ASSESSMENT OF ELECTRICAL ENERGY CONSUMPTION IN SOME SELECTED TERTIARY INSTITUTIONS ADMINISTRATIVE BUILDINGS IN NIGER STATE

BY

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ABSTRACT

High electrical energy consumption in public buildings and institutions is a major challenge to many nations over the world, particularly in developing countries. Meanwhile, inadequate empirical studies on building energy use had resulted into paucity of electrical energy data most especially buildings in tertiary institutions in Nigeria where bulk metering is the usual practice; thereby making energy consumption of individual building remains unknown. This study sought to assess the electrical energy consumption in some selected tertiary institutions administrative buildings in Niger State with a view to reducing electrical consumption and improving energy efficiency. An experimental data collection was conducted where direct field measurements were carried-out with a real-time Efergy wireless energy (EW4500) monitoring device. Where the current transformer sensors were clipped to the main panel distribution board of the administrative buildings of the Federal University of Technology Minna, Niger State Polytechnic Zungeru and the Niger State College of Education Minna respectively. In order to achieve the aforementioned aim, the set objectives are to; evaluation of electrical energy consumption of selected administrative buildings, compare the total consumption of the three different buildings studied, and compare also the energy consumption pattern of the three different buildings. The mean electrical energy consumed at the administrative blocks of the Federal University of Technology Minna, Niger State Polytechnic Zungeru, and Niger State College of Education Minna was collected on hourly pattern (1 hour) for the period of three (3) months and the results were as follow; for FUT Minna 2034 KWh/m^2, 1579.1 KWh/m^2, 2379.8 KWh/m^2, 2604.7 KWh/m^2, for Zungeru Polytechnic were 1579.1 KWh/m^2, 1636.2 KWh/m^2, 1637.7 KWh/m^2, 1581.9 KWh/m^2, and for COE Minna were 1579.1 KWh/m^2, 41636.2 KWh/m^2, 1637.7 KWh/m^2, and 1581.9 KWh/m^2 respectively. The hourly consumption patterns showed a distinct significant seasonal variation, indicating peak of electrical energy consumed at the early working hours at the studied administrative buildings during when the buildings were occupied by staff. The amount of energy consumed in the studied administrative buildings depends on many factors. The results showed that the administrative building of the Federal University of Technology Minna and the Niger State Polytechnic Zungeru were above the global best practices of 128KWh/m^2 and 130KWh/m^2 according to the Chartered Institute of Building Services Engineers (CIBSE) and the Building Energy Efficiency Guideline for Nigeria (BEEGN) benchmarks when compared, while the energy consumed at the Niger State College of Education Minna administrative block was within the benchmarks. In conclusion, the results depicted that the significant levels of the mean electrical energy consumed in the senate building of the Federal University of Technology Minna, and the administrative block of the Niger State Polytechnic were high which inplied that these institutions administrative buildings were energy inefficient while that of the administrative block of Niger State Collecge of Education Minna was within the benchmarks. Therefore, the study recommends the need for dedicated and effective monitoring of energy consumption through audit of the administrative buildings of FUT Minna and Zungeru Polytechnic.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

There has been a dramatic increase in the world‘s energy consumption, which has risen at an alarming rate. This occurs due to the global increasing pattern of building energy consumption. Growth in population, the rise in demand for building services and higher comfort levels together with the increased time spent inside buildings have led to increased global consumption of electrical energy and resources in the building sector (Pérez-Lombard *et al.,* 2008; International Energy Agency IEA, 2015; Allouhi *et al.,* 2015). In particular, buildings energy consumption accounts for approximately 40% of global electrical energy consumption and it is projected that commercial building energy use will grow worldwide with the arising living standard in future decades (Xing *et al.,* 2011; Urge-Vorsatz *et al.,* 2013; Nejat *et al.,* 2015; Ibn-Mohammed *et al.,* 2015). The International Energy Agency (2017) has gathered frightening data on energy consumption trends. Energy use by nations with emerging economies (Southeast Asia, Middle East, South America and Africa) will grow at an average annual rate of 3.2% and will exceed by 2020 that for the developed countries (North America, Western Europe, Japan, Australia and New Zealand) at an average growing rate of 1.1%.

Throughout the world electrical energy is the most widely used and desirable form of energy (Oyedepo, 2012a). It is the bedrock, indispensable driving force and essential ingredient as well as a basic requirement for socio-economic growth and development (Oyedepo, 2012b; Onakoya *et al.,* 2013; Oyedepo *et al.,* 2015). There is hardly any aspect of modern life that does not have the imprint of electrical energy input. Be it entertainment, recreation, agriculture, commerce, industry, transport, education, communication, health, architecture and many others (Unachukwu *et al.,* 2015).

However, high electrical energy consumption is a key issue facing all sectors of any economy worldwide and Nigeria is not exempted from the issue of high electricity demand (Ubani, 2013).

High electrical energy consumption in public buildings/institutions is a major challenge to many nations over the world, particularly in developing countries (Bos *et al.*, 2018). Low-efficient electrical appliances, poor building envelopes and poor energy conservation practices are major contributing factors to the high electrical energy consumption (Wang *et al.*, 2016; Chwieduk, 2017; Ding, *et al.*, 2018; Gyam, *et al.*, 2018; Nunayon, 2018). Studies have shown that energy efficiency standards and benchmarks for buildings and electrical appliances are crucial in reducing building energy consumption and carbon footprint (Chartered Institution of Building Services Engineers CIBSE, 2004; Energy Efficient Strategies & Maia Consulting, 2013; International Energy Agency IEA, 2017).

The Nigerian Electricity Regulatory Commission, NERC, approved an over 50 per cent hike in electricity tariff payable by customers of the 11 Distribution Companies, DisCos. The Daily Trust reported that a Multi-Year Tariff Order (MYTO) signed by the new Chairman of NERC, Sanusi Garba, on December 30, 2020, showed that the new tariff increase took effect on January 1, 2021.

Unlike the erstwhile order implemented in 2020, which exempted low power consumers, the revised Service Based Tariff (SBT) also saw increase in the rates payable by all classes of electricity users (Oladeinde, 2021). The Vice-Chancellor, University of Lagos (UNILAG), Professor Oluwatoyin Ogundipe has expressed concern over the sharp increase in electricity. Ogundipe, who raised the alarm recently, while giving an account of his stewardship during a media parley in Lagos, said before the COVID-19 lockdown, UNILAG was paying between N61 million and N62 million monthly as electricity bill, but with the increase in tariff, the university will be paying more than N90 million when students return to their hostels. The vice-chancellor said he checked other universities and found out that the situation is the same, saying there is hardly any university that can afford to pay such exorbitant charges in the country (Funmi, 2021; Iyabo, 2021). This has also been the case with the Federal University of Technology Minna, Niger State with an unusual and excessive increment of electricity tariff for the school from the Abuja Distribution Electricity Company (ADEC).

This prompted the Vice-Chancellor to call for a meeting with the school management and staff to notify them and to seek a solution to the present increase of electricity tariff and cost. At the conclusion of the meeting, the Vice-Chancellor decided to rationalize the usage of electricity between the student's hostel and the school campus for the best interest of the school. The Niger State College of Education Minna is not exempted from this situation, as the provost of the institution solicits for help from the Niger State governor to increase the student's fee in order for the school to meet up with the payment of the electricity and other bills (Funmi, 2021; Iyabo, 2021). It was learnt that the authorities of the University of Ibadan, UI, the Obafemi Awolowo University, OAU, and the University of Calabar among others have had serious faceoffs with DISCOs in their areas over the same issue (Adesina, 2021).

Higher institutions, such as universities, consume large amounts of energy on a daily basis. Improving the energy practices at post-secondary institutions can not only directly decrease their environmental impact but also act as an example for change across the country. Because of their peculiar nature as knowledge transfer-based institutions, the electrical energy source predominantly in use in tertiary institutions for educational aids is electricity (Unachukwu, 2010). Electrical energy consumption in university buildings is mainly driven by various factors such as; building type, building age, occupancy, operating hours, type of equipment installed and weather conditions.

Therefore, the issues of electrical energy availability, consumption in tertiary institutions with resident students, staff quarters and non-residential buildings can present a formidable challenge to any responsible administration. This is because its availability or otherwise can have profound effects not only on academic activities but also on the social and economic activities in the system (Akanmu *et al.,* 2019). It is against this back-drop that this study seeks to assess the electrical energy consumption in some selected tertiary institutions administrative buildings in Minna, Niger state.

1.2 Statement of the Research Problem

In 2001, an investigation on the end-use efficiency of electrical energy by households in Lagos Metropolis, Nigeria, revealed that the cause of waste of energy resulted from two factors according to Otegbulu (2011) and these are: (i) the use of inefficient technologies or equipment. (ii) behaviourial pattern of consumers. Not only is electrical energy consumption a significant cost to the university management but it also contributes to the depletion of natural resources and environmental problems. At colleges, polytechnics and universities, electrical energy consumption has a high impact on finance (Choong, *et al.,* 2012). According to Bosch and Pearce (2003) and Entrop *et al.* (2010), clients are faced with the problem of insufficient information and tested benchmarks on the actual electrical energy consumption in the built environment, especially in tertiary institutions. University managements are unaware of the actual electrical energy saving capability of sustainable technologies especially in improving existing buildings. By addressing these problems, tertiary institutions and particularly users will be provided with the tools needed to make decisions about the type, the nature and the extent to which sustainable technologies are adopted. The following questions would be addressed in the course of this study;

i. What is the actual electrical energy consumption in the administrative buildings?

ii. Is there a relationship between the actual electrical energy consumed and existing benchmarks/standards?

iii. Are there strategies that could be adopted in optimizing energy consumption?

1.4 Aim and Objectives of the Study

The aim of this study is to carry out the assessment of electrical energy consumption in some selected tertiary institutions administrative buildings in Niger State, with a view to reducing electrical consumption and improving energy efficiency. In order to achieve the aforementioned aim, the set objectives are to;

i. Evaluation of electrical energy consumption of the selected administrative buildings.

ii. Compare the total energy consumption of the three different buildings studied.

iii. Evaluate and compare the energy consumption pattern of the three different buildings.

1.5 Justification for the Study

Balancing electrical energy supply and demand in a power system in real time has always been a global practical challenge with the energy safety gap being below anticipated margins. Nikolaou *et al.* (2009) posited that the lack of building energy consumption detail is a critical impediment in analysing and drawing conclusions on the building stock with regards to their energy performance. According to the Nigeria Energy Support Programme (NESP) (2013) and the Federal Ministry of Power, Works and Housing (FMPWH) (2016), energy efficient buildings are buildings that consume less energy and at the same time maintaining and improving the comfortability of the users within the buildings (Geissler *et al.*, 2018).

The electrical energy consumption has a significant impact on the environment, economy, and health of the general public as well as is an important factor in the overall operations of most institutions and its efficient use helps to ensure the sustainability of their operations. As at the time this research was conducted, there were lack of data on the actual electrical energy consumed in the selected administrative buildings of the tertiary institutions to help building energy administrators (works and maintenance unit) manage energy use across the buildings of the tertiary institutions. However, understanding the electrical energy consumption of the selected administrative buildings in tertiary institutions would help to identify areas of inefficiency, inform policy decisions regarding energy efficiency, areas of potential savings and to develop strategies to reduce energy consumption. This study was considered important as it will help the management of tertiary institutions to enact appropriate legislation in order to enhance energy conservation opportunities in the buildings.

1.6 Scope and Delimitation of the Study

The scope of the research was basically concerned with assessment of electrical energy consumption, in this case, educational (non-residential) buildings. Therefore, the focus of the study covered the some selected tertiary institutions administrative buildings in Niger State which were; the Federal University of Technology Minna, Niger State Polytechnic Zungeru and Niger State College of Education administrative block in Minna, Niger state where energy consumed was collected on hourly (1 hour) pattern for three (3) months. The delimitation of the study was as at the time this research was carried out the architectural drawing for the Niger State College of Education Minna administrative block was not available.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Overview of Energy Use in Built Environment

Energy is an indispensable factor and a major determinant of the socio-economic growth and life quality all over the globe (American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), 2013; Kousksou *et al.*, 2014). The continuous increase in energy use by buildings sector globally has been a major source of concern. Statistically, between 2005 and 2011 the observed average annual growth of energy use in buildings was 3.15%. While in 2011, the global energy consumption rate was 8.92 Gigaton of oil equivalent/year (Gtoe/year). This has been predicted to increase to 14 Gtoe/year by 2020. This growing trend has been predicted to continue especially nations with emerging economies like Africa, South America, South-east Asia and Middle East (Energy Information Administration, EIA, 2008). The EIA report in 2022 predicts that the global energy consumption rate will be 16.03 Gtoe/year (EIA, 2022).

Meanwhile, brief overview of building energy demand of few developed nations shown that, in United States of America building sector consumes about 40% of energy supply and responsible for nearly 40% of greenhouse gas emissions. While in China, above 25% of entire energy use is consumed by the building sector, projection has shown that the figure will increase to 35% by year 2020. Furthermore, United Kingdom (UK) estimation stood between 40-50% of all the energy use and over 100 million tons of CO_2 emission per annum (Pout *et al.*, 2002; Perez-Lombard *et al.*, 2008; Bouchlaghem, 2012). Equally, in India building sector accounted for 35% of the of the total energy consumption (Manu *et al.*, 2016). Also Nigeria building sector consumed about 40% of electricity supply (Akinbami & Lawal, 2009), while energy scenario has shown that there was a gross inadequacy coupled with the epileptic nature of the supply (Aderemi, *et al.,* 2009; Noah *et al.,* 2012) only about 40% of the population have access to electricity supply (United Nations Development Programme UNDP, 2011).

A considerable literature exists on attempting to model and examine the determinants of electricity demand function within the context of developed and developing countries. Ward *et al.* (2008) carried out a sector review of United Kingdom (UK) higher education energy consumption. The findings indicated that energy consumption in the sector has been on the increase in the last 6 years up to 2006; rising by about 2.7% above the 2001 consumption levels. Gross internal area, staff and research student full-time equivalent were found to have highest correlation with energy consumption across the sector.

Rosin *et al.* (2010) analysed household electricity consumption pattern. The study found that loads with shiftable consumption (water heaters, dishwashers, and washing machines), almost shiftable loads (refrigerators, boiling kettles, coffee machines, floor heating, irons, and vacuum cleaners) and non-shiftable loads (Television sets, Personal Computers (PCs) with a modem, home cinema and music centers, cooking stoves, kitchen ventilation, bathroom lighting and ventilation) respectively accounted for 54%, 10%, 36% of the total consumption. Considering electricity consumption by customers' need or action, they found that eating, hygiene and free time/vacationing accounted for 31%, 56% and 13%, respectively. On the workday, two peak periods were detected: the morning and the evening. Both peak periods were in the high tariff period and consumption was affected mostly by water heater, cooking stove and lighting consumption.

However, on the holiday, the two peak periods detected were the midday and the evening. These peak periods were in the low tariff period and consumption was mostly caused by water heater, cooking stove and lighting consumption. Sapri and Muhammad

(2010) reviewed the state of knowledge of energy performance monitoring in the context of higher education institution in Malaysia. The study identified that developing a comprehensive building energy performance information system as one of the ways of promoting environmental sustainability in higher educational institutions.

Ekpo *et al.* (2011) empirically investigated the dynamics of electricity demand and consumption in Nigeria between 1970 and 2008 using Bounds Testing Approach. The results showed that real GDP per capita, population and industrial output significantly drives electricity consumption in the long-run and short-run while electricity price is not a significant determinant. Hawkins *et al.* (2012) investigated determinants of energy use in UK higher education buildings using statistical and artificial neural network methods. For University Occupier Buildings (UOB) it was found that generally electricity use is high and heating fuel use is low relative to the CIBSE TM46 benchmarks for the University campus category. There was appreciable variation in energy use between different university-specific building activities. Activity was also shown to have a high ANN causal strength together with material, environment and glazing type.

Emeakaroha *et al.* (2012) examined the challenges in improving energy efficiency among students in a University Campus. The results showed that immediate energy feedback from smart meters or display devices in addition to appointing an energy delegate in each hall to induce motivation among the students can provide savings of 5%–15%. Ahmad *et al.* (2012) presented the results of energy management program carried out at the Faculty of Electrical Engineering, Universiti Teknologi Malaysia. Various energy savings activities such as electricity tariff modification, energy management awareness campaign, energy consumption monitoring system and energy efficient lighting retrofits were initiated. The study showed the program has shown encouraging results with a reduction in the electricity consumption and provide further avenue for continuous energy saving programs. Lo (2013) analysed the energy conservation situation in China's higher education institutions (HEIs). A case study was conducted in Changchun, Jilin, where eight HEIs of various types were examined. The findings indicate that the HEIs have implemented comprehensive non-technical initiatives to conserve electricity, including electricity restrictions and extensions of winter breaks, as well as certain technical initiatives.

Tang (2012) carried out an energy consumption study for a Malaysian University to obtain information on the number and specifications of electrical appliances, built-up area and ambient temperature in order to understand the relationship of these factors with energy consumption. He reported that air-conditioning; major electrical appliances (computers, printers, fax machines and photocopy machines); lighting and other electrical equipment (microwave ovens and fans) consumed 50%, 30%, 19% and 1% respectively. It was found also that the number and types of electrical appliances, population and activities in the campus impacted the energy consumption of Curtin Sarawak directly. However, the built -up area and ambient temperature showed no clear correlation with energy consumption. An investigation of the diurnal and seasonal energy consumption of the campus was also carried out. From the data, recommendations were made to improve the energy efficiency of the campus.

Aishwarya *et al.* (2013) discussed the magnitude of voltage and current flowing through the campus of Easwari Engineering College, variation of peak load and calculation of maximum demand were also noted. An alert indicating the rise in power consumption was used as a monitoring system. Data obtained were grouped based on the service supplies - lighting, fans, air conditioning, computers, and miscellaneous. The results showed that fans, lighting, computers, Air conditioning, Uninterrupted Power Supply

(UPS) and motors respectively consumed 6%, 7%, 19%, 23%, 12%, 14% while miscellaneous consumption was 19%. Manjunatha *et al.* (2013) conducted energy audit at BMS Institute of Technology, Yelahanka, Bangalore, to seek the opportunities to improve the energy efficiency of the campus. Beyond simply identifying the energy consumption pattern, the audit sought to identify the most energy efficient appliances. Moreover, some daily practices relating common appliances have been provided which may help reducing the energy consumption.

Abimbola *et al.* (2015) investigated energy use pattern and emission discharge in Nigeria. Results obtained indicated strong relationship between energy use and emission with significantly different emission generation. The study concluded that about 38% and 25% reduction in global warming and acidification is achieved by a switch to prepaid meter for both income earners. A few studies on electricity in university have also been conducted (Adelaja *et al.,* 2008; Unachukwu, 2010; Oyedepo *et al.,* 2015).

2.2 Energy Consumption in Existing Buildings and the Environment

In the global efforts to reduce energy consumption and associated greenhouse-gas GHG emissions, research has shown that energy consumption in buildings has exceeded that of the industrial and transport sectors in many parts of the world (Perez-Lombard *et al.*, 2008). According to the United Kingdom Office of National statistics, estimates show that new buildings account for approximately 1% of the stock each year in the United Kingdom and in the United States of America, the Energy Information Administration reports that existing buildings make up close to 99% of the total building stock. It is similar in other developed and developing countries (Yohanis, 2012).

New buildings contribute only 2% to existing building stock, thus 98% of stock already exists (Australian Bureau of Statistics, 2012). This is a source of concern because the vast majority of the buildings to be occupied in the next 30 years or so have already been built (Gelfand & Duncan, 2011). It is often argued that as this large stock is to cater for the increase in population, a large proportion consume more energy thereby negatively affecting the environment as a result of greenhouse gas emissions.

Unfortunately, existing buildings are associated with several weaknesses such as defects (Ren & Chen, 2015), corrosion of steel components in old buildings (Demoulin *et al.*, 2010), heat losses as a result of poor insulation (Brunoro, 2006), highly unclassified (Theodoridou *et al.*, 2011) air infiltration (Brinks *et al.*, 2015) and leakages (Tiberio & Branchi, 2013). The leakages and other associated defects can be attributed to differences in design and workmanship (Laverge *et al.*, 2014). The natures of existing buildings and associated weaknesses have generated concerns about possible energy use and other environmental impacts (Kohler & Hassler, 2002).

Energy consumption of existing buildings is high. The global energy use by existing buildings is about 40% of which a significant proportion might be wasted due to various faults in building design, construction and particularly in operation (Raghunathan *et al.*, 2005; Dasgupta *et al.*, 2012). Existing buildings are responsible for 41% of energy consumption and 36% of carbon dioxide (CO_2) emissions in the European Union, and buildings consume as much as 48% and 76% of total energy use and around 38% of CO_2 emissions in the United States. Within countries of the European Union, buildings consume up to 40% total energy (Bowman *et al.*, 1997; Ürge-Vorstaz *et al.*, 2006). Similarly, buildings consume more than 50% of energy in Saudi Arabia, Bahrain, Egypt and Dubai (Al-Rabghi *et al.*, 1999; Said *et al.*, 2003).

These positioning places significant challenges on the already existing buildings, new developments, the projected increase in buildings needed to accommodate the expanding population, occupancy schedules and activities that have given rise to such energy demand in the first place. With an annual growth rate of 1.3% and projections that total global population will near 9 billion by 2030 of which up to 50% will live in urban areas (Burgess, 2000; Jenks, 2000; UNFPA, 2010; USCB, 2010), population growth can be said to be an important factor influencing building demand. This population pressure tends to deplete the time needed to restructure and evaluate the existing buildings' energy demand statuses, not to mention the new developments.

Hence, the challenge posed appears to be that of a prompt response towards achieving a balance in the provision of the human necessity of shelter along with the aspirations that come with it. As such, attention to its impact on energy and the environment tend to be relegated. According Department of Climate Change and Energy Efficiency (DCCEE 2012), energy consumption in standalone offices was estimated to be 26.4P J in 1999 and 33.6 PJ in 2009, and projected to reach 38 PJ by 2020 in Australia. This represents an increase of 14% from 1999 to 2009 and over 29% from 1999 to 2020 projections. This pattern is similar to other types of buildings studied by the Department of Climate Change and Energy Efficiency.

Notwithstanding, various schemes have been developed which attempt to reduce energy consumption in both existing and new buildings as a whole. In the case of existing buildings, various alteration and retrofit approaches have been proposed and widely used, particularly in developed countries, to incorporate new low energy technologies (Streicher *et al.*, 2007). However, this concept is not without financial implications despite the seemingly long term benefits (Mazria, 2010). Potentially, this can limit the extent and commitments to which building owners and governments/stakeholders can retrofit. For new building developments, however, "the compact city solution" or "the densification models" attract vigorous promotions as sustainable urban models for the future (Breheny, 2001; Rogers & Burdett, 2001; UNFPA, 2010). While proponents of this paradigm accept susceptibility of their model to high energy consumption, they argue that, such models are actually more energy efficient, sustainable and low in transport cost when considered as a whole system rather than viewed as individual buildings. They also argue that with the model, more valuable land is made available for agricultural use.

However, trends in technological advancements which facilitate diverse activities such as e-commerce, distance learning, shopping and social networking to take place within the comfort of our homes or workspace suggests another dimension of longer building occupational use (Perez-Lombard, *et al.* 2008) regardless of the adopted urban development model. This can automatically translate to extended hours of energy use, hence increasing carbon emissions from the built environment. Furthermore, the demand for iconic buildings suggests that modern buildings may aesthetically adhere to dictates of global mores. This is often epitomised in glazed high-rise buildings. In fact, this paradigm is overwhelmingly popular particularly in developing countries where buildings play an important role in expressing economic relevance and contemporary identity of international style reckoning (Uduku, 2006; Van-Tassel, 2006; Abu-Ghozalah, 2007).

Building projects such as the Petronas Towers in Malaysia, the Burj Khalifa in Dubai, the Hope-city in Ghana, the world Trade centre in Nigeria and the Financial Tower in Angola exemplifies this phenomenon. Each of these projects costs in excess of \$1billion. Arguably, these funds could have been better spent on social, services and technological projects (Al-Kodmany & Ali, 2012b). In Nigeria for example, basic provision of steady electricity, which is required to service these buildings, can at best described as erratic. Hence it is no wonder that the success of those building typologies is questioned in such locations (Imaah, 2004a). Indeed, Rapoport and El-Sayegh (2003) described that for most developing world, modernisation is nothing but westernisation.

Perhaps this disillusionment in itself enables the pursuit of building development while dissipating energy and environmental conscious reflections.

In sub-Saharan Africa, the demand for building is further complicated by significant shortages in housing and other building types, where the population growth rate, rapid urbanisation, poor infrastructure and limited energy alternatives still loom large (Burgess, 2000; UNFPA, 2007; UN-HABITAT, 2008). In Nigeria alone, it is estimated that there exists a 17 million housing units. Similar projections have also been estimated in numerous African countries including Angola, Zambia, Ghana and South Africa (UN- HABITAT, 2012). These socio economic pressures have undermined the importance of strategic energy planning in the overall development plan for developing countries (Foell, 1985).

Notwithstanding the dichotomy between developed and developing countries on energy, buildings and environment, it is apparent that it is increasingly becoming a fundamental challenge to develop low energy and environmentally responsive buildings. Oliver-Taylor (1993) envisioned the challenge facing building development and construction in general as that of achieving a design balance between the consumption entailed and resultant environmental quality. This will require a drastic change that may traverse orthodox design paradigms so as to incorporate all the tenets of sustainability (McLennan, 2004). Thus, a new approach is required, which encapsulates good understanding of buildings' inter-relationship with energy, energy use regulations as well as comprehensive inter disciplinary collaboration (McLennan 2004; King 2008).

2.3 Energy Performance of Existing Buildings

Globally, energy use in office buildings is about 70 to 300 kWh/m^2 per annum, 10 to 20 times that of residential buildings (Yang *et al.,* 2008). Figure 2.1 shows that the total annual energy consumed in office buildings in Australia was 33.6 PJ in 2009 which translates into 25% of the total energy consumption. Hotels used 15.2 PJ (11%), retail 47.2 PJ (35%), hospitals 19.1 PJ (14%), education buildings 17.2 PJ (13%) and public buildings 2.3 PJ (2%).

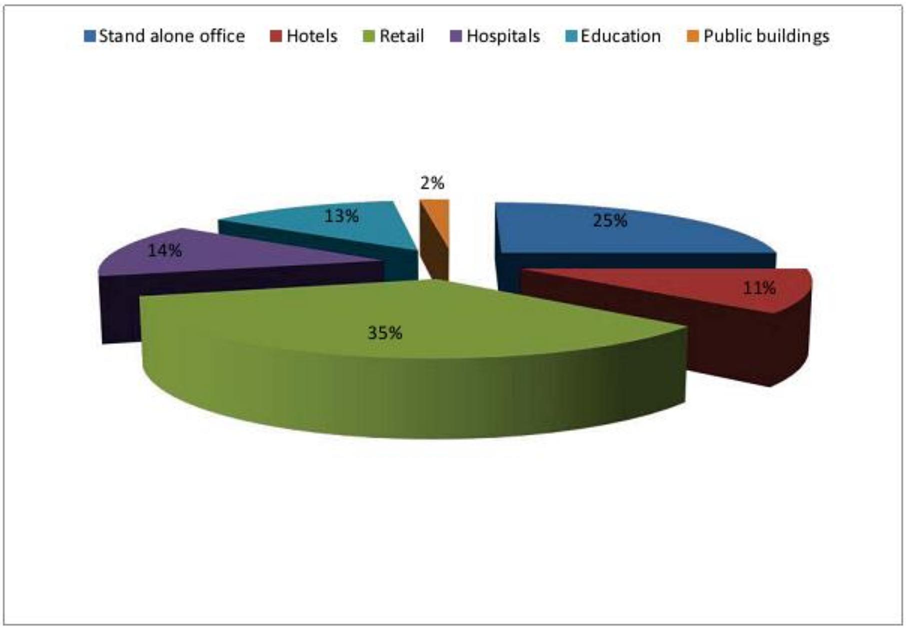

Figure 2.1: Total energy consumption by building type in Australia in 2009
Source: DCCEE, 2012

2.3.1 Policy, legislation and regulations on energy use in buildings

The challenge to reduce energy consumption in buildings has been increasing since the global concordance to reduce GHG emissions and subsequent research that showed the impact of buildings on global energy consumption. Understandably, emerging energy policies have been extended to include buildings in order to ensure a coherent approach in GHG mitigation approaches. However, even before development of energy policy at the global level as such, countries such as Sweden and Germany have been proactive in energy policies on buildings since the oil crises of the 1970s and the environmental agenda that followed (Nilsson, 2005; Wüstenhagen & Bilharz, 2006). Although their policy concerns were predominantly that of energy security, emphasis was also made on the need to conserve energy in the event of energy shortage in the future.

Although, according to Tomain (1990), “it is a mischaracterisation to apply the phrase energy policy/law to any period prior to the mid 1970’s”. He asserted that the oil supply crises following the Arab embargo in 1973 and the Iranian revolution in 1979 precipitated into a corpus of laws, forming pioneer templates for energy policies today. Also, the overarching transition in the evolving forms of energy can be said to delineate energy policy progressions (Tomain, 1990; Energy Information Administration EIA, 2009a). For example, regulations on public and private ownership of energy delivery system as well as price control mechanism became the initial sets of energy policy drivers (Tomain, 1990; Santa & Beneke, 1993). Then, the oil crises in the 1970’s, and ensuing tensions around major energy suppliers around the world as well as other issues of industrial air pollution and increased automobile use, caused a paradigm shift in energy policy towards energy security and independence (Hudson & Jorgenson, 1974; Lovins & Thorndike, 1978; Williams, 2008). In the 1990’s, issues of resource depletion and discourse on sustainability focused policy attention towards environmental responsiveness (Sabatier, 1993; Joskow, 2001; Kraft & Vig, 2006).

More recently, the discourse on climate change, renewable energy and low carbon future dominate the energy policy domain (Berndes *et al.,* 2003; Nilsson, 2005; Wüstenhagen & Bilharz, 2006; Armaroli & Balzani, 2007; Goldemberg, 2007; Doukas *et al.,* 2009). “Energy policy is multi-faceted and context driven” (Helm, 2005, 2007). That is, the process of its planning and formulation is governed by the stakeholders’ priorities and vision; shaped in response to the dictates of a prevalent milieu whether political, economic or environmental. The UK’s white paper “Meeting the Energy Challenge – 2007” and the consultation document on “Renewable Energy Strategy-2008” (Mitchell & Connor, 2004) are examples. In these scenarios, the UK government’s renewable energy agenda was developed in response to address environmental issues on climate change. Another example of such policy response includes the German Green Energy Policy which was initiated since 1974, in response to oil shortages, to enable energy independence (Wüstenhagen & Bilharz, 2006). Also, it can be observed that the issues related to climate change, sustainability and resource depletion are pivotal energy policy drivers in the present times. However, it has become apparent that more radical and cross-cutting transformations are needed (Strunz *et al.*, 2016), and the EU has pledged to achieve carbon neutral economy by 2050 (Intergovernmental Panel Climate Change IPCC, 2019).

Furthermore, policy formulation can take place at various levels of government, from local to international, and framed in accordance to varying implementation time scales. In most of the developed world today, the dynamics of environmental sustainability and renewable energy are prime policy drivers; hence making low carbon future, carbon trading/sequestration, carbon footprint and the likes, commonplace in contemporary international energy policy vocabulary. Most frameworks used to facilitate reduction in energy consumption of buildings were voluntary.

The Energy Star programme developed in the US is among pioneer initiatives to explore energy saving potentials, in which up to 30% savings on office equipment was illustrated (Nordman *et al.*, 1998). Also, there is the Leadership in Energy and Environmental Design (LEED) rating system, a sustainability assessment framework for buildings operating in the USA. Though it remains a voluntary scheme, its fast growth and widespread application tends to acclaim it as a national template to evaluate the sustainability credentials of buildings. Other countries have emulated such movements by creating National Green Building Councils. These include Canada in 2002, New Zealand and UAE in 2006, Germany and UK in 2007, Netherlands in 2008 and Russia in 2009 among others.

More recent energy policies show coherence with the need to reduce GHG emissions by reducing energy consumption. For example the UK's "zero carbon home" policy introduced in 2008 is targeted to reduce the carbon emissions from buildings to zero by 2016. King (2008) asserted that perhaps UK has the most ambitious policy to reduce energy use and carbon emissions throughout Europe. Nonetheless, it can be said that if such frameworks are not in place then energy use reduction can neither be achieved nor enforced. Furthermore, the Energy Performance of Buildings Directive - EPBD, an EU legislation which came into force in 2002 was designed to support policies on energy and carbon reduction. It aims to improve awareness of energy use and to stimulate investments on energy efficiency measures in buildings.

The directive binds all EU member countries to enforce the Directive where each country can further develop its own measures and energy reduction methodological framework depending on local needs. This indicates a shift from voluntary schemes to enforceable policy/regulations. Another important aspect of the Directive is the issue of building energy certificates. This ensures buildings' compliance with certain minimum energy conservation requirements such that clients/building owners/stakeholders are aware of energy use and sustainability credentials of their building investments; hence making it attractive to occupants and buyers.

Again the UK exemplifies proactive responses to these developments in its review of the Part L of the Building Regulations as well as the development of a Code for Sustainable Homes. From a broad perspective, most of the policy targets to enhance energy saving potentials are essentially a promotion of a "controlled-demand paradigm" or what can be referred to as a "demand side management approach" (Laughton & Kult'ck, 2004; Strbac, 2008) in building development that will apply to both new and existing buildings. But, a critical look at buildings and the construction process suggest that buildings will continue to be developed following known traditions of design, construction and then occupation. It may then be questioned, where will the energy savings be made or how does the demand control mechanism come into play? Could this be in building material manufacture process, the construction process or indeed from the occupational use of the building?

It is these types of questions, that have necessitated the review of the definition of the term zero energy buildings often used rather loosely (Torcellini *et al.,*2006; Basir & Basir, 2012) where buildings that subscribe to this paradigm demonstrate a continued energy consumption. However, various sustainable approaches to design, construction and material selection have been illustrated by such models, while other examples show how buildings can be designed or situated such that the physical enclosure itself can contribute in making buildings partly or fully self-sufficient (including onsite independent energy provisions) (Næss, 2001; Roaf *et al.*, 2009; Basir & Basir, 2012). Perhaps, it is these types of approaches that should be vigorously pursued instead of relying heavily on power grid provisions. Clearly, the ensuing policies and regulations are designed to force a re-evaluation of all the potential adverse consequences of buildings on energy and environment in the context of the durability and relative permanence of extant built environment. Therefore, architects and planners are increasingly forced to consider energy consumption and the environmental impact of their building designs (Schlueter & Thesseling, 2009).

Conversely, there is limited evidence of similar initiatives (in terms of both the awareness and development of policy and regulations) to deliver energy conscious and sustainable buildings among developing countries particularly in Africa (Iwaro & Mwasha, 2010). In most of sub-Saharan Africa for example, the demand for instant solutions to energy provision and economic development are major influences on energy policy and planning. Rapid urbanisation, deforestation due to fuel-wood usage and the recent oil discoveries across the continent are all potential conflicting issues in energy policy formulation. Van-Beeck (2003) provided a framework for energy policy and planning development and proposed a new approach towards local energy policy and planning in developing countries. The proposal adopted the use of modular approach to quantify future energy demand that entails a concise appraisal of energy demand in terms of quantity, purpose and type. But, accurate data are difficult to obtain in developing countries (Koolhaas & Van-der Haak, 2003).

Furthermore, poor accessibility and intermittent energy availability suggests a suppressed demand scenario, and the lack of digital records allows for error in the manual collection and analyses processes. Cumulatively, these question the reliability of the data and the required accuracy appropriate for a specific energy planning and policy formulation. Although Van-Beeck's approach is not entirely exclusive of other known schemes, it is designed to enable developing countries to make informed decisions on viable and sustainable energy choices since no substantive commitment has been made towards any energy model. Meanwhile, in the parts of the world where limited building energy use regulation exist, lies a vigorous pursuit in building developments (to mitigate housing and other building typology shortages) and infrastructural provisions amidst a continued rise in population. This is already evident in places such as Abuja, Nigeria.

2.4 Building Services and Electrical Energy Use in Administrative Buildings

This study reviewed related researches on energy use in office buildings. The reviews over office buildings in and out of academic domain because administrative buildings of tertiary institutions are typical office buildings with similar operational regimen like any other office buildings. To start with, Mambo and Mustapha (2016) had earlier exposed the open-ended nature of how much energy is consumed by an average building in

Nigeria. Also, Mua'zu (2012) investigated energy consumption of selected office buildings in Abuja to understand their status and energy performance. The derived performance was between 13KWh/m^2/a to 134KWh/m^2/a, this result was attributed to prevalent suppressed energy supply.

Also, Batagarawa (2013) investigated the likelihood of incorporating phase change material (PCM) on building envelope to save energy and improve indoor comfort. The end-use results shown that cooling, equipment and lighting loads was 40%, 48%, and 12% of the annual energy consumption respectively. The findings shown that 59%, 43%, 15% and 4% for cooling, equipment, lighting and services respectively and the EUI ranged between 90 KWh/m^2/a – 134 KWh/m^2/a. In like manner, Salihu *et al.* (2016) examined the demand, supply and consumption of energy in office buildings in Kaduna metropolis. The study revealed that cooling, equipment and lighting loads demanded. It was obvious that all these studies were out of academic environments.

Notwithstanding, quite a handful of studies had explored energy use of few individual buildings in tertiary institutions. Such studies included Colin and Christopher (2013) that investigated the effect of users on the energy demand of five academic buildings at the University of Sheffield, UK. In the same vein, Mehreen and Sandhya (2014) looked at the energy consumption and occupancy of a multi-purpose academic building of Heriot-Watt (HW) University, Edinburgh, Scotland to understand the relationship between electrical energy and users' activities. Also Adorkor (2014) studied the window opening behaviour in university office buildings as related to ventilation and energy use, while Orola and Adunola (2015) investigated impacts of fenestration on energy use in three office buildings in Obafemi Awolowo University, Nigeria. In like manner, Odunfa *et al.* (2015) explored the effect of building orientations on energy demand of three office buildings in University of Ibadan, Nigeria.

Adekunle *et al.* (2008) conducted survey on energy consumption and demand in university of Lagos, Nigeria. The study examined the various form of energy demand and the cumulative peak consumption by end-uses where cooling load accounted for the highest consumption. A study conducted by Shiming and Burnett (2002) in sub-tropical climate revealed that electricity is the source, for an average of 73%, of total energy use in hotels; air conditioning is responsible for about 50% of the energy. Furthermore, analysis indicated that electricity use in the administrative buildings is affected by both climate and occupancy level, with the former being the dominant affecting factor.

However, services such as lighting and other miscellaneous services are responsible for about 17% and 31% respectively. Kamaruzzaman, *et al.* (2009) concluded that office equipment for administrative buildings type building are responsible for high consumption of energy, typically above energy benchmarks hence should be given further attention. Presently, electrical equipment used in commercial buildings is growing. In fact, Hewlet (2005) predicted that energy use by electrical equipment is set to grow by up to 500% in the next decade.

2.5 Approaches to Energy Consumption Analyses in Buildings

Buildings have become research objects in order to assess the quantity of energy they consume, potential consumption patterns and evaluation of energy demand reduction strategies (Kohler & Hassler, 2002). However, the complexity of the processes involved in building development makes it difficult to assess energy consumption (Haapio & Viitaniemi, 2008). Notwithstanding, a popular approach applied in assessing buildings energy consumption since the early 1990’s is the life cycle assessment/analyses (LCA) (Crawley & Aho, 1999; Adinyira *et al.,* 2007). In the LCA, emphasis is laid upon potential energy and environmental impacts of a product/object irrespective of location or use (Crawley &Aho, 1999).

In the assessment, early LCA studies attempted to identify key stages in a buildings cycle that account for significant energy and environmental impacts, but were fairly ambiguous in categorising the phase developments of buildings due to the complexity of the building development processes, and had to rely on other inter-industry relations (Keoleian, 1993; Oka *et al.*, 1993). As such, a conventional building development phase in its entirety was applied. This included mainly material manufacture, construction, occupation/operation and decommissioning phases in which energy use were assessed. For example, Suzuki and Oka (1998) estimated energy consumption and CO_2 emissions in 10 office buildings built between 1976 and 1987 in Japan using LCA approach, the breakdown of the building development phases included construction, operation, renovation and demolition.

Similarly, Cole and Kernan (1996) determined the energy consumption implication of different building materials (using steel, wood and concrete) on a generic 3 storey office in two locations in Canada, using the LCA approach. The building development phases were defined as initial embodied energy (IEE- energy consumed for manufacturing processes) recurring embodied energy (REE- energy consumed for material replacement, refurbishment and maintenance) operational energy (OE- energy consumed for services during building occupation) and demolition energy (DE- energy consumed in building decommissioning, dismantling, carting away and off-site transport, recycle).

In both research studies, the OE, that is the occupational period of the building, accounted for the highest amounts of energy consumed. Suzuki and Oka (1998) showed that the operation phase ranked top with 82% energy consumption followed by the construction phase with 15%. While Cole and Kernan (1996) showed that OE accounted for between 80% and 90% of energy consumed for all the materials in the two locations while both IEE an REE accounted for less than 10% energy consumption for the entire 50 year time frame that was considered.

According to Norman *et al.* (2006) widened the research to an urban scale by comparing the impacts of urban density on energy consumption and associated CO_2 emissions using the LCA approach. The study concurred with previous studies showing the dominance of the operational phase/energy that accounted for 60% and 80% of total energy consumption in low and high density developments respectively. But in terms of overall GHG emissions, transportation had the highest causal effect accounting for 61% and 43% of total emissions for low and high-density developments respectively. Recent LCA studies show very similar energy distribution patterns within the phases of building development processes with the dominance of occupational/operational phase over other phases for office and residential buildings in many parts of the world (Eskin & Türkmen, 2008; Ramesh *et al.,* 2010; Cabeza *et al.,* 2014).

These assert the significance of energy savings potentials during the operational (occupancy/use) phase. Conversely, Yohanis and Norton (2002) argued that there could be a potential variation in energy distribution towards embodied energy rather than that of building operations due to lack of consistencies in parametric considerations. They demonstrated potential increase in IEE in a 30 year period compared to a 60-year assessment timeframe. They also demonstrated how design can have implications by comparing IEE of buildings with varied glazing ratio. Thormark (2002) and Kofoworola and Gheewala (2009) acknowledged the prospects of an increase in IEE, but indicated that with increasing environmental awareness, the concept of recycling will still reduce potential increase in IEE on the long term. Despite this counteracting embodied energy when longer building span is considered as well as the impact of other off-site production of building components (Junnila *et al.,* 2006;

Nässén *et al.,* 2007). However, the complexity and variety of available building products poses significant challenges on the availability of a widely acceptable template to assess embodied energy (Dixit *et al.,* 2010).

Notwithstanding, more recent LCA studies show a two pronged direction applied in the studies (Singh *et al.,* 2010; Cabeza *et al.,* 2014). These include mainly the life cycle energy analysis (LCEA) and the life cycle cost analysis (LCCA). The LCEA, very much like the main stream LCA, accounts for all energy inputs right from manufacturing through to end use while the LCCA takes into account all costs incurred in the process of acquisition, maintenance and disposal of building. Also, the review by Cabeza *et al.* (2014) which covered 167 publications around the world shows in the Fig. 2.2, that the concentration of LCA studies lies in Europe and North America, followed by Oceania and Asia while there is hardly any studies in Africa and South America except for one found in Brazil.

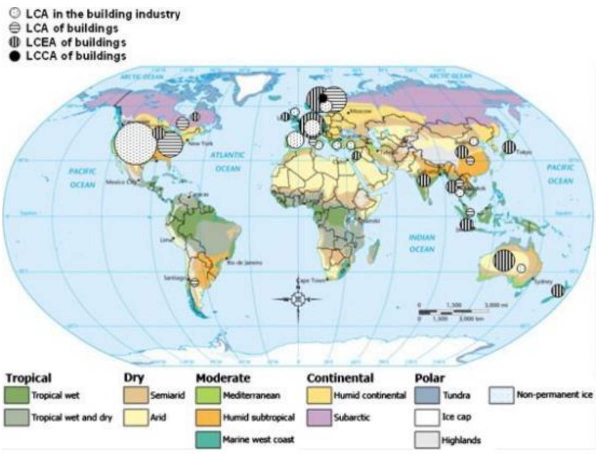

Figure 2.2: Distribution of studies on life-cycle assessments of buildings
Source: Cabeza, 2014

This suggests that research of this nature is likely to be challenged by paucity of relevant literature on the related field for the study location. However, in view of this research energy consumed during the operative/occupancy phase of the building will be taken into cognisance due to its iterative occurrence as the dominant phase in terms of total energy consumption as evidenced in aforementioned literature as well as the inherent potential it harbours for energy savings. More so, from an architectural perspective, it is the phase in which building design can be applied to mitigate energy consumption.

2.6 Estimation and Performance Assessment Methods for Buildings

Assessment of energy use in buildings can be as complex as the development of the building itself and the dynamics surrounding its use compound the complexity as indicated in the discussions above. In order to mitigate the impact on energy and the environment, building energy performance assessment is often undertaken both at inter-building and intra-building sense to illustrate its performance in relation to other buildings and the wider built environment respectively (Douglas, 1996). The performance status quo is used to define what is regarded as typical. This forms the benchmark upon which better performance is sought.

Over the years, different assessment methods had been developed to estimate consumption and performance of building energy use from early simple approaches that involved surveys, monitoring, metering, observations simple walkthrough/detailed energy audits to more complex engineering methods (Cole, 1998; Krarti, 2012). Building energy audit is the first step in energy analysis of buildings. Audit reveals type, cost, what, where and how energy is used towards identifying saving opportunities.

However, auditing buildings which is not metered individually is a herculean task. In this light, calculation methods using mathematical models/formulas are equally an acceptable alternative means which had been used in several studies in the absence of energy bills (Batagarwa *et al.,* 2013). Moreover, the calculation method had an added advantage of ability to disaggregate energy into end-uses like Heating, ventilation and air-conditioning (HVAC), lighting, equipment and building services as encapsulated in extant literature. Building services in this respect refers to any other energy consuming appliances apart from air-conditioning for example lift, pumping machines that ensure optimal functioning of the buildings. Meanwhile, according to Poel *et al.* (2007) energy consumption indicators are necessary for a successful evaluation of energy performance of buildings.

2.7 Relationship between the Actual Energy Consumed and Existing Benchmarks/Standards

The relationship between the actual energy consumed and existing benchmarks/standards should be based on a number of factors, including:

i. The actual energy consumed by the target application or system.

ii. Existing benchmarks or standards for the target application or system.

iii. The sensitivity of the target application or system to changes in energy consumption.

iv. The cost of energy.

v. The benefits of significantly reducing energy consumption.

2.7.1 Energy use indicators and whole-building benchmarking

For successful evaluation and assessment of energy use in buildings, certain criteria or indicators either assumed or established are required and Poel *et al.* (2007) and Cody (2009) provided some direction in their definitions of energy efficient buildings. Poel *et al.* (2007) described the efficiency of a building in terms of "the amount of energy actually consumed or estimated to meet the different needs associated with a standardized use of the building". While Cody (2009) posits that "energy efficiency is the relationship between the quality of internal thermal environment in a building and the amount of energy consumption required to maintain this environment".

These two criteria define the need for quantification of delivered energy (energy consumed), though they differ slightly in the specificity in terms of occupants' deliverables. It may seem simplistic to conclude that in a standardised manner, buildings that consume lesser amount of energy to deliver its designed function, have better performance. Hence, the need for this standardisation makes it essential that certain parameters such as, floor area or fuel type are taken into account to facilitate objective comparative analyses; otherwise a misleading conclusion can be arrived at (Deng & Burnett, 2000). This suggests that for an effective assessment, a responsive approach will be required which adequately evaluates energy use in ways peculiar to the building or sets of buildings in question. One important step is to identify or categorise the built environment using criteria such as purpose in which case its constituent sectors may include residential, institutional, industrial, educational, recreational and commercial after which, further sub categorisation can be sought.

A close examination of such standardised disaggregation of the built environment reveals that office buildings in particular consume huge amounts of energy despite their seemingly low proportion (Perez-Lombard *et al.*, 2008; Lam *et al.*, 2010). For example, Canada office buildings are the third highest energy consumer with 13% consumption of total energy. Same was the case in the USA, where office energy consumption has been the highest sector since 2003; thus disposing office buildings to pioneer various emerging assessment initiatives (EIA, 2009a). The performance of most office buildings in Europe, Hong Kong and China display similar characteristics (Ürge-Vorsatz *et al.*, 2006; Li, 2008).

Furthermore, such classifications serve as benchmarks to examine sectorial energy consumption profiles viz a vis other considerations and the UK's Energy Consumption Guide (ECG19) provides appropriate accounts of the considerations to be taken in classifying office buildings while CIBSE Guide F (Part C) highlights energy benchmarks and Energy Use Intensity (EUI) values for different building types (CIBSE, 2004). According to CIBSE (2004) good and typical practice benchmarks for similar office building stood at 128KWh/m^2/year and 226KWh/m^2/year. While the Building Energy Efficiency Guideline for Nigeria (BEEGN) where consumption of electrical energy is mainly in the form of electricity, are as follows:

i. Under 130KWh/m^2/year: best practice air conditioner office.
ii. 130 - 210KWh/m^2/year: good practice air conditioned office
iii. 210 - 320KWh/m^2/year: typical existing air conditioner office.
iv. Over 320KWh/m^2/year: poorly performing air conditioned office

The globally acceptable performance indicators are Energy Use Index or Intensity (EUI), Energy Cost Index (ECI) and Carbon Emission Index (CEI). One important primary indicator widely employed in buildings energy use assessment in the spatial context is Energy Use Intensity/Index – (EUI) (Baker & Steemers, 1996b; Chung *et al.*, 2006). These indicators are expressed mathematically as follows: EUI is the summation of total energy use per unit floor area of condition space per annum. Hence;

$$\text{EUI (KWh/m}^2\text{/a)} = \frac{\text{Total annual energy consumption}}{Total\ floor\ area\ of\ building} \qquad \text{Equation 1}$$

$$\text{CEI (KgC}_2\text{/KWH/a)} = \text{Total annual energy consumption X Carbon Intensity by energy source} \qquad \text{Equation 2}$$

$$\text{ECI (NGN/m}^2\text{/a)} = \frac{\text{Total annual energycost}}{Total\ floor\ area\ of\ building} \qquad \text{Equation 3}$$

Numerous EUI results for offices and other buildings in many parts of the world have been reported (Deng & Burnett, 2000; Li, 2008; Perez-Lombard *et al.*, 2008; Saidur & Masjuki, 2008). Although there is no established global threshold for energy consumption in buildings, it is useful at individual country or community level for energy use comparison and evaluations have been applied in building rating systems. This suggests importance of a localised application which can have a significant impact in developing specific energy use evaluation frameworks.

In addition, Zmeureanu *et al.* (1999) and Momodu *et al.* (2010) suggest that an economic dimension ought to be factored as a performance indicator. They suggested that monetary indicators such as running costs may be appropriate, particularly in context of developing countries. The energy cost indicator (ECI) can express not only energy saved but also potential financial gains through savings from utility bills. It may be self-evident that this economic dimension will provide better incentive to steer commitments towards sustainable built environments much more than the amounts of carbon emissions would, particularly in most of sub-Saharan Africa and developing countries at large, where endemic social challenges undermine the much needed commitment towards climate change adaptations.

In the built environment, benchmarking is a technique that is often used by building operators to evaluate their energy performance. In its simplest form, an indicator of the energy performance of a building would be compared to a reference performance, whether it be historical data or a publicly available standard, to acquire a sense of how efficiently the energy is being used (CIBSE, 2012). The technique generally aims to raise awareness of energy consumption but also provides motivation to improving the efficiency of operation. It is therefore an essential way to tackle one of the key barriers for improving the energy efficiency of existing non-domestic buildings, which is the lack of awareness of building performance (Carbon Trust, 2009).

Wang *et al.* (2012) explained that whole-building benchmarking uses a statistical standard to measure the energy performance index for a whole building. They aver that such benchmarks look at the whole assessment of existing buildings. This is done based on the comparison of the performance of energy of a building with reference to a standard. This is a simplified and very effective method. The key tool with performing a whole building benchmarking is the reference benchmark. Consequently, a suitable reference benchmark must be selected or an appropriate one must be developed (FMPWH, 2016). For this to be achieved, Wang *et al.* (2012) advances that benchmarks can be set up based on a statistical analysis of comparable and similar buildings referring to this as a statistical benchmark. However, in situations where there is no comprehensive energy performance data for a sample of buildings, benchmarks will have to be set up based on using hypothetical reference building for calculation.

2.8 Building Energy Consumption/Demand

According to Wargocki *et al.* (1999), people spend 80 to 90 per cent of their lives in buildings, living, studying, working, entertaining themselves, consuming and even exercising. Yet, there are a large number of “sick” buildings all over the world consuming energy disproportionately and causing increased operational costs for owners. According to surveys conducted in the US, energy usage intensity of the building, which are surveyed, deviated more than 25% from the design projections (Turner & Frankel, 2008).

2.8.1 The need for energy efficient buildings

Governments have a responsibility to ensure that there is secure supply of energy to ensure economic growth. In many developing countries there is normally very little margin between existing power supply and electricity demand (FMPWH, 2016). With increasing electricity use from existing consumers and new connections, new interventions need to be brought on line to meet increasing demand. The main benefit from measures to improve energy efficiency in buildings is to lower energy consumption (Uduma & Arciszewski, 2010).

2.8.2 The impact of overpopulation and fast urbanization on the building sector

According to the forecasts of the United Nations (United Nations, 2019), the global population, which was 7.6 billion in 2019, will grow to a number between 9.4 and10.1 billion in 2050,with a more probable value close to 9.7billion. Most of this increase of population will occur in developing countries. Urban population is expected to grow to 66% of the total population by 2050 from the current value of 54% equivalent to another 2.5 billion people by 2050. Most of the new urban population will be in India, China and in some African countries like Nigeria. As mentioned by the United Nations (United Nations, 2019), India is projected to add 404 million dwellers,

China 292 million and Nigeria 212 million by 2050 to the global urban population. Not surprisingly, the world rural population is expected to decline from the actual 3.4 billion to 3.1 billion by 2050. Successful management of the urban population and satisfaction of their basic needs on housing, infrastructures, environmental quality, health, and energy provision, is a major challenge for the building and construction sector. According to the latest statistics (United Nations Environment Programme, 2020), there currently is a shortfall of about 330 million homes in the world, and is expected to increase up to 440 million by 2025. By 2030, the additional housing needs will grow by more than 77 billion square meters of floor space (IEA, 2019b), equivalent or higher to the actual area of China. Forecasts report that during the next 30 years the total floor area of buildings will increase by 75%, or by more than 100% by 2070, adding a total floor area equal to the city of Paris per week (IEA, 2020, 2021a). It is foreseen that more than 225 billion square meters of floor area will be built in emerging economies and mainly in India, Indonesia and Brazil (IEA, 2019b), and new residential buildings will count more than 80% of the additional floor area.

To satisfy the current climatic engagements, new buildings should present an almost zero energy consumption while protecting the residents from extreme climatic events, promote resilience and guarantee the health and the wellbeing of the population. Given that by 2050 the world's population over 60 years of age is expected to double (World Health Organisation WHO, 2018), the need for efficient public health protection is a necessity. Current energy policies, building practices and economic conditions in the emerging economy countries seriously reduce the expectations for the adoption and implementation of adequate design and construction technologies for the new local building stock. It is therefore highly probable that by 2050, building stock equal to 2.5 times the current Chinese building stock, may present serious energy and environmental problems.

2.9 Factors Affecting Energy Consumption in Buildings

There are many factors that can affect the amount of energy used by buildings. This preamble will discuss some of the most common factors and how they can affect energy consumption.

i. Climate

Climate can play a large role in how much energy a building uses. For example, a building in a warm climate may use more energy to maintain its temperature than a building in a cold climate.

ii. Location

Location also plays a role in how much energy a building uses. For example, a building in a densely populated area may use more energy to power its lights and heating than a building in a sparsely populated area.

iii. Size and shape

Size and shape of a building also play a role in how much energy it uses. For example, a building that is long and narrow can use more energy to heat and cool than a building that is shorter and wider.

ii. Building materials

Building materials can also affect how much energy a building uses. For example, a building made of concrete may use more energy to build than a building made of wood.

iii. Activities performed in a building

Activities performed in a building can also affect how much energy a building uses. For example, a building that is used for offices may use.

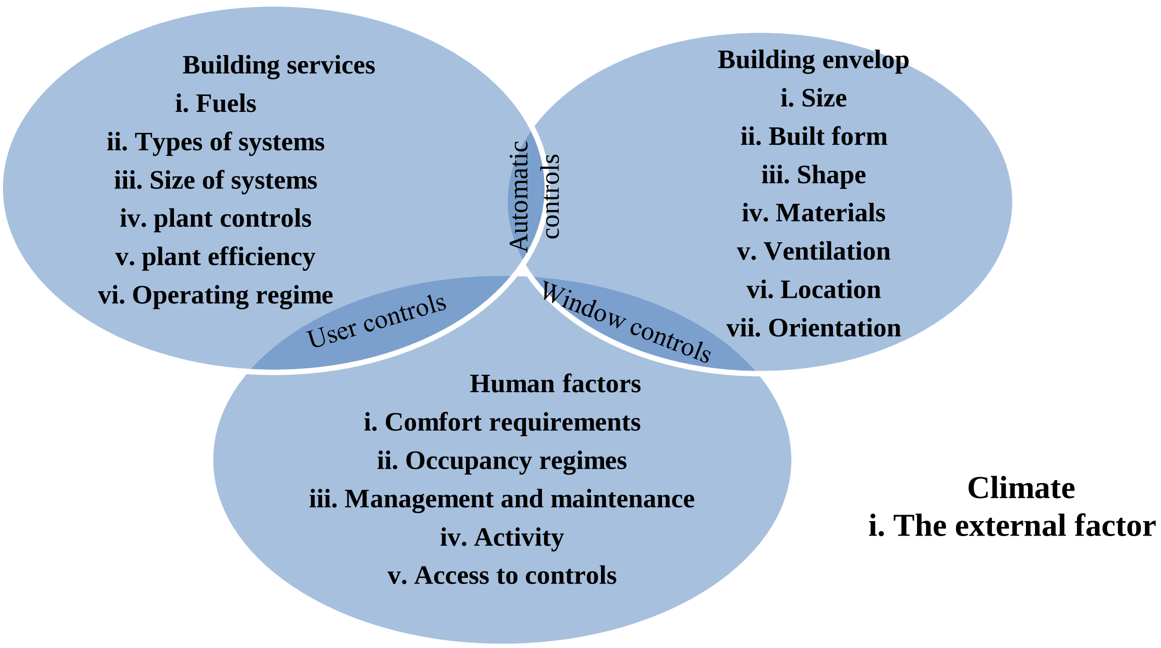

Figure 2.3: Key factors that influence energy consumption
Source: CIBSE Guide F, (2006)

2.10 Energy Management Strategies for Buildings Energy Management System (BEMS)

The essential idea of energy management is the consistent, methodical, and efficient review of energy use, focusing on energy cost optimization concerning user characteristics, financing ability, energy demands, funding opportunities, and emission reductions accomplished (Doukas *et al.*, 2009). Energy Management Systems (EMS) allows clients to achieve objectives and those of utility suppliers, based on renewable generation predictions and load demand patterns (Di-Piazza *et al.*, 2017). These systems could monitor and control the use of energy in industry, equipment, and building according to different developed functions or control logics (Lee & Cheng, 2016). BEMS is a term employed to typify various systems utilized to increase the energy efficiency of operational buildings (McGlinn *et al.*, 2017) and ensure indoor comfort for building occupants (Javed *et al.*, 2015). BEMS are an essential piece of an intelligent grid, enables building administrators to supervise and manage the energy used in their buildings, thus cutting the demand and energy use (Sivaneasan *et al.*, 2015). The usage of BEMS is highly flexible in both residential buildings and non-residential. There are two kinds of BEMS methods: active and passive. Passive methods are based on providing future strategies and improving the user's energy awareness to influence and decrease the utilization of energy in buildings indirectly. Active methods are based on the mix of the actuators and sensors' infrastructure in the building. They depend on reducing energy wastes contexts through the control of smart building actuators and gadgets (Degha *et al.*, 2019). Based on active approaches, BEMS classified was into four management strategies: model predictive control, demand-side management, optimization and fault detection, and diagnosis (Figure 2.4).

Figure 2.4: Energy Management Strategies
Source: CIBSE Guide F, 2006

2.10.1 Devices for optimizing energy consumption in buildings

The world's population is growing, and the need for energy is increasing. Buildings consume a large amount of energy, and the amount of energy that buildings consume is growing faster than the amount of energy that is available. Buildings can save energy by using devices that optimize energy consumption. This preamble is to provide guidance for devices that optimize energy consumption in buildings. Devices that optimize energy consumption must be, must be easy to use, affordable, reliable safe and effective.

1. Kill-A-Watt is one of these devices that are used to measure the power consumption for each appliance that is plugged into it. The measurement of this device is usually presented in watt units. However, it can be displayed in kWh by aggregating the power consumption that has been used over a time (Reysa, 2007). The benefit of using kill-A-Watt is that consumers can eliminate the power that is consumed when the appliance is on standby or when it is left plugged in the wall by monitoring each kilowatt which is used in their homes (Leehersch, 2011).

Figure 2.5: Kill-A-Watt

2. Belkin Conserve Insight is another smart device which is used to measure power usage for each appliance individually. This utility has a smart monitor that displays information about the energy consumption for a plugged device. In addition, it can display the cost of the running device in dollars and in watt units. The Belkin Conserve

Insight monitor can show the amount of carbon dioxide that result from this running device. The configuration and installation of Belkin Conserve Insight is very easy and in a few steps consumers can plug the appliance into Belkin Conserve Insight device and then into the wall (Global Smart Plug Market, 2021).

Figure 2.6: Belkin Conserve Insight

3. The PeakTech Meter is an electricity meter which displays the power cost of an appliance for a period of time; it is very easy to use. It is designed to encourage households to reduce their electricity bills and consumption. PeakTech works when the consumer plugs the meter into the power socket in the wall and then plugs the appliance into the meter. After that, the consumer can enter the power unit price and calculate the cost of the appliance's electricity consumption (PeakTeach, n.d.).

Figure 2.7: PeakTech Meter

4. Power-Mate is another electricity device monitor. It was designed and developed by Computer Control Instrumentation (CCI) to monitor the electricity use for each appliance individually. Power-Mate users can determine the operating cost for each appliance. They can also find out the amount of green gas emission that is released by

using an appliance. It is difficult for some appliances to identify their running cost due to irregular operation performance but Power-Mate eliminates this obstacle by showing the cost of running the appliance hourly, weekly, monthly and yearly (Computer Control Instrumentation, n.d.).

Figure 2.8: Power-Mate

5. Some smart devices can work with more than one appliance and control them at the same time. The UFO Power Center is one of these major power devices that can manage four home appliances concurrently. This device has many features such as supplying instant feedback, socket schedules, and socket timers. It can facilitate consumer understand the energy consumption for each appliance used and also make it easy for them to know its operation cost. The UFO Power Center enables consumers to switch the appliance off when it is not in use or when it is on standby state (Visible Energy, 2011). Consumers can manage their appliances energy usage in the home remotely via using iPad or iPhone with WiFi feature that is available in the UFO Power Center. Using UFO Power Center might assist consumers to save up to $150 annually (Scott, 2012).

Figure 2.9: UFO Power Center

6. Wireless 3-Outlet Mains Power Meter is another smart meter that has three separate outlets and one LCD monitor. It works by communicating through outlets to the monitor remotely using the wireless function. Consumers can only connect three appliances to three available outlets at the same time. After the connection they can see the current power, total power cost and the amount of greenhouse gas emissions in kilograms for the attached appliances (Electronic Choice, 2010).

Figure 2.10: Wireless 3- Outlet Mains Power meter

7. Wattson is one of the many power consumption measurement devices that is used to measure electricity consumption for the whole house. It is designed to assist households to save their electricity consumption. It works with software called Holmes to store daily consumption data. Wattson is a portable device and it can be used anywhere at home, and also can be used with small businesses. The device works when a transmitter is attached to the electricity meter and the sensor clip is connected to the cables running from the Fuse Box. There is a small portable LCD display that communicates with the transmitter via wireless communication to show information about current consumption for appliances. This display has three types of levels of light and each level of light indicates the rate of the electricity consumption. High rate is represented by red, average by purple, and low by blue (Energeno, n.d.).

Figure 2.11: Wattson

8. EnergyHub is a smart system that assists households to reduce their energy consumption and save money. This system gives information about the electricity use in the house and also assists the consumers to track every appliance. EnergyHub touchscreen dashboard has the facility for households to manage each appliances and devices connected to the power. Additionally, households can control their home energy consumption remotely. Working with Energy Hub system requires installing equipment such as smart meter with ZigBee including dashboard, temperature control unit, strip and socket (EnergyHub, 2012).

Figure 2.12: EnergyHub

9. Power-Cost Monitor is a portable energy device that allows users to read their home energy in real time. The uses of Power-Cost Monitor can assist users to know the total energy consumption for their homes at any time. It can also help them to change their attitudes toward their electricity consumption in the home as well as saving up to $250 yearly on their electricity bills. In addition, the users can explore their house's energy data via online services when they install and configure the Power-Cost Monitor WiFi Bridge appliance (Blue Line Innovations, 2010).

Figure 2.13: Power-Cost Monitor

10. Envi energy monitor device is a multi-function energy monitor that can be used to measure the whole house and also to measure individual appliances. This device consists of three major items: the display item which is used to show the electricity consumption including the cost, temperature and time; the sensor clamp device that is used to measure the electricity consumption via connecting this sensor to the transmitter; and the transmitter item that is used to transmit data to the display. This utility brings a large number of features with it and one of these is that the households can display and extract their homes energy consumption data by installing and using Techtoniq software on their computers. When households use Envi energy monitor, they can reduce their total energy consumption by 15 percent to 20 percent (Steplight, 2010).

Figure 2.14: Envi Energy Monitor

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Purpose of Research

A research study can be classified into different types, depending on the research problem and the purpose of the research. The research purpose can be categorised into instrumental, descriptive, exploratory, explanatory and interpretive (Zikmund, 2000; Fellows and Liu 2008). Saunders *et al.,* (2009) argues that more than one purpose of research can be adopted.

3.2 Research Design

It has already been shown that the research design links the collated empirical data to the primary research objectives (Yin, 2009). The next step after selecting a suitable method based on the necessary philosophical paradigm is to decide on the research design. The selected research design will consequently influence the selection of research instruments to be employed (Sarantakos, 2005). Guided by the aim and the research objectives, the decision on the research design has to be made. The research design adopted in this study was mainly direct field measurements. While the secondary data needed for the study were obtained from literature review of thesis, journals, articles, and equipment manufacturer's manual. The field and experimental measurements were necessary as they enabled the researcher to examine the studied selected administrative buildings and its actual electrical energy consumption (Mua'zu, 2015).

3.2.1 Research strategy

Case study was adopted as the research strategy for this research because it is based on observation of an occurring and existing situation (rising electrical energy consumption) in a real context through using of multiple sources of evidence (Robson, 2002; Yin, 2009). This strategy is seen by the researcher as best-fit to fulfill the objectives of the research and answer the research questions. Robson (2002) defined case study as “a strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon within its real life context using multiple sources of evidence”. According to Yin (2009) case study highlights the importance of context, which it is been undertaken when the boundaries between the fact being studied and the context within which it is being studied are not clearly evident.

3.2.2 Case study design

Letters were served to the directors of works and maintenance of the three studied tertiary institutions to grant the research student access to the main panel distribution board of the institutions, prior to the commencement of data collection, and unstructured interview was conducted to confirm the historical data of electrical energy usage of the institutions administrative buildings.

3.3 Materials

3.3.1 Study area

The building case study was educational (non-residential) buildings. The total ground floor areas for the buildings are 16001.67m^2, 16597.40m^2 and 14981.51m^2 for Federal University of Technology Minna, Niger State Polytechnic Zungeru, and Niger State College of Education located along Minna-Bida,, Zungeru-Wushishi-Bida and Tungagoro FGC express road respectively (9°32’30” N, 6°26’15” E, 9^{o}6’44”46” N, 6^{o}8’6” E and 9°35’ 0.798”, 6°32’ 46.7”). These buildings were studied at their final design (architectural drawing) and operational stage.

3.4 Methods

To record hourly electricity use profile of the selected administrative buildings an electronic tool called Efergy Wireless Energy (EW4500) was used in this research to measure the actual electrical energy consumed in the study areas. The Efergy E2 Classic is a wireless electricity monitor that allows monitoring of electrical energy consumption trends overtime in buildings.

The measuring device has three components namely; a current transformer (CT) scanner (12–19mm conductor diameter, nominal current of 90–120A for the12mm CT and 120–200A for the 19mm CT), a transmitter with 70m radius operating range, and a receiver (wireless frequency 433.5MHz, a measurement range of 50m A to 120A per phase and a voltage range of 110–300VAC) as shown in Figure 3.1. and a typical connection is shown in Figure 3.2 and Figure 3.3.

Sensor unit: This component is hooked onto the electricity meter's incoming supply cable for aggregated building energy measurement but for individual appliance measurements, it is connected to the live wire of the appliance three-core cable. Transmitter unit: The purpose of the transmitter is to link the sensor cable to the display unit through transmission of measured data. This component captures data at least every 6 seconds. Display unit: The function of the unit is to display energy usage information and demand profile and the cost of energy being consumed. The numerical hourly average data are provided for analysis. This device is kept at a distance of not more than 70m from the transmitter unit.

CT Sensor Unit

Figure 3.1: Efergy Wireless Energy (Efergy E2 classic energy monitor components)

3.4.1 Setup and direct measurement

The time-series dataset presented in this study was captured using a real-time energy monitoring device which was clipped to the live wires of the main panel of the electricity distribution board of the selected administrative buildings by the researcher. The CT sensor clips on the power supply cable (phase) was what to monitor and with its jack-plug connected to the available ports of the transmitter. The sensor inductively measured the current passing through the live wire of the feed cable and transferred this information to the transmitter, which were then transmitted wirelessly to the energy monitor's display for processing and viewing.

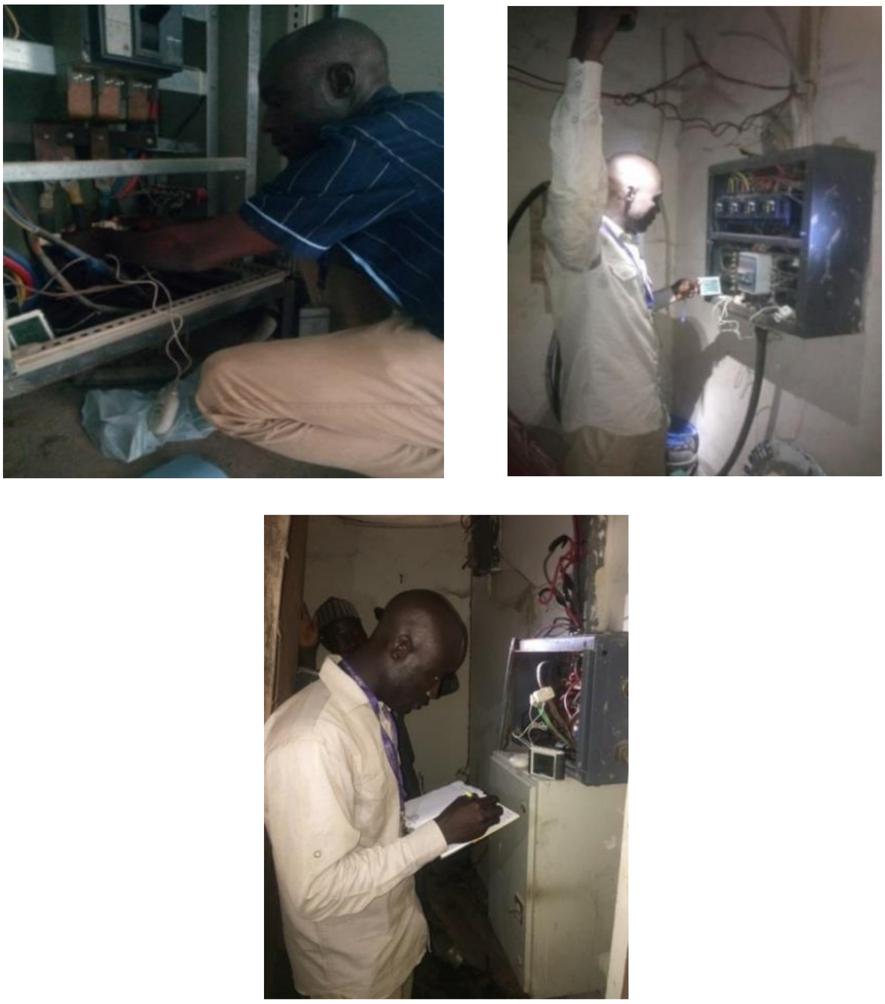

Figure 3.2: Clipping the jack-plug on the live wires at senate building FUT Minna, Zungeru Polytechnic and Niger State College of Education administrative blocks the main panel distribution board (MPDB).
Source: Author 2021

Figure 3.3: Connection at the senate building FUT Minna, Zungeru Polytechnic and Niger State College of Education administrative buildings MPDB.
Source: Author 2021

3.4.2 Documentations and instrumentations

Data was collected by reading and adhering to the experimental procedure described below.

Steps: The following were the six steps that were followed to carry out the measurement in the study areas:

i. Sampling Location: These include the selected administrative buildings.

ii. Sampling Session: Sampling times was selected in an attempt to collect data during potential high activity. The two (2) time windows (Sampling Sessions) include:

a. Morning time (Session 1): 8:00 - 10:00 a.m. and 11:00 – 12:00p.m

b. Afternoon time (Session 2): 1:00 - 2:00 p.m. and 3:00 – 4:00p.m. The buildings were observed to have operational period of eight hours (8) per day (08:00am-04:00pm), five days per week.

iii. Calibration of the Equipment: Efergy Wireless Energy monitor was calibrated according to the manufacturer’s instructions.

iv. Positioning of the Equipment: Efergy Wireless Energy monitor was connected to the administrative buildings of the electricity distribution board.

v. Documentation of Results: The resulting values were documented on a sampling form.

vi. The Precision Requirements: Efergy Wireless Energy monitor calibrate automatically before the start of new measurement. These were done to ensure accuracy of results.

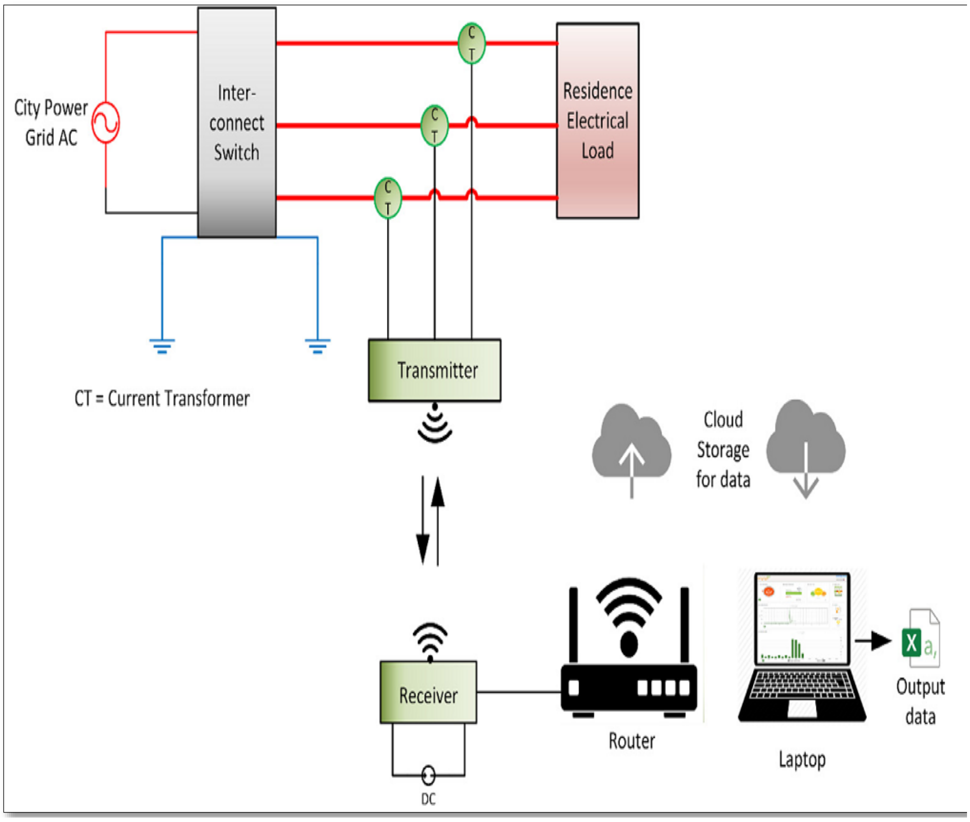

Figure 3.4: Schematic diagram for the layout of the energy monitoring system

3.5 Data Collection and Analysis

This study was quantitatively oriented by the numerical nature of the collected data. The data was analysed using Microsoft Excel Software.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Description of the Administrative Buildings

The focus of the research was on assessment of electrical energy consumption in some selected administrative buildings in Niger state as this was the main source of energy used in the administrative buildings. Electrical energy is supplied from the grid as well as from the generators installed in the administrative buildings. While the electrical energy consumption was monitored and metered in KWh. At the time this research was conducted there was not smart meter installed to monitor the electrical energy consumed at the administrative buildings of Federal University of Technology Minna and Niger State Polytechnic Zungeru, and Niger State College of Education Minna respectively.

The envelope of the administrative buildings was composed of outer walls in concrete and sandcrehollow walls. The buildings consist of interior reception where it leads to other pathways of the following offices; typist, personal account, personal staff, deputy bursar, council chamber, registrar, bursar, vice chancellor, senate chamber, deputy chancellor, academic planning, secretary, cashiers, chief accountant, physical planning and development unit, deputy rector academic, rector office, provost, to mention but few.

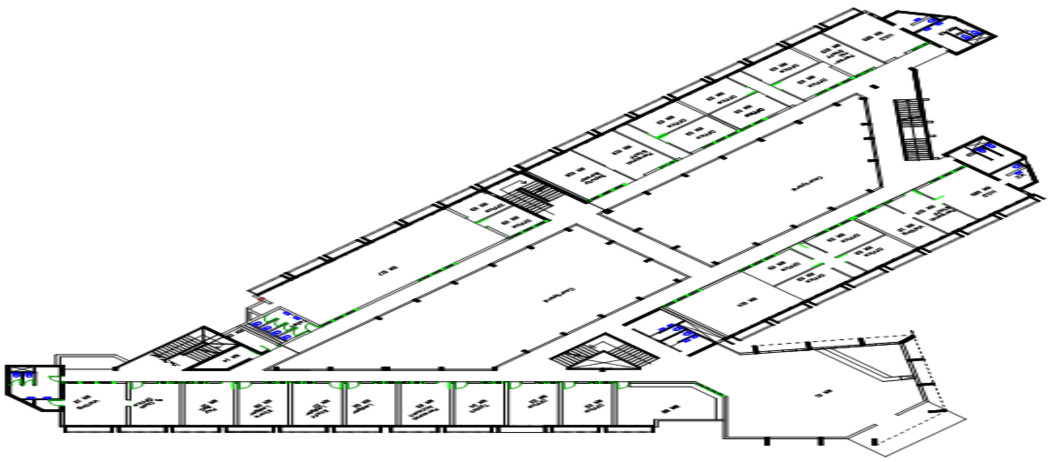

Plate I: Architectural floor plan of Federal University of Technology Minna

Figure 4.1: Facade view of the Administrative Building (Senate Building) of FUT Minna

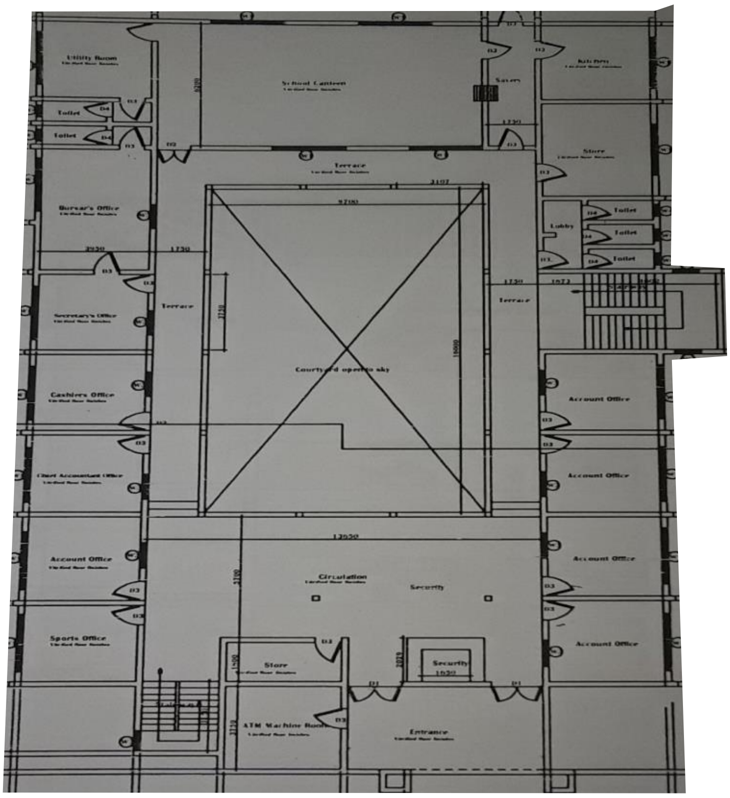

Plate II: Architectural floor plan of Niger State Polytechnic Zungeru

Figure 4.2: Facade view of the Administrative Block of Zungeru Polytechnic

The architectural floor plan for the Niger College of Education Minna was not avaliable when this research was conducted.

Figure 4.3: Facade view of the Administrative Block of Niger State (COE) Minna

4.2 Electrical Energy Consumption in the Administrative Building (Senate Building) of Federal University Technology Minna

Table 4.1: Electrical energy consumed at Senate Building of FUT Minna

1st month Time stamp	Energy (KWh/m^2)				Ave. Energy (KWh/m^2)	2nd month Time stamp	Energy (KWh/m^2)				Ave. Energy (KWh/m^2)	3rd month Time stamp	Energy (KWh/m^2)				Ave. Energy (KWh/m^2)
	1	2	3	4			1	2	3	4			1	2	3	4	
9am -10am	1394	1284	1640	1773	1523	9am -10am	1587	1632	1677	1692	1647	9am -10am	1387	1572	1622	1689	1568
11am - 12pm	1829	1991	2097	2166	2021	11am - 12pm	1712	1787	1871	1992	1841	11am - 12pm	2171	2244	2273	2276	2229
1pm - 2pm	2319	2313	2373	2396	2350	1pm - 2pm	2207	2227	2428	2979	2460	1pm - 2pm	2319	2329	2305	2363	2329
3pm - 4pm	2979	2977	2840	2026	2706	3pm - 4pm	3575	2857	2743	2181	2800	3pm - 4pm	2343	2324	2300	2111	2269
Summation of energy consumed					**8600**						**8748**						**8395**
Total energy consumed					**25743**												

Table 4.1 shows the analysed results of the data obtained as follow; the day time stamp, the summation of the average electrical energy consumed in the senate building of the Federal University of Technology Minna were 8600KWh/m^2, 8748 KWh/m^2 and 8395KWh/m^2 for the first, second and third months respectively, while the total energy consumed was 25743KWh/m^2. The hourly pattern of mean energy consumption refers to the variation in energy use over the course of a day, typically broken down by hour.

4.3 Mean Energy Consumption Hourly Pattern (1 Hour) for Three Months at Senate Building of FUT Minna

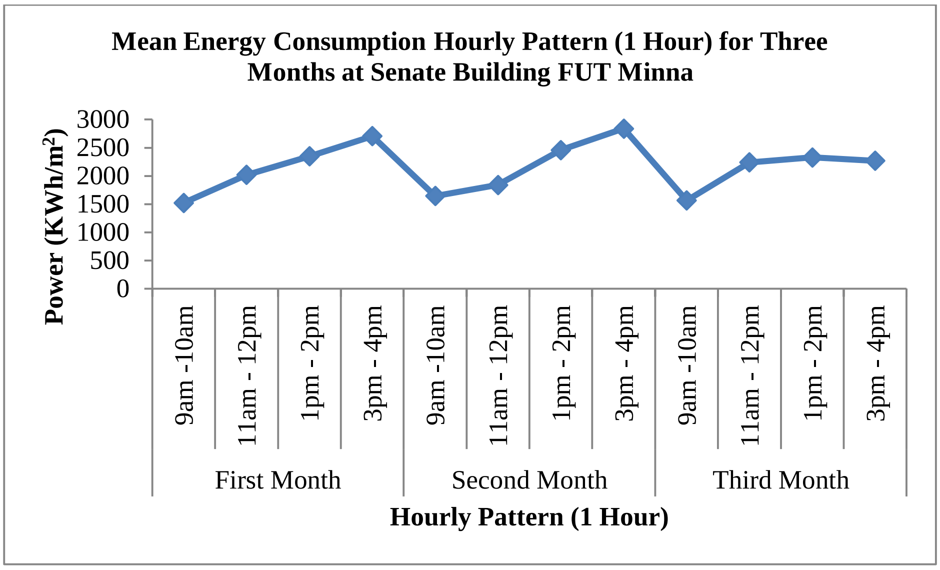

Figure 4.4: The mean energy consumption hourly pattern at Senate building

As shown in Figure 4.4, there were fluctuation on hourly pattern for the mean energy consumption to peak in the early working hours when the senate building was occupied by staff from 9am to 12pm with a value of 1522.75KWh/m^2 and 2020.75KWh/m^2. There was a decrease of consumption of energy during the launch hours, while a steep increase of energy consumption after staff resumed from launch with a value of 2350.25KWh/m^2 to 2705.5KWh/m^2 and a decline throughout the closing hours in the evening. There are several factors that can influence the hourly pattern of mean energy consumption at the senate building of FUT Minna. From the results it was deduced that this was likely that the peak energy consumption in the administrative building during early working hours is due to increased activity in the building as people arrive for work and begin using lights, computers, and other electrical equipment. The decline in energy consumption during lunch hours may be due to the fact that many people leave the building to go out for lunch or may be taking a break from work and therefore not using as much energy.

4.4 Electrical Energy Consumption in the Administrative Block of Niger State Polytechnic Zungeru

Table 4.2: Electrical energy consumed Administrative Block of Zungeru Polytechnic

1st month Time stamp	Energy (KWh/m^2)				Ave. Energy (KWh/m^2)	2nd month Time stamp	Energy (KWh/m^2)				Ave. Energy (KWh/m^2)	3rd month Time stamp	Energy (KWh/m^2)				Ave. Energy (KWh/m^2)
	1	2	3	4			1	2	3	4			1	2	3	4	
9am -10am	1407	1410	1451	1467	1434	9am -10am	1729	1662	1640	1631	1666	9am -10am	1645	1647	1640	1832	1691
11am - 12pm	1478	1506	1475	1455	1486	11am - 12pm	1657	1647	1681	1643	1662	11am - 12pm	1820	1842	1847	1832	1836
1pm - 2pm	1467	1477	1499	1484	1482	1pm - 2pm	1659	1655	1647	1647	1647	1pm - 2pm	1855	1837	1830	1851	1843
3pm - 4pm	1700	1674	1645	1463	1434	3pm - 4pm	1688	1652	1640	1638	1655	3pm - 4pm	1931	1926	1909	1895	1915
Summation of energy consumed					**5956**						**6630**						**7285**
Total energy consumed					**19871**												

Table 4.2 shows the analysed results of the data obtained as follow; the summation of the average actual electrical energy consumed in the administrative block of the Niger State Polytechnic Zungeru were 5956KWh/m^2, 6630KWh/m^2 and 7285KWh/m^2 for the first, second and third months respectively, while the total energy consumed was 19871KWh/m^2.

4.5 Mean Energy Consumption Hourly Pattern (1 Hour) for Three Months at Zungeru Polytechnic's Administrative Building

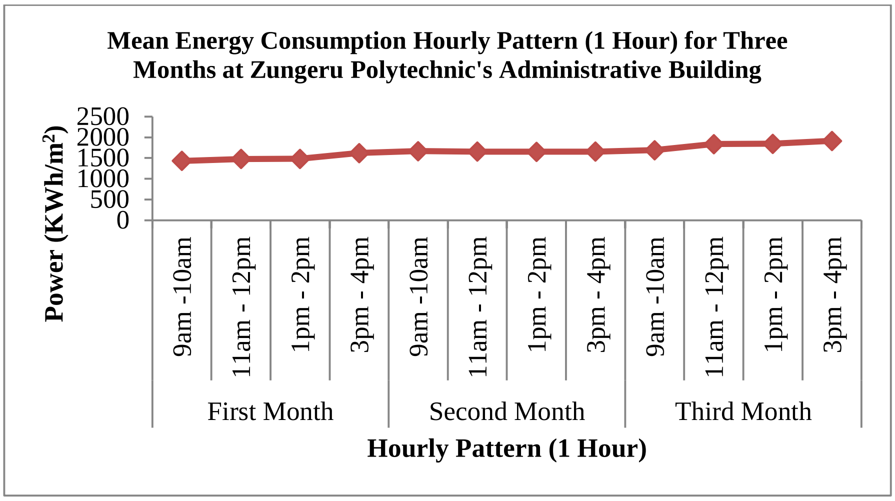

Figure 4.5: The mean energy consumption hourly pattern at admin block

As shown in Figure 4.5, there was a stable trend variation in the mean energy consumption for the period of three months during when the research was conducted. There was an increase of energy consumed at 9am to 12pm, decreased during launch hours and an increase after launch hours. The mean energy consumed values were as followed; 1433.75 KWh/m^2, 1478.5 KWh/m^2, 1481.75 KWh/m^2, 1620.5 KWh/m^2, 1665.5 KWh/m^2, 1657 KWh/m^2, 1652 KWh/m^2, 1654.5 KWh/m^2, 1691 KWh/m^2, 1835.25 KWh/m^2, 1843.25 KWh/m^2 and 1915.25 KWh/m^2. The peak energy consumption in the administrative building in the early working hours was likely due to a combination of factors. The increased number of people in the building means that more energy is required to keep the building functioning, such as lighting, and cooling; people tend to be more productive in the morning and require more energy intensive equipment to get their work done, such as computers, printers, and other office equipment and the higher energy consumption during this time was also likely due to the fact that more people are using the building’s amenities. The decline in energy usage during lunch hours was likely due to the fact that many people leave the building to get food or take a break, thus reducing the number of people in the building and the associated energy consumption.

4.6 Electrical Energy Consumption in the Niger State College of Education (COE) Administrative Block

Table 4.3: Electrical energy consumed at Administrative Block of COE

1st month Time stamp	Energy (KWh/m^2)				Ave. Energy (KWh/m^2)	2nd month Time stamp	Energy (KWh/m^2)				Ave. Energy (KWh/m^2)	3rd month Time stamp	Energy (KWh/m^2)				Ave. Energy (KWh/m^2)
	1	2	3	4			1	2	3	4			1	2	3	4	
9am -10am	1552	1565	1544	1568	1557	9am -10am	1514	1512	1475	1549	1513	9am -10am	1582	1643	1716	1729	1668
11am - 12pm	1561	1543	1503	1515	1536	11am - 12pm	1551	1586	1573	1548	1570	11am - 12pm	1818	1833	1813	1790	1821
1pm - 2pm	1486	1618	1572	1546	1559	1pm - 2pm	1539	1559	1552	1528	1540	1pm - 2pm	1804	1802	1821	1825	1813
3pm - 4pm	1534	1522	1507	1510	1509	3pm - 4pm	1483	1474	1497	1490	1486	3pm - 4pm	1806	1769	1713	1678	1742
Summation of energy consumed					**6161**						**6109**						**7043**
Total energy consumed					**19313**												

Table 4.3 shows the analysed results of the data obtained as follow; the summation of the average actual electrical energy consumed in the administrative block of the Niger State College of Education Minna which was 6161KWh/m^2, 6109KWh/m^2 and 7043KWh/m^2 for the first, second and third months respectively, while the mean energy consumed was 19313KWh/m^2.

4.7 Mean Energy Consumption Hourly Pattern (1 Hour) for Three Months at COE's Administrative Building Minna

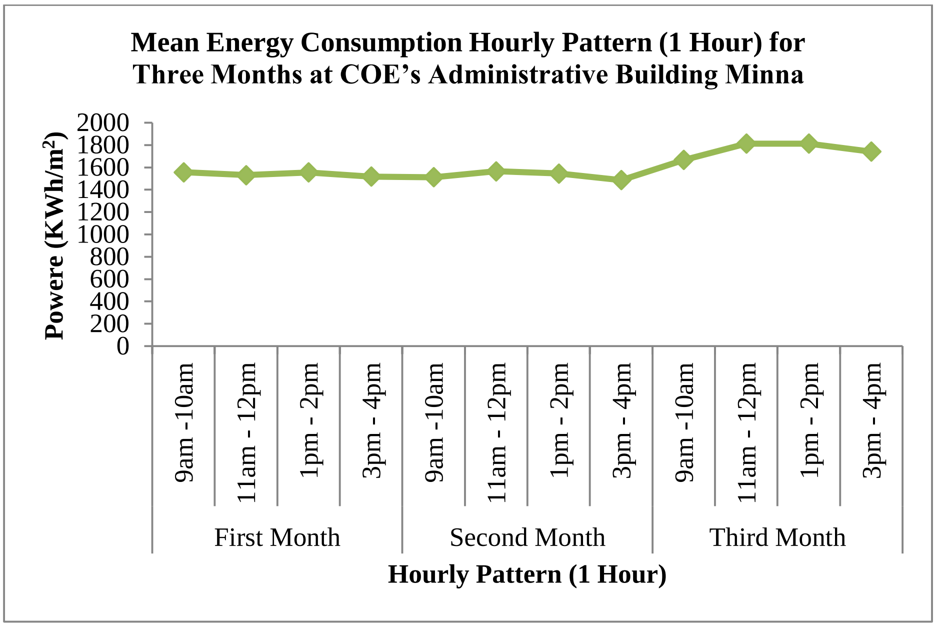

Figure 4.6: The mean energy consumption hourly pattern in administrative buildings

As shown in Figure 4.5, there was a stable trend variation in the mean energy consumption for the period of three months during when the research was conducted. There was an increase of energy consumed at 9am to 12pm, decreased during launch hours and an increase after launch hours for the first two months while for the third month there were rise in energy consumption. The mean energy consumed values were as followed; 1557.25 KWh/m^2, 1530.5 KWh/m^2, 1555.5 KWh/m^2, 1518.25 KWh/m^2, 1512.5 KWh/m^2, 1564.5 KWh/m^2, 1544.5 KWh/m^2, 1486 KWh/m^2, 1667.5 KWh/m^2, 1813.5 KWh/m^2, 1813 KWh/m^2, and 1741.5 KWh/m^2. It is common for there to be a peak in energy consumption in administrative buildings during the early working hours because this was a when most people are arriving at work and turning on lights, computers, and other electrical equipment. The decline in energy consumption during lunch hours may be due to the fact that many people take lunch breaks and may turn off their equipment or reduce their energy usage during this time. It is also possible that there are energy-saving measures in place that are activated during these hours, such as occupancy sensors that turn off lights when a room is unoccupied.

4.8 Variation Comparison of Mean Energy Consumed at the Studied Administrative Buildings

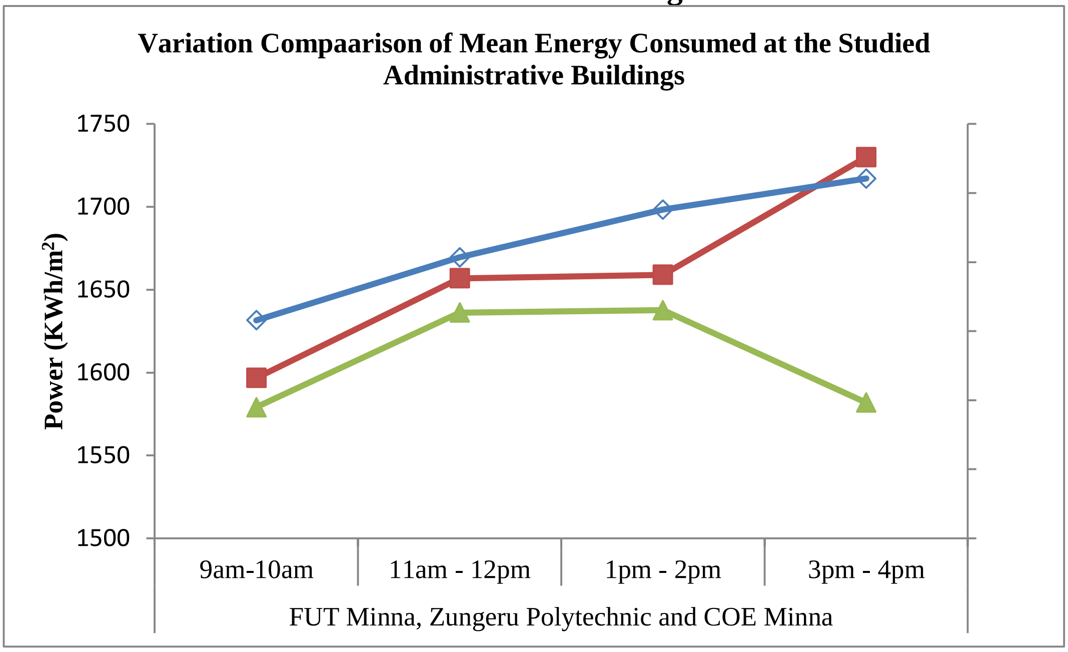

Figure 4.7: Variation Comparison of Mean Energy Consumed at the Studied Administrative Buildings

As shown in Figure 4.7, there was a significant impact on the trend variation comparison of the mean energy consumed at the studied administrative buildings. From the graph it depicted that the administrative buildings maintains a stable steep of energy consumption from the early working hours at 9am to 12pm, but the administrative building of FUT Minna continues with at peak even during lunch hours. There could be several reasons why energy consumption at the administrative building of FUT Minna might remain stable during lunch hours. Some possibilities include:

a. The size and layout of the building,

b. The building systems (such as heating, ventilation, and air conditioning) may continue to operate at a constant level to maintain a comfortable environment for the staff,

c. The administrative building has a high occupancy rate, with people coming and going throughout the day, including during lunch hours. This could result in energy being used for lighting and powering equipment such as computers and other electronic devices.

d. The administrative building have facilities such as cafeterias, meeting rooms, or other common areas that are in use during lunch hours, which could also contribute to energy consumption.

On the other hand, the administrative buildings of Zungeru Polytechnic and COE have shown a decline of energy consumption during the lunch hours at 12pm to 2pm. After lunch it shown that there was an increase in energy consumption at the administrative building of Zungeru Polytechnic where it intercepted with the administrative building of FUT Minna at 3pm with a value of 2604.67KWh/m^2, while that of the COE Minna shows a total declination of energy consumption after lunch hours.

The above figure shows distinct morning and afternoon variations. Even though the variation is not in a regular pattern but the consumption patterns showed distinct seasonal variation, indicating peak of electrical energy consumed at the administrative building of the FUT Minna during when the building was occupied by staff at 9am to 4pm and a stable gradual decrease of electrical energy consumption during the launch period at 12pm to 2pm for the Niger State Polytechnic Zungeru and Niger State College of Education Minna. The amount of energy consumed in the studied administrative buildings depends on many factors. Key factors include the original building envelope design, operation efficiency of the ventilation and air conditioning systems, fresh air load for maintaining the indoor air quality required, types of lamps and their efficacy, internal plug loads (example, office equipment), special equipment, which require special environmental control, and the building operation and maintenance due to significant air conditioning requirements.

4.5 Summary of Findings

Table 4.1, 4.2 and 4.3 gives an insight into the raw data structure and the distribution of electrical energy consumption of the end users at different time of the day in the selected administrative buildings. During the field energy measurements, there were variations of electrical energy consumed with respect to the time the buildings was occupied and the activities carried out by the end-users during the working hours in the administrative buildings as shown in the tables. The comparison analysed value of the energy performance for the Senate Building of the Federal University of Technology Minna was very high with 25743KWh/m^2 consumed followed by the Niger State Polytechnic Zungeru with 19871KWh/m^2 consumed while the Niger State College of Education Minna consumed 19313KWh/m^2. The results were above the Building Energy Efficiency Guideline for Nigeria and the CIBSE benchmarks when compared as shown in Table 4.1. and Table 4.2. For the Senate Building and the Niger State Polytechnic Zungeru administrative block. While the energy consumed at the Niger State College Minna administrative block was within the benchmarks when compared as shown in Table 4.3. The administrative buildings of FUT Minna, Zungeru Polytechnic, and COE have demonstrated a decrease in energy usage from 12 to 2 p.m., but not from 9 to 12 a.m., according to Figures 4.7.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The research assessed the administrative buildings of the Federal University of Technology Minna, Niger State Polytechnic Zungeru and Niger State College of Education Minna in order to ascertain the electrical energy consumption from the dominant source of energy – electricity, against established benchmarks. The results indicated that the energy performance in the metric assessed of the administrative building of the Federal University of Technology Minna, and Niger State Polytechnic Zungeru was poorly performed for air conditioner office. While the energy performance of Niger State College of Education Minna was typical for existing air conditioner office. In conclusion, the results shown that the significant levels of the actual electrical energy consumed in the senate building of the Federal University of Technology Minna, and the administrative block of Niger State Polytechnic Zungeru were high while that of the administrative block of the Niger State College of Education Minna was within the benchmarks. These results implied that the senate building of the Federal University of Technology Minna and the administrative block of Niger State Polytechnic Zungeru were energy inefficient. From the research findings it can also be induced that the administrative buildings FUT Minna and Zungeru Polytechnic consumed more energy because of their big size per square foot. Another major factor that contributes to the energy consumption of these buildings is the cooling of the space. They also have more electronic equipment, such as computers and photocopy machines and printers.

5.2 Recommendations

Energy efficiency is a major priority for the studied tertiary institutions looking to reduce its carbon footprint and maximize its profits. There are many steps that can be taken to reduce energy consumption and improve the efficiency of the tertiary institution's facilities and operations.

1. A dedicated and effective monitoring of energy consumption through audit of the administrative buildings of FUT Minna and Zungeru Polytechnic that focuses on reducing consumption and maximizing efficiency should be put in place and implemented throughout the tertiary institutions in order to ensure that all activities are as energy efficient as possible.
2. In order to improve energy efficiency and reduce carbon emissions, tertiary institutions should look for ways to conserve energy and save money on their energy bills. Some measures that can be adopted include replacing incandescent light bulbs with energy-saving fluorescent bulbs, installing motion sensors and timers for lights, heating controls for hot water tanks, caulking and weather stripping around doors and windows, switching off computers and other equipment when not in use, and installing insulation around the building to reduce heat loss.
3. Other measures that tertiary institutions can take to reduce their energy consumption include implementing an energy saving policy within the institutions, promoting a culture of energy conservation within the institution, and using more energy efficient equipment and machinery such as Kill-A-Watt, Belkin Conserve Insight, PeakTech Meter, Power-Mate and Wattson to mention but few which will help in tracking electrical energy consumption in each of the appliances used. This will make end-users more aware of the power consumed by each of the appliances they use on daily/weekly/monthly and annually basis.

5.3 Contribution to Knowledge

The research topic "Assessment of Electrical Energy Consumption in Some Selected Tertiary Institutions Administrative Buildings in Niger State" contributes to knowledge in several ways. Firstly, the study provides insights into the energy consumption patterns and efficiency of administrative buildings in tertiary institutions in Niger State, Nigeria. This knowledge can be used to guide policy decisions and resource allocation in the energy sector, particularly with respect to energy efficiency targets.

Secondly, the study highlights the need for more efficient energy management practices in the administrative buildings of tertiary institutions. The recommendations made by the study, such as implementing an energy-saving policy, promoting a culture of energy conservation, and using energy-efficient equipment, can be applied not only in Niger State but also in other regions with similar challenges.

Thirdly, the study provides a basis for further research on energy consumption in other types of buildings in Niger State, such as residential and commercial buildings, and in other regions of Nigeria. This can contribute to a better understanding of the energy consumption patterns and efficiency of buildings across the country, and inform the development of policies and programs aimed at reducing energy consumption.

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