant difference between the mean score of civil servant building owners and private building owners on the energy consumption indicators of residential buildings in Minna Metropolis

Table 4.5: t-test analysis on the energy consumption indicators of residential buildings in Minna Metropolis

Variables	N	Mean	SD	Df	T	p-value
Private owners	120	3.37	0.44	223	0.96	0.34
Public Owners	125	3.23	0.41			

Table 4.5 shows the comparison of t-test of the mean rating of the responses of the respondents on the energy consumption indicators of residential buildings in Minna Metropolis. The results revealed that the mean and standard deviation of private owners are 3.37 and 0.44 while the mean and standard deviation of public owners are 3.23 and 0.41 respectively. Since the p-value (0.34) is greater than 0.05, the result revealed that there was no significant difference between the mean ratings of private owners and public owners on the energy consumption indicators of residential buildings in Minna Metropolis. Therefore, the null hypothesis was accepted.

4.2.3 Hypothesis three

There is no significant difference between the mean score of civil servant building owners and private building owners on the impact of environmental factors on energy consumption in residential buildings in Minna Metropolis.

Table 4.6: t-test analysis on the impact of environmental factors on energy consumption in residential buildings in Minna Metropolis

Variables	N	Mean	SD	Df	T	p-value
Engineers	125	2.70	0.27	223	0.78	0.69
Electrical Technicians	120	2.96	0.42			

Table 4.6 shows the comparison of t-test of the mean rating of the responses of the respondents on the impact of environmental factors on energy consumption in residential buildings in Minna Metropolis. The results revealed that the mean and standard deviation of private owners are 2.70 and 0.27 while the mean and standard deviation of public owners are 2.96 and 0.42 respectively. Since the p-value (0.69) is greater than 0.05, the result revealed that there was no significant difference between the mean score of civil servant building owners and private building owners on the impact of environmental factors on energy consumption in residential buildings in Minna Metropolis. Therefore, the null hypothesis was accepted.

4.3 Summary of Major Findings

1. It was revealed that the respondents agreed that the selected residential buildings consume energy
2. The respondents agreed on the energy consumption indicators of residential buildings in Minna Metropolis.
3. The respondents agreed on the impact of environmental factors on energy consumption in residential buildings in Minna Metropolis
4. There was no significant difference between the mean score of civil servant building owners and private building owners on the characteristics of selected residential buildings, with respect to their energy consumption in Minna Metropolis.

5. There was no significant difference between the mean score of civil servant building owners and private building owners on the energy consumption indicators of residential buildings in Minna Metropolis.
6. There was no significant difference between the mean score of civil servant building owners and private building owners on the impact of environmental factors on energy consumption in residential buildings in Minna Metropolis.

4.4 Discussion of Findings

The findings on the characteristics of selected residential buildings, with respect to their energy consumption in Minna Metropolis revealed that most of the respondents agreed on it, among them are detached house, terrace house, semi-detached house, block of 6 flats and Bungalow. The findings corroborate with the study of Nicol *et al*. (2015) who study of occupants control of temperature in mixed mode buildwings seems to provide a design solution in the inevitability scenario of air-conditioning and end energy use control in the study area. A building that is heated in winter, free-running in mid season and has cooling available in summer, as required, is called a 'MIXED-MODE' building. They are usually characterised as likely to consume less energy than a fully air conditioned building. Their energy consumption as well depends greatly on how occupants use the available control, such as windows, fans, heating and cooling technology. It was also reported that International Energy Agency (IEA 2018) pointed out that worldwide, households consume about 1/3 of the total end use energy. Sureh *et al*. (2019) study indicated that US residential buildings account for more than 20% of total energy consumption.

The findings on energy consumption indicators of residential buildings in Minna Metropolis revealed that the respondents agreed on the energy consumption indicators of residential buildings. The findings agreed with Adebamowo (2017); Olaonipekun (2012); Burbery (2017); and

Lutzenhenzer (2014) that identified dwelling characteristics such as orientation, shape and size, site location, use of buildings, design Layout and building envelope as important factors which influence energy consumption pattern. However continuous researches on this have led to different categorisation of factors with various identified indicators weighting. Furthermore Adebamowo' s (2017) study in Kwara found out that occupants still express satisfaction with 27°c indoor temperature in most residential buildings. The implication of this to energy consumption is that occupant's available control of operating fan or au conditioner could be made depending on the building mode of the household. Kwara minimum temperature usually occurring between the evening and the early morning, and the day temperature is usually high. This usually has a significant effect on energy consumption, as the city is noted for hybrid of day activities.

The findings on the impact of environmental factors on energy consumption in residential buildings in Minna Metropolis revealed that the respondent agreed on the impact of environmental factors on energy consumption. According to Mason and Hughes, (2016), modem buildings have various purposes, but all provides an internal environment different from the external. At the same time, a climate of the natural environment, the shelter of the built environment and human activities are linked by physical process and an outline of independent relationship. It is therefore the environmental factors which drive this relationship that explain energy demand. The findings concur with Oyeleke (2018) carried out a research on Comparative Analysis of Household Energy Consumption in Ibadan Region; A Spatio-quantitative Approach. The Multiple Regression Analysis (MRA) and Analysis of Variance (ANOVA) indicate that socioeconomic characteristics significantly influenced quantity of household energy consumption at the urban area only. Major variations between locations appear to be in energy types and end uses rather than quantity consumed.

CHAPTER FIVE

5.0 SUMMARY CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The study assessed the electrical energy usage in residential buildings in Minna Niger State. Three objectives were formulated to guide the study and three research questions were raised to guide the study. The study revealed that the respondents agreed that the selected residential buildings consume energy. It was also revealed that respondents agreed on the energy consumption indicators of residential buildings in Minna Metropolis. Furthermore the study also shows that there is the impact of environmental factors on energy consumption in residential buildings in Minna Metropolis. The study conclude that the paradigm shift in the living condition of most residential occupants is due to their upward comfort requirement and increased economic level of income, make indoor comfort a significant problem of high energy consumption.

5.2 Recommendations

Based on the findings of the study, the following recommendation were made;

1. The buildings owners should erect their residential building in a comfortable way that will reduce energy consumption
2. The government should establishes a proper policy for residential buildings in an effective minimize way to reduce any consumption
3. The residential occupant should also ensure that the environmental factors that lead energy wastage are being controlled to a reasonable level.
4. The energy agency such as AEDC, DISCOs and NERC should ensure that prepaid meters are installed in most residential buildings, so as to take readings of energy consumed.

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APPENDIX

QUESTIONNAIRE ON ASSESSMENT OF ELECTRICAL ENERGY USAGE IN RESIDENTIAL BUILDINGS IN MINNA NIGER STATE

Dear respondent,

This Questionnaire is designed to obtain information on **Assessment of Electrical Energy Usage in Residential Buildings in Minna Niger State**. Please, kindly assist by filling the necessary information where appropriate. Any information obtained will be held in strict confidence and will be used solely for the purpose of this academic study. Please tick or write in the appropriate location.

SECTION A

Civil Servant owners [ ]

Private owners [ ]

SA= Strongly Agree (4 points)
A= Agree (3 points)
D= Disagree (2 points)
SD= Strongly Disagree (1 point)

SECTION B

Research Question One

What are the characteristics of selected residential buildings, with respect to their energy consumption in Minna Metropolis ?

S/N	ITEMS	SA	A	D	SD
1.	Detached house				
2.	Terrace house				
3.	Semi-detached house				
4.	Block of 6 flats				
5.	Bungalow				
6.	Rooming house				
7.	Face to Face House				

Research Question Two

What are the energy consumption indicators of residential buildings in Minna Metropolis?

S/N	ITEMS	SA	A	D	SD
1.	Indoor thermal Environment				
2.	Lighting of the building				
3.	Acoustic of the building				
4.	Indoor air quality				
5.	Lighting and water facilities				
6.	Insulation of the building				
7.	Air tightness and shading of the building				
8.	Facilities operators qualification				
9.	Energy efficiency consumption statistic awareness				
10.	Outdoor environment of the building				
11.	Heat, Air, Ventilation and Cooling (HAVC)				
12.	Indoor thermal humid environment				
13.	Occupancy Rate				
14.	Outdoor thermal temperature				
15.	Size of Building				

Research Question Three

What is the impact of environmental factors on energy consumption in residential buildings in Minna Metropolis?

S/N	ITEMS	SA	A	D	SD
1.	Take bath more often				
2.	Change cloth to light clothing				
3.	Get more cold drink				
4.	Open windows and doors wide				
5.	Switch on fan				
6.	Switch on Air-conditioner				
7.	Go outside for fresh air or to the cooler places				
8.	Change cloth to heavy clothing				
9.	Closing the windows				
10.	Turn up some lighting fixtures				
11.	Lighting a heater				