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Evaluation of Building Energy Use in South Western Nigeria

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Abstract: The study investigated the energy needs of buildings in South Western Nigeria; examined factors influencing energy loss in buildings and examined the factors influencing implementation of energy saving opportunities in South Western Nigeria with a view to providing information that will enhance economic (cost) and environmental sustainability. The study made use of primary data collected by carrying out building energy audits on 40 buildings that utilize the heating, ventilation and air conditioning (HVAC) system in the study area selected through a purposive sampling technique and administration of questionnaires to the building users. Data collected included energy needs in buildings, building user's needs for thermal comfort, air leaks in building envelopes and the envelope characteristics, and user's agreement on energy saving measures. The data were analyzed using frequency, percentage, mode, mean score and heat transmission formular. The results on energy needs revealed that space cooling accounts for the highest (100%) energy need than space heating (10%) in South Western Nigeria. Results on energy loss revealed that inadequate envelope from air leaks with external windows having the highest percent (72.5%) of air leaks, and (67.5%) unawareness of building users are factors influencing energy loss in buildings. The results on energy saving opportunities revealed that efficient building insulation is a vital measure (MS= 3.8) to save energy in buildings in South Western Nigeria and it is influenced by financial capability of building users (MS= 3.7). The study concluded that efficient building insulation is a vital measure to enhance energy savings in buildings and it is greatly influenced by the financial capability of the building users.

Keywords: Energy Loss, Energy Saving, HVAC, Buildings

1. Introduction

In buildings, energy is used for various purposes such as heating and cooling, ventilation, lighting and the preparation of hot sanitary water among them [9]. However, most analysis examines energy use in building as defined by end-use such as space heating, cooling, lighting [19].

According to Asif, globally, buildings account for approximately 40% of total end use of energy; this includes energy used for controlling the climate in buildings, for the buildings themselves, and also energy used for appliances, lighting and other installed equipment [3]. According to Fluke Corporation, a considerable amount of energy loss is actually temperature related; hot or cold air leaks from a building are an obvious issue [10]. According to Luis et al, opportunities to save energy are best considered by eliminating waste to ensure the building need is exactly met by the energy system; maximizing the efficiency of energy systems through the selection of technology and the improvement of operational and maintenance practices;

optimizing the energy supply by selecting the most economical energy source on a per unit energy basis, and utilizing waste energy as possible [20].

Having noted the use, consumption, and the importance of ensuring reduced energy in buildings, it is necessary to assess the probable factors influencing energy loss in buildings which in turn enhances more energy bills, and thus recommend the implementation of energy saving opportunities in a developing country like Nigeria with hot, humid and cold climate, so as to achieve economic (cost) and environmental sustainability.

Research concerning energy in buildings has been on for years, a lot of the research were carried out to develop and make use of several insulating materials to minimize energy loss and thereby conserve energy consumption and increases the efficiency of energy in buildings; using renewable sources to manage the energy deficiency [10, 28, 30, 31, 20, 33]. Many of these studies on energy use in buildings were performed through different techniques in different ways and different locations, and they all had a common goal of energy (cost) saving and environmental sustainability. For instance, Abrahamse et al. conducted a meta-analysis on the effectiveness of interventions aiming to encourage households in the Netherlands to reduce their energy consumption [1]. Barr et al, examined the gap between energy saving behaviors and purchasing-related behaviors to conserve energy in UK households [4]. Sadineni et al. studied the main determinants of household energy conservation patterns in Greece [26]. Oyedepo surveyed 3000 Swedish house owners to analyze the factors that influence their adoption of investment measures to improve the energy efficiency of their buildings [22].

Zhuolun and Xiaowei in their research in China used the concept of the evaluation index system for energy saving in residential housing, and stated that in that way, building energy saving work can be further developed and plays an important role in saving energy and protecting the environment [35].

Perez et al. conducted a study on the application of Vertical Greenery Systems (VGS) to be used as passive tool for energy savings in buildings [24]. Sadineni et al. also provided an exhaustive technical review on the different building envelope components and respective improvements from an energy efficiency perspective [26].

The above analysis shows that research and utilization of energy saving technologies has been in many other countries of the world. However, most of these techniques are being utilized in most developed nations across the globe [9]. This study intends to research into energy use in buildings in a developing country like Nigeria, as well as the study area, which has her distinct nature, and her continuous usage of energy will influence both economic cost and environmental sustainability in her nation. Several researches which were carried out looked into energy crisis in Nigeria, investigation on electrical energy conservation and related problems. Most of the studies on energy in buildings and other sectors in Nigeria focused majorly on electrical energy usage and related studies, and others on energy sources, energy efficient appliances, energy conservation and management, energy efficiency with the common goal on sustainability [15, 34]. Thus, there is dearth in research as regards assessment of energy use in buildings in South Western Nigeria as well as the study area. Therefore, this study intends to fill the gap by assessing energy loss in buildings and also the implementation of energy saving opportunities in South Western Nigeria with a view to enhance economic cost and sustainability which is the main aim of this study.

Aim and Objectives

The aim of this study is to assess energy loss, and implementation of energy saving opportunities in buildings in South Western Nigeria with a view to providing information that will enhance economic cost and environmental sustainable energy. The specific objectives of this research are to: (1) investigate the energy needs of buildings in South Western Nigeria; (2) examine the factors influencing energy loss in buildings in the study area and (3) examine the factors influencing the implementation of energy saving opportunities in South Western Nigeria.

2. Literature Review

2.1. Concept of Energy in Buildings

Buildings come in a wide amount of shapes and functions, and have been adapted throughout history for a wide number of factors, from building materials available, to weather conditions, to land prices, ground conditions, specific uses and aesthetic reasons [3]. So there is a big variety of building and also there is a big variety of requirements for these buildings and all these types of buildings have to create suitable indoor microclimate for purpose for which they were built [30]. William and Pinto defined energy as fuels and materials that ignite at moderate temperature, burn with comparative rapidity and are obtainable in quantities of reasonable prices [32]. Wei stated that energy in buildings can be classified into two types namely; energy for the maintenance and servicing of a building during its useful life; and energy capital that goes into production of a building (embodied energy) using various building materials [31]. However, according to O'Hara, of all these, the most widely used energy sources are the hydrocarbon compounds or fossil fuels which account for more than 80% of global primary energy consumption [23]. For instance, fossil energies provide about 67% of the energy needed to produce electricity which is a veritable and the most terminal form of energy for transmission and distribution for industrial production processes [18]. Energy consumption per capita is one of the indicators or benchmarks for measuring the standard of living of a people or nation; energy is therefore an inextricable part of a nation’s development and security [6].

2.2. Energy Need and Consumption in Buildings

Energy consumption is the amount of energy consumed by a person or an apparatus shown as a unit, and a great amount of energy consumption occurs in buildings due to indoor heating, cooling, ventilation and lighting [34]. According to Zhuolun and Xiaowei, building energy consumption is defined as the energy consumption during the building usage, including heating condition, air conditioning, hot water supplement, lighting, household applications, and elevators; the energy lost through building enclosure structure and consumed in heating and cooling system takes up a large part of total building energy consumption [35]. In addition, the extent of energy usage in buildings to meet the needs of building users in Nigeria cannot be overemphasized. Yohanna et al. is of the opinion that residential buildings in Nigeria accounts for the largest share of energy usage in the country which is about 65% and the major energy consuming activities in Nigeria's households are cooking, lighting, use of electrical appliances and the HVAC system [34]. This consumption is said to be dominated by electricity.

2.2.1. The Building Envelope

The building envelope is a term for the parts of the building which surround the heated and cooled parts of the building and this includes external walls, floors or ground deck, roofs or constructions towards unheated ceilings, windows and doors and foundations of buildings [13]; they also control the flow of heat, moisture, and air and their color and other optical properties affect the way heat is absorbed and how the building radiates heat back into the atmosphere, but they must do so in ways that meet aesthetic standards and serve functions such as building stability and fire-resistance [8]. The skin of the building, named the envelope, works like an exchanger with the external climate conditions, gaining heat from exposure to solar rays and releasing heat towards the outside (due to ventilation and an inadequate envelope); the envelope, apart from having the task of wrapping and defending the building, should allow it to breath, in order to avoid indoor humidity and reach a proper balance between heat gains and losses [28]. In addition to protecting the building occupants from the prevailing outdoor elements, the conditions inside the building must be maintained within a range that is conducive to the occupant's comfort, health and safety [3]. Hence, the building systems must control the space temperature, relative humidity, air movement, air quality, and lighting levels within acceptable limits.

2.2.2. Air Filtration

Air filtering around windows and glass areas creates an indoors draught. When considered thermally, the undesired air filtration is a loss of energy as it requires redundant heating or cooling. Similar filtrations come from the connection of building parts in general and for some constructions such as boards, which have contracted allowing small openings to appear [28]. Infiltration is similar to ventilation except it is the unintentional entry of outside air into a building. Infiltration occurs when air outside the building leaks in through cracks and other openings in the building envelope, such as around windows, doors, dampers, window and through the wall air conditioning units, skylights and whenever a door or window is opened [2]. However, energy is required to raise the mass of infiltrated air from the outside temperature to the space temperature inside the building. The rate of energy required at any given time depends upon the amount of air being introduced into the building, and the difference between the outdoor and indoor temperatures [17].

2.3. Energy Loss in Buildings

According to Fluke Corporation, a considerable amount of energy loss is actually temperature related; hot or cold air leaks from a building are an obvious issue, it took energy to heat or cool that air, and when it dissipates due to a leak, you've wasted that energy [10].

Similarly, the heat losses in buildings generally occur through external walls, ceiling, floor, windows and air infiltration; Heat loss through the building envelope can be controlled in many different ways i.e. orientation, types of building and optimum insulation thickness [29]. Most of the building energy loss is due to an inadequate envelope from the design, construction, maintenance and component materials of the envelope which is composed of the walls, floors, roof, doors, and windows as shown in Figure 1 respectively. Often the inability of an HVAC system to meet the space conditioning needs of the occupants and process is a clue to the existence of savings opportunities [18].

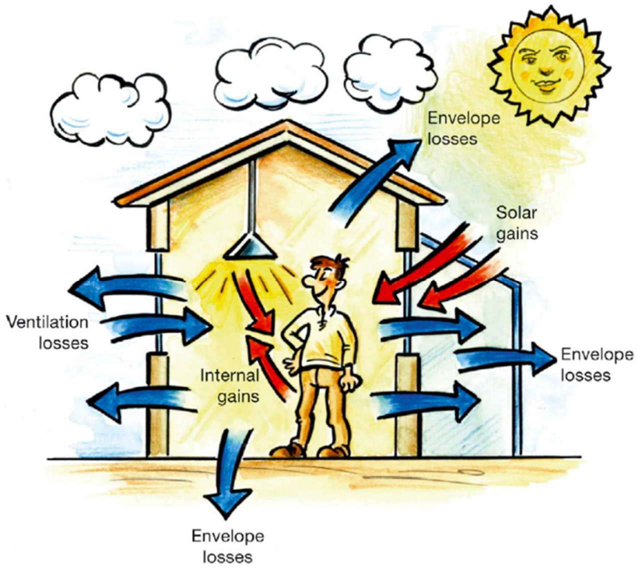

Figure 1. *Energy loss in the building envelope [28].*

2.3.1. Energy Audit and Methods of Determining Energy Loss in Buildings

According to Jon and Grace, the first step toward increasing your home's energy efficiency and comfort is to conduct a whole house energy audit [16]. A diligent tour of your home with a detailed energy audit sheet will help determine how well one's home operates and what upgrades are needed to improve its energy performance. Professional tools, including test equipment for air leakage and infrared camera scans, allow one to see energy losses in new ways.

According to Jon and Grace, home energy audit can be done by:

a) Blower door test: This is done by depressurizing the home with a large fan and then measuring airflow into the home, the overall air leakage of the entire home can be measured. The test can also be used to determine the location of leaks.
b) Duct pressure test: This will identify the area and location of leaks in the duct system. A related 'balance' test of the heating ducts determines if the right amount of air is flowing to each room for comfort and efficiency. Other tests confirm combustion safety and ventilation fan flows.
c) Heat pumps and A/C commissioning: This involves a set of tests that confirm the systems have the correct air flow and refrigerant charge. Equipment may have been sized using only rules of thumb, which can mean poor performance and durability.
d) Thermal Imaging: this is done by utilizing a thermal image device measures surface temperatures using infrared cameras and creates a visual image of heat loss. The cameras detect radiation in the infrared range of the electromagnetic spectrum. Typically, warmer surfaces appear brighter, and cooler surfaces appear darker. The images can reveal where walls, ceilings or floors are inadequately insulated or where windows and doors aren't well sealed [16].

2.3.2. Energy Loss Areas in a Building

According to Fluke Corporation, the top places to look for energy loss in buildings are;

a) Building envelope: estimates affirms that following up on the findings of an energy audit of a building's envelope saves most facilities at least 15% on energy bill. Areas to scan includes roofs, walls between conditioned and unconditioned spaces including external walls, construction joints and connections, penetrations of the building envelope (pipes, conduits, chimneys), door and window frames and seals.
b) HVAC system: Studies indicate that commercial buildings with constant-air-volume systems often experience energy losses from air leakage of as much as 33 %. Also, studies indicate that air-supply temperature differentials due to conduction losses can be as great as 6 °C (10.8 °F) or more. Considerable savings can be achieved in with duct-sealing and insulation remedies. Areas to scan includes ductwork and registers, fans and blowers, electrical connections, compressors and coils.
c) Steam heating systems: Studies revealed that in a 100-psig-steam system, if a medium-sized trap fails open it will waste about $3,000 per year. Areas to scan includes steam traps, radiator coils, steam line and valves, condenser.
d) Electrical systems: According to some estimates, lighting accounts for about 20 % of all electricity use in the U.S. and more than 40 % of electricity use in offices, stores, and other commercial buildings [10].

In conclusion, apart from an inadequate envelope being a major factor influencing energy loss in buildings, the researchers [10, 31] stated that unawareness of people on energy loss in buildings is also a factor in the sense that energy is invisible and people are unaware of certain air leaks which occur in the building envelope.

2.4. Energy Saving in Buildings

According to John and Akinloye, energy saving in building is expressed as buildings which in their planning, design, and usage process, new type of materials are adopted, building energy standard is executed, operation and management of building device is enhanced, the thermal performance of enclosure structure of building is designed reasonable, the efficiency of heating, refrigeration, illumination, ventilate, water supply and drainage, and aisle system is improved, and take advantage of reproducible energy, in the premise of ensuring the using functional and indoor thermal environment quality in the building, the energy consumption is reduced, and the resource is utilized reasonably and efficiently [15].

The objective of energy saving is to save energy cost by reducing the energy required for cooling, and minimizing energy loss while maintaining an environment suitable for both processes and occupants. Zhuolun and Xiaowei stated that in developed countries, building energy saving has experienced three stages, namely: energy saving in buildings, that is to save energy in building process; energy conservation in buildings, that is to conserve the energy and reduce the energy loss; energy efficiency in buildings, that is to improve the building energy usage efficiency from a positive view [35].

2.4.1. Energy Saving Measures

Energy saving strategies for the building envelope can be narrowed down to reducing losses of the three types: conduction (i.e. add insulation); convection (i.e. minimize air infiltration); and radiation (i.e. replace or improve windows) [28]. According to Jon and Grace, how to reduce energy loss in buildings are; to increase insulation for the building envelope; reduce air infiltration by utilizing polyurethane sealants and adhesives; increasing the thermal resistance of windows and doors; increasing the efficiency of heating and cooling equipment [16]. Researchers have identified various energy saving measures [10, 28, 29, 25, 8, 17] for a building. They are identified as follows: efficient heating and cooling technology with efficient appliance and equipment, improved sensors and control systems to regulate consumption, automation of building appliance and system, good landscaping design around the building envelope, efficient building insulation, use of building design codes and regulations, passive building designs, intelligent and well-designed building envelope, seasonal energy audit and renovation, airtightness in building envelope during construction and roof insulation and airtightness.

2.4.2. Factors Influencing Energy Saving Opportunities

Many barriers impede energy saving in buildings, and perfect function of the building sector market in economic terms [8]. When buildings are designed and constructed, energy saving is but one concern amid many, some considered more urgent by decision-makers. Energy saving in buildings may hence be low on the list of requirements. However, of the studies on energy saving measures in buildings [15, 5, 22, 12], the factors influencing energy implementation of energy saving opportunities are; lack of awareness of energy saving opportunities in design, construction, and building usage, lack of technological know-how, unawares of energy loss in building envelope, ineffective regulatory policies on building energy deign and usage, inefficient energy pricing policies on buildings energy consumption in the locality, financial capability of building users, lack of improved software for building design and operation, accessibility and availability of energy efficient equipment and cost of implementation of energy saving designs and technologies.

3. Research Methodology

3.1. Research Approach and Population

The research design that was adopted is a mixed approach using quantitative and qualitative survey which encompass buildings in the study area using questionnaires designed and an energy audit sheet to extract information on energy use in buildings which was filled by building users and inspected by the researcher in the buildings that utilize the HVAC system. The research population involves gathered information from building users and buildings that utilize the HVAC system. In this research, a purposive sampling technique was used where a total number of 20 buildings each were inspected in each of the two study areas making the total number of distributed questionnaires to be forty (40). These questionnaires were distributed to the building users.

3.2. Study Area

The researched is centered to assess energy loss and the implementation of energy saving opportunities in South Western Nigeria. South Western Nigeria consists of the following states; Ekiti, Lagos, Ogun, Ondo, Osun, and Oyo. However, the study was limited to the use of questionnaire-based survey research using Akure, Ondo state, and Lagos Island, Lagos state as a case study. These states were used as case studies because they share similarities with the other states in the region. So, due to the impracticable nature of eliciting information from all the states, these states (Akure, Ondo state and Lagos Island, Lagos state) were picked by the researchers as the study area.

3.3. Data Analysis Tools

3.3.1. Objective One

Primary data were collected on the energy needs of building user. Frequency distribution and percentages were used to evaluate the energy needs of buildings.

3.3.2. Objective Two

Data was collected on energy loss channels through the air blower technique with the aid of an energy audit sheet, and level of awareness and energy management of the air conditioning system by building users. Frequency distribution and percentages were used to analyze the energy loss channels in building envelope and how the HVAC system is utilized.

3.3.3. Objective Three

Primary data were collected on the factors that influence energy saving using twenty-two variables. Multiple response command was used to analyze the predominant factors influencing energy saving opportunities while Mean Score referred to as Users Agreement Score (UAS) was used to determine the factors that most influence energy saving opportunities in South Western Nigeria as well as their line of influence. Formular for Mean Score;

$$\text{Mean Score} = \frac{\text{SWN}}{\text{N}} \quad (1)$$

Where SWV = Summation of weight value

= Σ (Rating weight × Number of respondents.)

= Σ F1 + (2 × F2) + (3 × F3) + (4 × F4) + (5 × F5)

F1 to F5 = frequency of response (1 to 5) on the agreement scale. (i.e 1= strongly disagree, 5= strongly agree on a Likert scale)

N = total number of respondents.

4. Data Presentation and Analysis

4.1. Demographic Attributes of Respondents

Table 1. *Demographic Attributes of Respondents.*

Demography	Frequency	Percent (%)
Residential location		
Akure	20	50
Lagos Island	20	50
Total	40	100
Type of residential building		
Bungalow	12	30
Flats	12	30
Duplex	16	40
Terrace	0	0
Total	40	100
Age range		
Below 21 years	0	0
21-40 years	24	60
Above 40 years	16	40
Total	40	100
Number of AC in buildings		
1	12	30
2	8	20
3	4	10
4	4	10
8	2	5
10	1	2.5
11	3	7.5
12	2	5
13	3	7.5
14	1	2.5
Total	40	100

Demography	Frequency	Percent (%)
Number of years of utilizing HVAC system		
1-5	20	50
6-10	11	27.5
above 10	9	22.5
Total	40	100.0

From Table 1, the result of the type of building showed that duplex has the highest frequency 16 (40%), this is because there seemed to be a lot of duplex buildings mostly in the axis of Lagos Island. It also reveals that the residential location of the respondents is 20 (50%) from Akure and 20 (50%) from Lagos Island, which satisfies the sample frame and sample size required to provide necessary information or the research. On the age range of respondents, it can be seen in Table 1 that, none (0%) of the respondents were below the age of twenty-one, 24 (60%) were between the age of twenty-one and forty years, and 16 (40%) were above the age of forty years. The frequency and percentage showed that the respondents sampled had minimum age of twenty-one years, thus making them fit in knowledge to provide reliable information. Information was sought on the number of air conditioning system utilized in each building. Table 1 revealed that 12 (30%) of the respondents have one air conditioning system in their homes, 8 (20%), 4 (10%), 4 (10%) have two, three and four air conditioning systems respectively in their homes, 2 (5%) have eight air conditioning system in their homes and 10 (25%) have between ten and fourteen air conditioning system in their homes. This showed that a large percentage of the respondents use more than two air conditioning system in their homes. More so, with regards to information sought on the number of years the respondent has been utilizing the HVAC system, Table 1 revealed that 20 (50%) of the respondents has been utilizing it between one and five years, 11 (27.5%) between six and ten years, and 9 (22.5%) has been utilizing it for more than ten years. This reveals that half of the respondents have been utilizing it for more than six years and therefore fit to adequately respond to the need of the research.

4.2. Energy Bills of the Respondents

Table 2. *Energy bills of respondent*

Energy Bills	Frequency	Percent (%)
2500 – 15000	18	45
15001 – 30000	2	5
30001 – 45000	4	10
45001 – 75000	3	7.5
75001 – 90000	4	10
Above 90000	2	5
Prepaid system	7	17.5
Total	40	100

Table 2 revealed that 18 (45%) of the respondents pay between ₦2,500 and ₦15,000 monthly for energy bills to meet their building needs, 2 (5%) of the respondents pay between ₦15,000 and ₦30,000 monthly, 4 (10%), 3 (7.5%), and 4 (10%) of the respondents pay between ₦30,000 and ₦45,000, ₦45,000 and 75,000, and between ₦75,000 and ₦90,000 respectively. Also, 2 (5%) of the respondents pay above ₦90,000 monthly to meet energy needs, and 7 (17.5%) of the respondents utilize the prepaid system and could not decide how much exactly they spend monthly for energy bills. In addition, it can be inferred that the highest amount paid on energy bills are within the range of over ₦90,000 monthly in South Western Nigeria and this rate can be reduced by efficiently utilizing energy saving opportunities as opined by Wei [31]; besides, the HVAC system and lighting are the highest consumer of energy in buildings [18].

4.3. Energy Needs of Buildings in South Western Nigeria

Table 3. *Energy bills of respondent.*

Energy needs of buildings	Frequency of use	Percent (%)
Lightning	40	100
Cooking		
Electric cookers	20	50
Electric microwave	28	70
Electric oven	18	45
Toaster	30	75
Dishwasher	5	12.5
Electric blender	32	80
Electric heater	24	60
Refrigeration (food preservation)	37	92.5
Home Entertainment Electronics		
Television	40	100
Home theaters	30	75
Video games console	13	32.5
DVD (digital video display)	29	72.5
Digital and Satellite Network	21	52.5
Radio	20	50
Computer equipment		
Desktop computer	16	40
Laptop computer	31	77.5
Scanner and printers	16	40
Copier	7	17.5
Security devices		
Automated gate	10	25
Electric fence	12	30
Security cameras	13	32.5
Laundry		
Washing machine	30	75
Tumble dryers	11	27.5
Electric iron	40	100
Pumping machine	34	85
Space heating (room heaters)	4	10
Space cooling		
Air conditioning	40	100
Fan (ceiling)	32	80
Water heaters	25	62.5
Rechargeable devices		
Mobile phones	40	100
Lamps	34	85
Rechargeable fan	15	37.5
Mp3 player	16	40
Digital camera	8	20
Electric toothbrush	2	5
Power tools (UPS)	17	42.5

Table 3 revealed that 40 (100%) of the building users in South Western Nigeria purchase energy to utilize lighting in their homes. Also as regards purchasing energy for cooking activities in South Western Nigeria, 20 (50%) of the building users need energy for electric cookers, 28 (70%) need energy for electric microwaves, 18 (45%) need energy for electric oven, 30 (75%) need energy for toaster, 5 (12.5%) need energy for dish washer, 32 (80%) need energy for electric blender and 24 (60%) of the building users need energy for electric heater. This implies that a larger percent (80%) of building users require energy for electric blender, followed by toaster (75%), electric microwave (70%), electric heater (60%), electric cookers (50%), electric oven (45%), and dish washer (12.5%) respectively. More so, in respect to energy purchased for refrigeration, Table 3 revealed that 37 (92.5%) of the building users require energy for refrigeration. For home entertainment electronics, a larger percentage 40 (100%) of building users in South Western Nigeria require energy for television, followed by 30 (75%) for home theaters, 29 (72.5%) for digital video display, 21 (52.5%) for digital and satellite network, 20 (50%) for radio and 13 (32.5%) for video games console. Table 3 revealed that 31 (77.5%) of the building users in South Western Nigeria require energy for laptop computer, 16 (40%) for desktop computer, scanners and printers each, and 7 (17.5%) require energy for copier. As regards security devices, 13 (32.5%) of building users in South Western Nigeria require energy for security cameras, 12 (30%) require energy for electric fence, and 10 (25%) of building users in South Western Nigeria require energy for automated gate. Furthermore, as regards energy need for laundry, Table 3 revealed that 30 (75%) of building users in South Western Nigeria require energy for washing machine, 11 (27.5%) need energy for tumble dryers and 40 (100%) need energy for iron. It also revealed that 34 (85%) of building users need energy for pumping machine.

The table also reveals that 25 (62.5%) of building users in South Western Nigeria need energy for water heaters, and of energy required for rechargeable devices in South Western Nigeria, it revealed that 40 (100%) of building users need energy for mobile phones, 34 (85%) need energy for rechargeable lamps, 15 (37.5%) need energy for rechargeable fan, 16 (40%) need energy for Mp3 player, 8 (20%) need energy for digital camera, 2 (5%) need energy for electric toothbrush and 17 (42.5%) of building users need energy for power tools (UPS). This implies that there is a high demand for lighting, HVAC system and refrigeration and this agrees with the findings of John and Akinloye (2012) [15]; hence proper attention and research should be given to these areas of the building needs to develop and encourage usage of energy saving techniques to enhance environmental sustainability and economic cost. As regards information on energy needs to achieve thermal comfort in buildings, of the HVAC systems, Table 3 revealed that 4 (10%) of building users in South Western Nigeria need room heaters to achieve thermal comfort, and 40 (100%) of the buildings users need air conditioning system, and 32 (80%) of building users need fan to achieve thermal comfort in their homes. This implies that space cooling in homes of South Western Nigeria is more needed by building users compared to space heating. This agrees with the research of Luis et al. and Yang et al. that there is a high demand of the HVAC system in buildings, and space cooling has a higher demand in South Western Nigeria. Hence more research should be done to investigate space cooling in buildings and develop energy saving schemes to enhance environmental sustainability and economic (cost) [20, 33].

4.4. Energy Loss Channels in Building Envelope of South Western Nigeria

Table 4. *Energy loss channels in building envelope.*

Building Component Inspected		Frequency	Percent (%)	Rank
External windows	Air leaks	29	72.5	1
	No air leaks	11	27.5	
Front doors	Air leaks	23	57.5	2
	No air leaks	17	42.5	
Walls between external and internal	Air leaks	12	30	3
	No air leaks	28	70	
Ceiling	Air leaks	10	25	4
	No air leaks	30	75	
Doors to uncooled area	Air leaks	8	20	5
	No air leaks	32	80	
Windows to uncooled area	Air leaks	7	17.5	6
	No air leaks	33	82.5	
Internal walls	Air leaks	3	7.5	7
	No air leaks	37	92.5	
Base boards and wall fans	Air leaks	3	7.5	8
	No air leaks	37	92.5	
Pipe and wire penetrations	Air leaks	2	5	9
	No air leaks	38	95	
Walls between cooled and uncooled area	Air leaks	2	5	10
	No air leaks	38	95	
Floor	Air leaks	1	2.5	11
	No air leaks	39	97.5	
Switches and outlets	Air leaks	0	0	12
	No air leaks	40	100	
Roof gutters and eaves	Air leaks	0	0	13

Building Component Inspected		Frequency	Percent (%)	Rank
	No air leaks	40	100	
Crawl spaces and vents	Air leaks	0	0	14
	No air leaks	40	100	
Foundations to walls	Air leaks	0	0	15
	No air leaks	40	100	

Table 4 revealed that there are air leaks in building envelopes of South Western Nigeria with external windows having the highest range 29 (75%) of air leaks from the buildings inspected. That is, windows in 75% of buildings in South Western Nigeria are not air tight and this could result from either the method of construction, state of usage, or level or awareness of the building users.

Furthermore, Table 4 revealed that 23 (57.5%) of front doors in South Western Nigeria have air leaks which results to energy loss from the building envelope, 12 (30%) of walls between the internal of buildings, 10 (25%) of ceilings, 8 (20%) of doors between cooled and uncooled area, 7 (17.5%) of windows to uncooled area, 3 (7.5%) of internal walls, 3 (7.5%) of base boards, 2 (5%) of pipe and wire penetrations, 2 (5%) of walls between cooled and uncooled area, and 1 (2.5%) of floor in buildings of South Western Nigeria have air leaks which results to energy loss from the building envelope.

In addition, there appeared to be air leaks from 40 (100%) of buildings in South Western Nigeria resulting from air leaks from either of the various components of the building envelope. This implies that inadequacy of the building envelope in South Western Nigeria is a factor influencing energy loss in building in South Western Nigeria and this agrees with the findings of [10, 16, 26]. In view of this careful attention is required in the design, construction and maintenance of building envelope, the component materials used, method of construction and as well the state of awareness of the building users and the constructers. All these should be properly checked to prevent or correct energy loss in various building envelopes and thereby enhance economic (cost) and environmental sustainability.

Table 5. *Awareness on Energy loss and State of Energy Management.*

Question	Frequency	Percent (%)
Are of you aware of the air leaks in your buildings?		
Yes	7	17.5
Partially aware	6	15
No	27	67.5
Are you aware you can save your energy bills by carrying energy audit and management in your buildings?		
Yes	10	25
No	30	75
Have you ever carried out an energy audit on your building?		
Yes	2	5
No	38	95
When the room is naturally cool do you switch off your A/Cs?		
Yes	34	85
No	6	15
Are A/Cs in other rooms switched off when no one is in them?		
Yes	35	87.5
No	5	12.5
Are doors to the outside opened longer than necessary?		
Yes	1	2.5
No	39	97.5
Do you switch off your A/Cs when not home?		
Yes	40	100
No	0	0
Do you service and maintain your A/Cs?		
Yes	40	100
No	0	0

Table 5 revealed that 7 (17.5%) of the building users are aware of the air leaks in buildings, 6 (15%) of the building users are partially aware, and 27 (67.5%) of the energy users are unaware of energy loss in buildings. This implies that a larger percentage of building users in South Western Nigeria are unaware of the energy loss in buildings, this agrees with the findings [8, 31]; hence, since they are unaware of energy loss from various air leaks, necessary corrective actions may not be put in place to reduce energy bills and enhance economic cost and environmental sustainability.

Furthermore, Table 5 revealed that 10 (25%) of the building users are aware they can save energy bills by carrying energy audit and management in their buildings, while 30 (70%) are unaware. Meanwhile, 2 (5%) of the building users had carried out an energy audit on their building while 38 (95%) had not done it at all. This implies that the state of awareness and utilization of energy audit in buildings in South Western Nigeria is low and this will not enhance economic cost and environmental sustainability and this agrees with the findings [25]. In view of this, awareness schemes should be provided to enlighten building users on the effect of energy loss in buildings and the benefits of carrying out building energy audit in buildings.

More so, Table 5 revealed that 34 (60%) of building users switch off air conditioning systems when the rooms are naturally cool while 6 (15%) of the building users do not. Also, 35 (87.5%) of the building users switch of their air conditioning systems in rooms when no one is in them while 5 (12.5%) do not, 40 (100%) of the building users switch off their air conditioning systems when no one is in the entire building, and 40 (100%) of the building users service and maintain their air conditioning systems. The findings of David and Oyedepo [22] revealed that there is lack of overall energy management policy in Nigeria, and this study reveals that the state of energy management of HVAC system by building users in South Western Nigeria is good and does not promote energy loss in the buildings of South Western Nigeria [8, 22].

Factors Influencing Energy Saving Opportunities in South Western Nigeria

Table 6. *Factors influencing energy saving.*

Measures	Mean score	Rank
Efficient building Insulation	3.8	1
Financial capability of building users	3.7	2
Seasonal Energy audit and renovation	3.66	3
Accessibility and availability of energy efficient equipment and installation of technologies	3.66	4
Ceilings and walls airtightness	3.61	5
Passive building designs (building with comfortable indoor climate.)	3.59	6
Unawareness of people on energy loss in building envelope.	3.59	7
Efficient heating and cooling technology with efficient appliances and equipment.	3.5	8
Roof insulation and airtightness.	3.5	9
Lack of technological know-how on utilizing opportunities	3.5	10
Good landscaping design around the building envelope	3.48	11
Airtightness in building envelope during construction	3.48	12
Lack of awareness on energy saving opportunities in design, construction and building usage.	3.48	13
Improved sensors and Control systems to regulate consumption	3.45	14
Passive glazing materials for buildings	3.45	15
Intelligent and Well-designed energy saving building envelope	3.45	16
Inefficient energy pricing policies on buildings energy consumption in the locality.	3.39	17
Ineffective regulatory policies on building energy design and usage	3.36	18
Automation of building appliances and system	3.25	19
Cost of implementation of energy saving designs and technologies.	3.25	20
Building Design codes and regulations	3.23	21
Lack of improved software for optimizing building design and operation	3.09	22

Table 6 revealed that the major factor influencing energy saving opportunity in South Western Nigeria is efficient building insulation (M.S = 3.8) and line of influence of the factors in decreasing order are: financial capability of building users (MS = 3.7), seasonal energy audit and renovation (MS = 3.66), accessibility and availability of energy efficient equipment and installation of technologies (MS = 3.66), ceiling and walls air tightness (MS = 3.61), passive building designs (MS = 3.59), unawareness of building users on energy loss in buildings (MS = 3.59), efficient heating technology with efficient appliances and equipment (MS = 3.5), roof insulation and air tightness (MS = 3.5), lack of technological know-how on utilizing opportunities (MS = 3.5), good landscaping design around the building envelope (MS = 3.48), airtightness in building envelope during construction (MS = 3.48), lack of awareness on energy saving opportunities in design, construction and building usage (MS = 3.48), improved sensors and control systems to regulate consumption (MS = 3.45), passive glazing materials for buildings (3.45), intelligent and well-designed energy saving building envelope (MS = 3.45), inefficient energy pricing policies on buildings energy consumption in the locality (MS = 3.39), ineffective regulatory policies on building energy design and usage (MS = 3.36), automation of building appliances and system (MS = 3.25), cost of implementation of energy saving designs and technologies (MS = 3.25), building design codes and regulations (MS = 3.23), lack of improved software for optimizing building design and operation (MS = 3.09).

This shows that the major measure agreed by the building users to influence energy saving opportunities in South Western Nigeria is efficient building insulation and agrees with the findings of Sergio et al. and Subhash et al. and it is followed by financial capability of the building users [28, 29]. This implies that the ability to utilize and benefit from energy saving opportunities in buildings in South Western Nigeria is greatly influenced by the financial capability of the building users as agreed by John and Akinloye, Oyedepo, Frederick et al. and James and Thomas [15, 22, 11-12]. Meanwhile, all factors were agreed to influence energy saving opportunities in South Western Nigeria.

In view of this, efficient building insulation should be utilized either at the early stage of construction of a building or in existing buildings by means of several insulating materials that best has the ability to save energy in buildings. However, considering the financial capability of the building user, several means should be sought to assist the provision of funds because the life cycle cost of the building will be greatly influenced positively at the long run of utilizing efficient building insulation.

5. Conclusion and Recommendations

5.1. Conclusion

As a conclusion to this study, through the building energy audits, administration of questionnaires and analyzing the data, this research work has assessed energy loss in buildings and the implementation of energy saving opportunities in South Western Nigeria with a view to provide information that will enhance economic (cost) and environmental sustainability. Based on the objectives of the study, the major conclusions made from the results obtained from the data analyses in the preceding chapter (chapter four) are summarized below:

The study concluded that most percentage (100%) of building users in South Western Nigeria require space cooling than space heating (10%) to achieve thermal comfort in their homes.

The study also concluded that inadequate building envelope and the awareness of building users are factors influencing energy loss in buildings in South Western Nigeria. Lastly, the study concluded that efficient building insulation is a vital measure to influence energy saving in South Western Nigeria and it is also influenced by the financial capability of the building users; meanwhile the energy need for cooling can be greatly reduce by utilizing efficient building insulation in buildings.

5.2. Recommendation

In the light of the findings, the following recommendations are made: (1) Awareness schemes should be provided for building users on energy loss in buildings and benefits of energy audits in buildings; (2) Proper attention should be given to air tightness in the building envelope during design and construction; (3) The utilization of efficient building insulation should be encouraged in buildings to enhance energy savings in buildings and; (4) In respect to the financial capability of the building users, several schemes (e.g. mortgage) should be provided by government, private organizations or estate developers to support building users financially in utilizing several energy saving measures and technologies.

5.3. Contribution to Knowledge

This study provides information on energy needs of buildings in South Western Nigeria, energy need to cool a building, factors influencing energy loss in buildings, factors influencing implementation of energy saving opportunities in South Western Nigeria, and suggests energy saving measure to be utilize to enhance economic cost and environmental sustainability.

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Conflicts of Interest

The authors declare no conflicts of interest

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