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Research Article

Achieving sustainability in Nigerian households: Investigating factors impacting energy efficiency practices

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ABSTRACT

The looming global energy crisis of the 21st century is predicted to worsen as building energy consumption is expected to rise by 50% by 2060. Investing in energy-efficient technologies and reducing carbon emissions is essential to combat this crisis. To this end, this paper delves into the complex issue of energy-efficient building practices in Nigerian households and how they can help curb carbon emissions. Using a statistical method known as the Relative Importance Index (RII), we analyzed nine key factors that influence a building's energy efficiency. The research revealed that government oversight, support, and financial and technical assistance are crucial for achieving household energy efficiency. It also highlights the significance of addressing the energy crisis in Nigeria through the development, implementation, and adaptation of energy-efficient building practices.

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1. INTRODUCTION

Energy is essential in promoting different countries' economic expansion, development, and financial feasibility [1]. However, the energy sector has been dramatically affected by the COVID-19 pandemic, resulting in a 5% decline in worldwide energy consumption and a 7% reduction in carbon dioxide emissions related to energy in 2020 [2]. Nevertheless, energy demand is predicted to recover to its pre-pandemic level by the beginning of 2023[2]. With the planet's population projected to reach 9.7 billion by 2050, the energy demand is anticipated to rise, further exacerbating climate and environmental change [46,48]. To address these issues, its essential for stakeholders to explore older explore alternative solutions to mitigate the impact on their economies and promote energy efficiency across all sectors, particularly the buildings sector, which accounts for about 19% of global GHG emissions and 40% of overall global energy usage through lighting and air conditioning [5]. Building energy consumption is expected to rise by 50% by 2060, contributing to increasing global carbon emissions [6]. This increase is

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mainly due to rapid urbanization and social demand [8,18], which contributes to the sector's consumption of about 30% of the total energy usage worldwide [9,10]. Consequently, there is an urgent need to improve the overall energy efficiency of both commercial, residential, and industrial development through the implementation of distributed energy systems (DESs), as they are the most feasible and least contentious method to address the energy crisis and environmental issues [3], although their development, performance, and operational strategies are not yet fully utilized [4, 12].

Many countries are currently focusing on buildings that consume less energy, industries that require less energy, and transportation systems that use less energy to address the various issues related to their energy crisis. However, in Nigeria today, energy efficiency practices are less considered, resulting in energy waste, increased demand, and energy expenses [47]. As such, it is essential to look into the factors influencing the implementation of energy-efficient building practices in Nigerian households and the adaptation of those practices by users and various public stakeholders. Applying these remedies will significantly reduce energy waste, modifying the country's energy demand and saving unnecessary expenses [13].

A. Energy Crises in Nigeria

Nigeria is a major oil producer in West Africa; however, the nation is facing a significant energy crisis resulting from the inability of its fuel-generated energy to meet the needs of its densely populated citizens [30]. Nigeria's energy resources are mainly non-conventional, depending mainly on the nation's oil, primarily depending on natural gas, tar, and coal while putting less emphasis on the country's numerous renewable energy resources [29]. The main grid power systems are thermal and central electric power plants with an installed capacity of 8,18MW. Unfortunately, 25.1% of this capacity is lost due to technical issues in transmission, distribution, and residential inefficiencies [26]. The problem is further compounded by issues such as poor maintenance of power plants, outdated equipment, and widespread gas pipeline vandalism [35]. The heavy reliance on fossil fuels contributes to climate pollution and can be costly and hard for certain parts of the country [31, 32].

Furthermore, the energy crisis in Nigeria has been linked to inefficient construction and usage of buildings [35,36]. Many buildings in Nigeria are not energy-efficient and lack insulation, leading to high energy consumption for cooling and heating [36]. As a result, most residents are ten unfamiliar with energy efficiency and unaware of the differences between conventional and more energy-efficient materials. Thus, to have a deeper understanding of the implications of energy conservation, it is necessary to investigate the behavior of residents in their daily energy consumption [26]. Therefore, improving power generation in the country should focus on reducing transmission and distribution losses and understanding residents' perceptions of energy conservation by considering key essential policy formulations and execution strategies [27].

Despite all these challenges, a glimmer of hope is on the horizon. Renewable energy sources, such as biomass, solar, wind, and hydroelectricity, offer a sustainable, locally-produced solution to Nigeria's energy crisis [33]. These technologies can create jobs, reduce dependence on fossil fuels, and improve the environment [34]. But to fully harness their potential, Nigeria must invest in the necessary infrastructure and technology and educate the public on the significance of energy saving and the effect of their actions on the environment. The government could also explore other options, such as implementing energy-efficient building policies, incentivizing companies to use renewable energy, and promoting sustainable materials [36].

B. Nigerian Building Energy Efficiency Code

Nigeria's code for energy efficiency in buildings was agreed upon and formally introduced in 2017 by the "federal minister of power, works, and housing" [24, 50]. The code was created in partnership between the "Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)" and Solid Green sustainability experts, who acted as primary consultants, and the code covers various essential rules and guidelines for the country's energy efficiency practices [49]. The "Nigerian Energy Support Program (NESP)" and the "Federal Ministry of Power, Works, and Housing" are tasked with putting the code into effect in conjunction with related professional organizations like the "Green Building Council of Nigeria (GBCN)" and the "Architect's Registration Council of Nigeria (ARCON)" [17,19]. The developed efficiency guidelines for a building include measures for energy efficiency and breaking them into passive and active elements of an energy-efficient structure. The principles aid Nigerian experts in planning, constructing, and operating energy-efficient buildings. It also teaches the general public about energy efficiency methods and tells clients about a better alternative to constructing energy-efficient buildings [19].

The existing building code and guidelines, set by the federal government, elaborate on system structure, fire safety, and general safety procedures but lack detailed information on renewable energy or energy efficiency practices [17]. As such, there is a need for the code to be available legally to all the member states across the country to formulate an operational rule for practice and enforcement at the local and state level. Building license regulations and standards are vital requirements in metropolitan settings, except in minor construction specified by project size or in rural regions where such activities are rarely regulated. Nevertheless, one of the significant obstacles to effectively enforcing regulations in the country's building sector has been the lack of a strong enforcement mechanism for absentee landlords [17,19].

C. Challenges in the Adaptation of Energy Efficient Building Practices in Nigeria.

The energy crisis in Nigeria is a pressing issue that has been plaguing the nation for decades. Despite the several efforts made by non-governmental organizations, the private sector, and the government, the challenges of inadequate energy generation and inefficient energy usage continue to plague the country [1]. The barriers to the mainstreaming of building energy efficiency practices in the country are multifaceted and include financial challenges, corruption in the administration, lack of sufficient information, and a host of legal and regulatory policy, technical, and development barriers [47]. Residents of Nigeria are not known for their energy-saving habits, often leaving appliances on when not in use and neglecting to use natural ventilation to achieve thermal comfort. This lack of consideration for energy efficiency in household practices significantly contributes to the country's energy crisis [19]. To address this, the government and other stakeholders must take a proactive approach by implementing energy efficiency policies, providing regular information and education, and raising awareness about the importance of energy efficiency.

The rapid population growth in Nigeria has also led to an increase in energy demand and consumption across all sectors of the economy, exacerbating the already dire energy situation. This increase in energy demand, coupled with inefficient consumption patterns and environmental problems in energy transmission and distribution, has emerged as a significant source of worry for the country [19]. The construction industry is among the country's most energy-intensive and consuming sectors. Therefore, implementing energy-efficient design principles and practices in this sector is crucial for achieving energy efficiency and sustainability. This includes using materials with low embodied energy, designing for natural ventilation, and incorporating energy storage systems [18]. Additionally, it is equally vital to note that although building energy efficiency may have a higher initial cost, it ultimately counterbalances unnecessary costs associated with its provision [45].

D. Factors Influencing Energy-Efficient Building Practice Implementation

The primary factors influencing energy efficiency practices in buildings are the building itself (its shape, ideal insulation depth, building wall insulation, orientation, window glazing, insulation materials, as well as window-to-wall ratio), the technology and equipment used in the building (thermal energy storage, variable air volume, heating retrieval, control upgrade, and evaporative cooling), and the behavior of its occupants (smart grid, smart meter, control upgrade, and plug load). The building attributes alone cannot be used to determine the optimal design approach, as the other two factors could influence it. For example, some energy-efficient design solutions do not consider economic and environmental benefits under certain conditions. On the other hand, building designers have access to many technological advancements, but cost-effectiveness remains challenging [15].

Occupant behavior intervention can provide a cost-effective and easy-to-implement avenue for increasing energy efficiency for the residents. Ultimately, building service systems, technical improvements, and resident behavior engagement in energy efficiency monitoring is essential as a channeling basis to help the country conserve its energy from the sector [15]. Moreover, occupant responsiveness to energy-saving behaviors may influence innovation, while responsiveness may increase the need for creation and subsequent implementation [16].

In general, lack of suitable technological access, resource limitations, and knowledge of energy efficiency techniques are significant obstacles to adopting energy-saving measures in most emerging economies. As a result, urgent measures and increased awareness are required to motivate human behavior toward energy-efficient practices [14]. Many factors influence the adoption of building energy efficiency practices. However, this paper considered nine factors based on the relative importance index (RII) to determine the factors that impact building energy efficiency and suggest better ways to implement these practices in Nigerian households. Figure 1. summarizes some factors affecting the adoption of energy-efficient building practices.

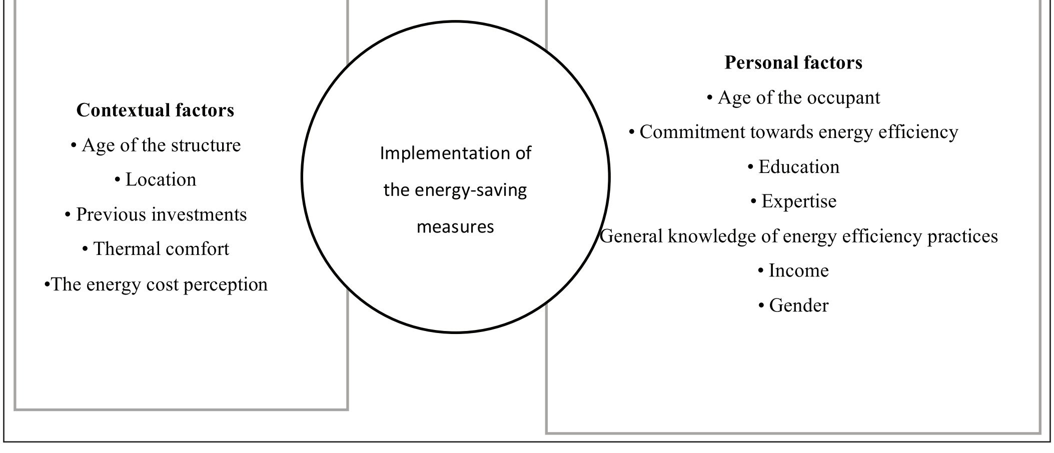

Figure 1. Factors influencing the implementation of building energy-efficient practices.

E. Contribution to Knowledge

This study adds to the current body of knowledge on energy efficiency in Nigeria's building industry by providing insight into the factors that influence the application of energy-efficient practices in the country. Previous studies in this field have also examined the implementation of building energy-efficient practices in the country, but this study provides a much more detailed examination of the specific factors influencing adaptation. For example, some of the previous researchers have looked at the role of government policy in promoting energy efficiency. Still, this study delves deeper by explicitly examining the importance of government supervision and support in encouraging households to adopt energy-efficient practices.

The study also fills a gap in the literature by focusing on the specific case of Kano state, the second-largest industrialized state in Nigeria and a commercial and economic center. By analyzing the situation in this region, the study provides valuable insights into the opportunities and challenges for energy efficiency in a significant urban area. Moreover, the study provides a more comprehensive examination of the energy consumption patterns in Nigerian households, including the use of multiple sources of energy, generator usage, and dependence on the national grid. The study also provides insight into the respondents' behavior toward energy efficiency, which is not covered in most previous studies.

2. APPROACH AND METHODS

The research presented in this paper is both applied and exploratory, as it aims to address practical difficulties and discover new insights. The research questions were designed to survey the country's current level of energy efficiency in buildings and shed light on the critical drivers of adoption [43, 44].

A. Research Population and Sampling

Sampling is a powerful tool that allows researchers to make sense of complex data sets by selecting a smaller, more manageable population subset. This is particularly useful when resources or time are limited, as it allows researchers to focus on the most important aspects of their study [37]. For this research, we looked at Nigeria's rapidly growing energy needs, a developing nation with a rapidly expanding population, and the booming construction sector, particularly in major cities like Kano [45]. Kano state was selected as a case study as it is the second-largest industrialized state in Nigeria. This economic and commercial center faces tremendous issues due to energy inefficiency and scarcity [26]. The state is sitted in the northwest part of Nigeria, covering about 20760 sq. km of area and with a demography of approximately 9,384,682 people, according to the 2006 census [20,21].

B. Data Collection

The research presented in this paper relies on a combination of data sources to comprehensively understand the topic. These sources include archival documents and residential household owners' responses [38]. We used self-structured questionnaires that included open and closed-ended questions to gather data from household owners. Archival records, such as articles, published papers, and journals, were also consulted to provide additional context and support for the research objectives and questions [38,39]. The data collected was analyzed using various methods, including explanatory and descriptive statistics for sections one, two, and three of the questionnaires and the Relative Importance Index (RII) for section four. For data cleaning and analysis, both SPSS and Microsoft Excel were used [40,41]. At the same time, a Likert Scale was also employed to gather information about the respondents' feelings and perceptions about buildings' energy efficiency. The participants were asked to assess how much they agreed or disagreed with various topics and questions on a scale of one to five [42]. This simple scale was chosen for its ease of use and ability to provide clear and easy-to-analyze data.

C. Data Analysis

To analyze the collected data a "relative importance index (RII)" method was employed using the "statistical package for social sciences (SPSS)". Each response was analyzed and ranked based on the selected factors influencing the implementation of energy-efficient building practices in the country using the RII formula below [23].

$$RII \ \frac{\Sigma w}{AN} = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{5N} \quad (1)$$

Were,

W = Weight as allocated to "Likert's scale" by each participant on a scale of 1 to 5 (very low to very high).

A = is the heaviest weight (5)

N = Total number of people that responded

Note: 1 indicates Very Low, 2 indicates Low, 3 indicates Moderate, 4 indicates High, and 5 shows Very High.

3. RESULTS

A. Demographic Information

According to the findings from 190 households, most respondents are 92.6% male, 5.3% female, and 2.1% missing, as shown in Table 1. Most surveyed respondents are between 20 and 30, with 9.5% between 30 and 40 and 0.5% between 40 and 50. The majority of participants (around 50.5%) are postgraduates, followed by 'graduate' (40.5%), 'other' (5.8%), 'diploma graduate' (2.1%), and missing value (1.1%). Furthermore, the results identify the number of people in households, which reveals that 19.5% of houses have 1–5 people, 37.9% have 6–10 people, 21.6% have 11–15 people, and 21.1% have more than 15 people. It also reveals that 6.1% of households have a single apartment in the buildings, 8.4% have a room and parlor, 1.1% have a mini flat, 11.1% have a 2-bed room flat, 16.8% have a 3-bed room flat, 33.7% have a 3-bed room flat, and 22.1% have other, with 0.5% missing value.

B. Nigerian Household Energy Consumption Pattern.

This section gathers data to evaluate the different types of energy usage in Nigerian houses, determine the standard supply and services, and evaluate the methods of energy usage.

i. Source of energy in the buildings

The presented data below was collected to help determine the various household energy sources.

The above figure describes the energy sources (both renewable and non-renewable) of the various household from the survey conducted. The results show that 66.5% of the respondent gets their energy from PHCN, personal fuel-powered generators generate 10.2%, 3.6% from solar panels/other renewable sources, and 4.1% from other sources. Furthermore, 12.7% of the households obtain energy from PHCN (NEPA) and Generator sources. 1.5% from PHCN (NEPA) and solar panels; 0.5% from solar panels and other renewable sources; 0.5% from PHCN (NEPA), Generator, and solar panels; and 0.5% from Generator and Other sources.

ii. Average Daily Supply/Usage

The daily average energy supply to individual residents is presented in table 2. The survey results indicate that a significant % of households, 13.2%, receive no energy supply at all. Most respondents, 45.5%, reported receiving 1-5 hours of energy supply daily, while 24.1% reported receiving 6-10 hours. A smaller percentage, 15%, reported receiving 11-15 hours of collection, with 1.1% receiving 16-20 hours and 1.1% receiving 21-24 hours. These findings suggest that the primary energy source for most households is PHCN (NEPA) at 45.5%. However, the survey also revealed that a considerable number of respondents, 44.4%, do not use generators as a source of energy, while 42.7% use generators for 1-5 hours, 11.7% use generators for 6-10 hours, and 1.2% use generators for 11-15 hours.

Table 1. Personal information

Demographic variable	Description	Frequency	Percentage (%)
Gender	Male	176	92.60
	Female	10	5.30
	Missing value	4	2.10
Age range	20-30	171	90.00
	30-40	18	9.50
	40-50	0	0.00
	Above 50	0	0.00
	Missing value	1	0.50
Level of education	Diploma graduate	4	2.10
	Graduate	77	40.50
	postgraduate	96	50.50
	Other	11	5.80
	Missing value	2	1.10
Number of residents in the building	1-5	37	19.50
	6-10	72	37.90
	11-15	41	21.60
	more than 15	40	21.10
Apartments in the buildings	single	12	6.30
	Parlor & rooms	16	8.40
	Mini apartment	2	1.10
	Two bedroom apartment	21	11.10
	Three bedroom apartment	32	16.80
	Four bedroom, terrace, or duplex	64	33.70
	Others	42	22.10
	Missing value	1	0.50

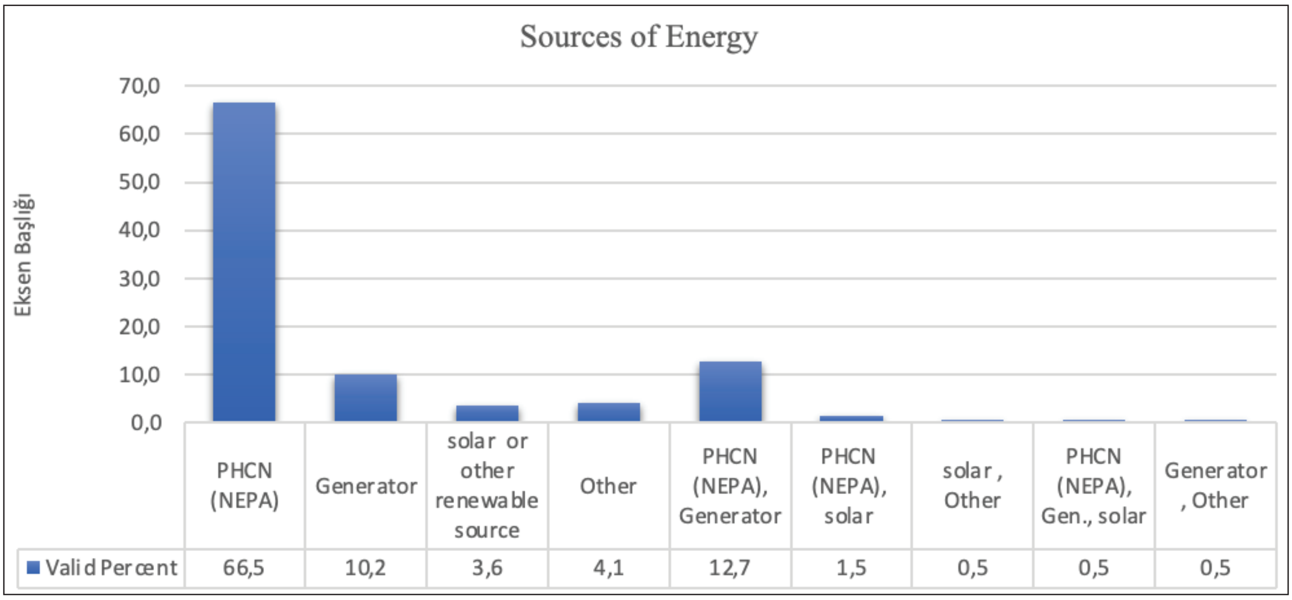

Figure 2. Sources of energy.
Note: PHCN refers to the Power Holding Company of Nigeria

C. Implementation of Energy Efficiency Practices

The section collects information to evaluate Nigeria's household energy consumption concerning building energy efficiency practices.

i. Number of appliances, fittings, and fixtures in the survey buildings

To study the energy consumption of these households, we collected data concerning the number of fittings, fixtures, and appliances used in the buildings, as presented in the table below;

The table above presents the prevalence of various household appliances, fixtures, and fittings. The data reveals that many households utilize LED bulbs, with 34.1% having more than 4 in their buildings. Fluorescent bulbs are also commonly used, with 31.9% of households having more than 4. However, most families do not use halogen and incandescent bulbs, at 57.6% and 59.8%, respectively. Additionally, many households have one electric pressing iron and electric water heater, at 60.8% and 45.0%, respectively. Most households do not have air conditioners, at 60.0%, and a significant number have one refrigerator, at 38.9%. Furthermore, 36.7% of households have one TV, 27.4% have more than four fans, 55.0% don't have a pumping machine, 53.3% do not use electric cookers, and 27.4% do not use any other appliances

Table 2. Daily average energy supply

Sources/ Hours	0 (%)	1 – 5 (%)	6 – 10 (%)	11 – 15 (%)	16 – 20 (%)	21 – 24 (%)
PHCN	13.40	45.50	24.10	15.00	1.10	1.10
Generator	44.40	42.70	11.70	1.20	0.00	0.00

Table 3. Nigerian Households Energy Efficiency Practices

Questions	Yes (%)	No (%)	Remarks
Do you turn off the lights and appliances when not in use?	86.8	13.2	Most survey participants turn off their appliances while they are not in service.
Energy consumption measurement	20.8	79.2	They don't measure their energy consumption.
Implementation of energy efficiency practices and guidelines in the building	43.8	56.2	Most of the respondents do not consider any energy efficiency guidelines.
Do you have the proper ventilation in your building?	79.4	20.6	The majority have proper ventilation in their buildings.
Does your building envelope have a focus on insulation?	50.8	49.2	Some buildings focus on insulations while some do not have.

ii. Daily average energy consumption duration of the fittings, fixtures, and appliances.

To have more understanding of the household consumption pattern, we collected information on the daily average duration of energy consumption in the buildings from fittings/appliances/fixtures, which is summarized in the table below;

The above table describes the average daily usage time of the building's utilities, fixtures, and fittings. The results indicate that most homes (45.60%) use LED lights for 1.0 - 5.0 hours per day, and fluorescent bulbs for 1.0 - 5.0 hours per day, while halogen bulbs aren't used. Furthermore, 61.10% do not use incandescent bulbs, 71.70% use electric pressing iron for 1.0–5.0 hours daily, 55.20% use electric water heaters for 1.0–5.0 hours, 62.60% do not use air conditioners, 31.90% use refrigerators for 1.0 – 5.0 hours, 37.90% spend 1.0 –5 .0 hours on TVs, 33.10 use fans for 11.0–15.0 hours, 52.90% do not use pumping machines, 50.00% do not use electric cookers, and 34.50% spend 1.0 – 5.0 hours on other appliances.

D. Assessment of factors influencing the adaptation of energy-efficient building practices.

In this part, we collect data to assess the factors influencing adoption of energy-efficient practices in Nigerian homes [49]. The data is based on respondents' perceptions of the variables that impact the adoption of building energy efficiency practices[51]. The detailed data is shown in the table below;

Table 6 highlights the factors that significantly influence efficient construction techniques in Nigerian households. The survey results illustrate that government supervision has a strong impact, with an RII value of 0.376. On the other hand, government support has an RII value of 0.394, and economic and technical support has 0.437. Legal,

Table 4. Building's Fittings, Appliances, and Fixtures

Fittings/Appliances/Fixtures (%)	Not in use	1.0	2.0	3.0	4.0	More than 4.0
Air Conditioner	60.00	14.00	14.00	4.70	4.00	3.30
Electric Cooker	53.30	32.00	6.70	6.70	0.70	0.70
Electric Pressing Iron	11.40	60.80	16.50	6.30	1.90	3.20
Electric Water Heater	20.60	45.00	18.10	10.00	3.80	2.50
Fan	5.10	18.90	22.30	13.70	12.60	27.40
Fluorescent Bulbs	25.90	10.20	17.50	7.80	6.60	31.90
Halogen Bulbs	57.60	18.40	8.80	5.60	2.40	7.20
Incandescent Bulbs	59.80	14.80	10.70	4.10	7.40	3.30
LED Bulbs	13.40	10.60	25.70	8.40	7.80	34.10
Other Appliances	27.40	20.50	21.90	10.30	11.00	8.90
Pumping Machine	55.00	28.20	9.40	5.40	1.30	0.70
Refrigerator	29.90	38.90	19.70	5.70	5.20	0.60
Tv	11.80	36.70	29.00	10.70	5.90	5.90

Table 5. Daily average energy consumption

Fittings/Appliances/Fixtures (%)	Not in use	1 to 5 hrs	6 to 10 hrs	11 to 15 hrs	16 to 20 hrs	21 to 24 hrs
Air Conditioner	62.60	21.10	12.20	2.70	0.70	0.70
Electric Cooker	50.00	34.20	11.00	3.40	1.00	0.00
Electric Pressing Iron	16.40	71.70	8.80	1.90	1.30	0.00
Electric Water Heater	27.30	55.20	14.90	0.00	2.60	0.00
Fan	5.20	27.90	33.10	16.90	10.50	6.40
Fluorescent Bulbs	25.00	34.40	26.30	13.10	0.60	0.60
Halogen Bulbs	63.00	17.80	14.80	3.70	0.70	0.00
Incandescent Bulbs	61.10	18.30	16.80	3.80	0.00	0.00
LED Bulbs	15.80	45.60	23.40	12.30	2.30	0.60
Other Appliances	32.40	34.50	14.80	12.00	4.20	2.10
Pumping Machine	52.90	32.10	10.00	4.30	0.70	0.00
Refrigerator	25.80	31.90	20.90	14.70	3.70	3.10
Tv	7.10	37.90	30.80	13.60	7.10	3.60

Table 6. Factors influencing the adaptation of energy-efficient building practices

Identified factors	Very high 5.0	High 4.0	Moderate 3.0	Low 2.0	Very low 1.0	Total	Total number (N)	(A×N)	(RII)	Rank
Government Supervision	0	20	132	128	77	357	190	950	0.376	1
Governments Support	5	24	126	154	63	372	189	945	0.394	2
Economic & Technical Support	5	36	174	150	44	409	187	935	0.437	3
Legal Environment Code & Enforcement	10	52	153	156	43	414	187	935	0.443	4
Occupant's Behavior	0	64	195	130	44	433	190	950	0.456	5
Knowledge & Information	10	56	213	124	39	442	179	895	0.494	6
Awareness	45	32	255	108	33	473	189	945	0.501	7
Equipment & Technologies	40	56	306	90	16	508	185	925	0.549	8
Construction Quality	25	100	288	88	40	541	190	950	0.569	9

environmental code, and enforcement have 0.443; occupancy behavior scores 0.456; knowledge and information scores 0.494; awareness scores 0.501; equipment and technology have 0.459. And construction quality score of 0.569. The lower the value, the more significant the impact of the respective factor on energy efficiency practices. Therefore, it is clear that government supervision, support, technical and economic support, and enforcement of a solid legal, environmental code are critical elements in ensuring building energy efficiency.

4. DISCUSSION

The study's findings have uncovered a significant shortfall in adopting building energy conservation practices in Nigeria. Most respondents acknowledged a poor understanding and prior knowledge of energy-efficient design principles and a failure to implement energy-efficiency measures [48]. The lack of awareness and understanding of energy-efficient practices is a significant barrier to sustainable development in the building sector. Previous studies, such as those conducted by Painuly (2001) [52], Thorne (2008) [53], and Bagaini (2020) [54], have uncovered a significant barrier to sustainable development in the sector: a lack of awareness and understanding of energy-efficient practices. However, this new study takes a closer look at the Nigerian scenario and adds to the existing knowledge. It becomes apparent that industry-wide and government awareness initiatives to educate the public on the numerous benefits of energy efficiency are urgently needed. In terms of household consumption patterns, the study found that many households do not rely on one energy source but instead use multiple sources. Most households reported receiving energy from the national grid (PHCN) for only 1–5 hours per day, which is insufficient to meet their energy needs [36]. This explains why many households must look for alternative energy sources [35]. Additionally, many households do not use generators, which is positive for the environment but indicates low living standards as they cannot afford to purchase or maintain them.

It was also revealed that about 13.4% of the respondents do not have any supply from the national grid, and in such instances, they have to look for other alternatives to cater to their energy demands. Such alternatives are mostly small-scale generators, as they are cheap, but at the same time, they are carbon-intensive, contributing to the country's total carbon footprint. Therefore, there is a need for the authority to foresee energy efficiency and supply improvements in the country [35]. Also, considering the vast availability of sunlight in the country, it is an excellent opportunity for the government to diversify energy sources by shifting towards renewable and sustainable energy programs. In addition, the research further evaluated the implementation of energy-efficient practices in Nigerian households [19]. Most households cannot afford to install energy-efficient appliances, fittings, and fixtures. However, a positive finding was that many respondents reported turning off their appliances, fittings, and fixtures when not in use. But this might be more a result of saving on fuel costs rather than a proper understanding and adoption of energy-efficient practices. The study also revealed that many households do not measure their energy consumption or consider any energy efficiency guidelines, indicating a poor implementation of energy-saving practices [36].

Finally, the study analyzed the factors influencing implementation of energy-efficient building practices in Nigeria. The findings suggest that government regulation and supervision, support, financial and technical aid, etc., are the most crucial household considerations concerning the country's adoption of energy-efficient practices. Previous studies conducted by esteemed researchers such as Painuly (2001) [52], Doukas et al. (2009) [55], Thorne (2008) [53], Ravindranath and Balanchandra (2009) [58], Karakosta et al. (2010) [56], Jagadeesh (2000) [57], and Bagaini (2020) [54] identified these barriers as part of their research findings. This study has proven to be a valuable insight into their results, as it has revealed that none of the barriers identified by these researchers are insignificant, indicating their impacts on the implementation of building energy efficiency practices.

5. CONCLUSION

As the world faces a pressing energy crisis, countries must take action to handle the situation. The study presented in this paper delves into the challenges faced by Nigeria in adopting building energy-efficient practices. Using the Relative importance index (RII)" approach, the study examines the various elements influencing the adoption of energy-efficient building policies and procedures in Nigeria. The finds find a significant gap in energy-efficiency practices in the country, with residents relying on the national grid, which cannot meet their energy demand. Additionally, most residents do not measure their energy consumption or follow energy efficiency guidelines. Furthermore, the study highlights the crucial role that government supervision and support and technical and economic assistance play in adopting energy efficiency practices in buildings. To address the challenges faced by the country, the study recommends the following measures;

- The government should improve existing policies, implement new ones, and raise residents' awareness of building energy efficiency practices.
- There is an urgent need for the country to incorporate green building concepts into the curricula of its educational institutions to address the country's massive gap in green building awareness.
- Provision and enforcement of mandatory smart grid metering policies for all residential properties.
- The judiciary arm of the government needs to provide solid legal support for the defaulters.
- There is a need for technical assistance from both industries and researchers supported by government grants to develop low-cost materials using locally available resources.
- It is important to increase the utilization of renewable energy sources to decrease expenses and the emission of greenhouse gases.

In conclusion, the presented study highlights the significance of addressing the energy crisis and the need for countries to take action toward energy conservation. The study calls for additional research to establish a structure for energy-efficient design in the sector and to outline ways to enhance the professional code of ethics towards energy conservation practices in the country. We can work toward a greener, more sustainable future for all with the right measures.

6. LIMITATION

This research has some limitations, including the small sample group size and the self-reported nature of the information retrieved from the survey. The sample size of 197 households, while representative of the population in Kano State, may not be generalizable to the entire country. The study also relies on the accuracy of the respondents' self-reported energy consumption patterns and energy efficiency practices, which may be subject to bias or inaccuracies. In addition, it is equally vital to note that the research conducted does not consider the impact of cultural or societal factors on energy efficiency adoption. However, despite the limitations mentioned offers a significant understanding of the present state of building energy efficiency practices in Nigeria and pinpoints key areas that require improvement. Future research should consider expanding the sample size and incorporating a more diverse range of respondents to further examine the barriers and facilitators to energy efficiency adoption in the country. Additionally, further research could also investigate the role of cultural and societal factors in energy efficiency practices.

ETHICS

There are no ethical issues with the publication of this manuscript.

DATA AVAILABILITY STATEMENT

All graphs and data obtained or generated during the investigation appear in the published article.

CONFLICT OF INTEREST

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

FINANCIAL DISCLOSURE

The author declared that this research study has received no financial support.

AUTHOR'S CONTRIBUTIONS

The author confirms sole responsibility and contribution for the study conception and design, analysis and interpretation of results, and manuscript preparation. Further, the author has validated and approved the final manuscript.

PEER-REVIEW

Externally peer-reviewed.

REFERENCE

[1] Oyedepo, S.O. (2012) Energy Efficiency and Conservation Measures: Tools for Sustainable Energy Development in Nigeria. *International Journal of Energy Engineering,* 2, 86-98.

[2] IEA. *Buildings: A source of enormous untapped efficiency potential, June 11, 2020*. IEA. https://www.iea.org/topics/buildings.

[3] Lu N., Taylor T., Jiang W., Correia, J., Leung, L. R., & Wong, P. C. The temperature sensitivity of the residential load and commercial building load. 2009 IEEE Power & Energy Society General Meeting, Calgary, AB, Canada, 2009. [CrossRef]

[4] Wen, Q., Liu, G., Wu, W., & Liao S. (2020). Genetic algorithm-based operation strategy optimization and multi-criteria evaluation of distributed energy systems for commercial buildings. *Energy Conversation Management,* 226, Article 113529. [CrossRef]

[5] IEA. World Energy Outlook 2020 shows how the response to the Covid crisis can reshape the future of energy. IEA. https://www.iea.org/news/world-energy-outlook-2020-shows-how-the-response-to-the-covid-crisis-can-reshape-the-future-of-energy

[6] Ma, M., Ma, X., Cai, W., & Cai, W. (2020). Low carbon roadmap of the residential building sector in China: Historical mitigation and prospective peak. *Applied Energy*, 27, Article 115247. [CrossRef]

[7] Yang, C., Wang, X., Huang, M., Ding, S., & Ma, X. (2017). Design and simulation of gas turbine-based CCHP combined with solar and compressed air energy storage in a hotel building. *Energy and Buildings* 153, 412–420. [CrossRef]

[8] Amasyali, K., & El-Gohary, N. M. (2018). A review of data-driven building energy consumption prediction studies. *Renewable and Sustainable Energy Reviews* 81, 1192–1205. [CrossRef]

[9] Hong, T., Koo, C., Kim, J., Lee, M., & Jeong, K. (2015). A review on sustainable construction management strategies for monitoring, diagnosing, and retrofitting the building's dynamic energy performance: focused on the operation and maintenance phase. *Applied Energy,* 155, 671–707. [CrossRef]

[10] Berardi, U. (2017). A cross-country comparison of the building energy consumption and their trends. *Resource Conservation Recycle,* 123, 230–241. [CrossRef]

[11] F. Birol. (2020). *Put clean energy at the heart of stimulus plans to counter the coronavirus crisis. The coronavirus is turning into an unprecedented international crisis, with serious repercussions for people's health and economic activity.* IEA. https://www.iea.org/commentaries/put-clean-energy-at-the-heart-of-stimulus-plans-to-counter-the-coronavirus-crisis

[12] Hernandez, P., Oregi, X., Longo, S., & Cellura, M. Life-cycle assessment of buildings.

[13] Bose, R. K. (2010). *Energy efficient cities: assessment tools and benchmarking practices*. The World Bank. http://documents1.worldbank.org/curated/en/602471468337215697/pdf/544330PUB0EPI01BOX0349415B01PUBLIC1.pdf [CrossRef]

[14] Ebinger, J., & Vergara, W. (2011). Climate impacts on energy systems, no. September 2016. [CrossRef]

[15] Sousa, J. L., Martins, A. G., & Jorge, H. (2013). Dealing with the paradox of energy efficiency promotion by electric utilities. *Energy*, 57, 251–258. [CrossRef]

[16] Sunarso, O., Widiasa, S. J., Budiyono, I. N., 2010. The effect of feed to inoculum ratio on biogas production rate from castle manure using rumen fluid as inoculums. *International Journal of Science and Engineering,* 1(2), 41-45. [CrossRef]

[17] W. & H. Federal Ministry of Power. (2016). Building energy efficiency guidelines for Nigeria's federal ministry of power, works and housing. https://energypedia.info/images/c/c7/Building_Energy_Efficiency_Guideline_for_Nigeria_2016.pdf.

[18] Labaran, Y. H., Mathur, V. S., Muhammad, S. U., Musa, A. A. (2022). Carbon footprint management: A review of construction industry. *Cleaner Engineering and Technology*, 9, 2022, Article 100531. [CrossRef]

[19] Ley, K., Gaines, J., & Ghatikar, A. (2015). *the Nigerian energy sector - an overview with a special emphasis on renewable energy, energy efficiency and rural electrification*. Int. Zusammenarbeit GmbH. www.gopa-intec.de.

[20] Craig, K. T. O., Verma, H., Iliyasu, Z., Mkanda, P., Touray, K. (2016). Role *of serial polio seroprevalence studies in guiding implementation of the polio eradication initiative in Kano, Nigeria: 2011–2014. The Journal of Infectious Diseases*, 213(3), 124–130. [CrossRef]

[21] Koko, A. F., Wu, Y., Abubakar, G. A., Alabsi, A. A. N., Hamed, R., Bello, M. (2021). Thirty years of land use and land cover changes and their impact on urban climate: a study of Kano Metropolis, Nigeria. *Land* 10, Article 1106. [CrossRef]

[22] Jibrin, A. M., Muhammad, N. Z., & Labaran, Y. H. (2020). Evaluation of factors responsible for variation order in civil engineering projects: A clients' perspective (a case study in Kano state, Nigeria). *International Research Journal of Engineering and Technology (IRJET),* 7(5), 1373-1377.

[23] Shen, Z., Chen, A. (2020). Comprehensive relative importance analysis and its applications to high-dimensional gene expression data analysis. *Knowledge-Based Systems,* 203, Article 106120. [CrossRef]

[24] Geissler, S., Österreicher, D., & Macharm, E. (2018). Transition towards energy efficiency: Developing the Nigerian building energy efficiency code. *Sustain* 10(8), 1–21. [CrossRef]

[25] Abdul Majid, N. H, Hussaini, I. U. (2011). *Housing design practice and energy efficiency consideration in Nigeria.* Third International Conference on Applied Energy - 16-18 May 2011 - Perugia, Italy, 1459-1470. http://irep.iium.edu.my/29079/.

[26] Martinez, K. E. (2008). Changing habits, lifestyles, and choices: the behaviours that drive feedback-induced energy savings, renewable and sustainable energy institute. University of Colorado 305 Flemming Boulder, CO 80309.

[27] Creswell, J. W. (2009). Research design: qualitative, quantitative, and mixed methods approaches, 3rd edition. London: Sage.

[28] Sekaran, U. (2005). Research methods for business: A skill building approach. 4th edition. India: John Wiley & Sons.

[29] Akinbulire, T. O., Awosope, C. O. A & Oluseyi, P. O. (2007). Solving the technical problems facing electrical energy development in Nigeria. *3rd Annual Conference Research and Fair of the University of Lagos,* Nigeria, December 3.

[30] Akhator, E. P., Obanor, A. I., & Ezemonye, L. I. (2016). Electricity generation in Nigeria from municipal solid waste using the Swedish Waste-to-Energy Model. *Journal of Applied Sciences and Environmental Management, 20(3), 635.* [CrossRef]

[31] Adeyemi, A. O. (2013). Electricity consumption and economic growth in Nigeria *Journal of Business Management and Applied Economics*, 2, 1–14.

[32] Rabah, A. B., Baki, A. S., Hassan, L. G., Musa, M., Ibrahim, A. D. (2010). Production of biogas using abattoir waste at different retention times. *Science World Journal* 5, 1597–6343.

[33] Odekanle, E. L., Odejobi, O. J., Dahunsi, S. O., & Akeredolu, F. A. (2020). Potential for cleaner energy recovery and electricity generation from Abattoir wastes in Nigeria. *Energy Reports* 6, 1262–1267. [CrossRef]

[34] Olanipekun, B. A., & Adelakun, N. O. (2020). Assessment of renewable energy in Nigeria: challenges and benefits. *International Journal Of Engineering Trends And Technology,* 68(1), 64-67. [CrossRef]

[35] Emovon, I., Samuel, O. D., Mgbemena, C. O., & Adeyeri, M. K. (2018). Electric power generation crisis in Nigeria: A review of causes and solutions. *International Journal of Integrated Engineering,* 10(1), 47-56. [CrossRef]

[36] Festus, M. O., & Ogoegbunam, O. B. (2015). Energy crisis and its effects on national development: The need for environmental education in Nigeria. *British Journal of Education*, *3*(1), 21-37.

[37] Bell, E., & Bryman, A. (2007). The ethics of management research: an exploratory content analysis. *British Journal of Management*, 18(1), 63–77. [CrossRef]

[38] The word bank. Primary data collection. https://dimewiki.worldbank.org/Primary_Data_Collection

[39] Ellram, L. M., Tate, W. L. (2016). The use of secondary data in purchasing and supply management (P/SM) research. *Journal of Purchasing and Supply Management*, 22(4), 250-254. [CrossRef]

[40] Garth, A. (2008). Analyzing data using SPSS, Sheffield Hallam University. https://students.shu.ac.uk/lits/it/documents/pdf/analysing_data_using_spss.pdf

[41] Azmy, A., Shane, J., & Shelley, M. (2012). *Implementation of survey method in a construction team effectiveness study. Construction Research Congress* 2012, 1471-1480. [CrossRef]

[42] Ira H. Bernstein, Likert Scale Analysis. (2005). Kimberly Analysis, Editor of Social Measurement. Elsevier. [CrossRef]

[43] Tran, Q., Nazir, S., Nguyen T. H., Ho, N. K., Dinh, T. H., Nguyen, V. P., Nguyen, M. H., Phan, Q. K., Kieu, T. S. (2020). Empirical examination of factors influencing the adoption of green building technologies: the perspective of construction developers in developing economies. *Sustainability,* 12(19), 8067. [CrossRef]

[44] Estache, A., & Kaufmann, M. (2011). Theory and evidence on the economics of energy efficiency. Lessons for the Belgian building sector. Reflets Et Perspectives De La Vie Économique, Tome L, 133-148. [CrossRef]

[45] Adedayo, H. B., Adio, S., & Oboirien, B. O. (2021). Energy research in Nigeria: A bibliometric analysis. *Energy Strategy Reviews,* 34, Article 100629. [CrossRef]

[46] Santamouris, M., Vasilakopoulou, K. (2021). Present and future energy consumption of buildings: Challenges and opportunities towards decarbonization. *e-Prime - Advances in Electrical Engineering, Electronics and Energy,* 1, Article 100002. [CrossRef]

[47] Oyedepo, S.O. (2012). Energy and sustainable development in Nigeria: the way forward. *Energy Sustain Society*, 2, Article 15. [CrossRef]

[48] Kumssa, A., Mosha, A.C., Mbeche, I.M., Njeru, E.H.N. (2015). Climate change and urban development in Africa. Springer, Berlin, Heidelberg. [CrossRef]

[49] Oyalowo, B., Ohiro, Y., Oginni, A. (2020). Barriers, drivers and prospects of the energy efficiency code in the Lagos real estate market. *Earth and Environmental Science,* 588, Article 022033. [CrossRef]

[50] Abisuga, A. O., Okuntade, T. F. (2020). *The Current State of Green Building Development in Nigerian Construction Industry: Policy and Implications*. In: Gou, Z. (eds). Green Building in Developing Countries. Green Energy and Technology. Springer, Cham. [CrossRef]

[51] Qin, Y., Xu, Z., Wang, X., Škare, M. (2022). Green energy adoption and its determinants: A bibliometric analysis. *Renewable and Sustainable Energy Reviews*, 153, Article 111780. [CrossRef]

[52] Painuly, J. (2001). Barriers to renewable energy penetration; a framework for analysis. *Renewable Energy,* 24(1), 73–89. [CrossRef]

[53] Thorne, S. (2008). Towards a framework of clean energy technology receptivity. *Energy Policy,* 36(8), 2831–2838. [CrossRef]

[54] Bagaini, A., Colelli, F., Croci, E., & Molteni, T. (2020). Assessing the relevance of barriers to energy efficiency implementation in eight European countries' building and transport sectors. *The Electricity Journal*, 33(8), Article 106820. [CrossRef]

[55] Doukas, H., Karakosta, C., & Psarras, J. (2009). RES technology transfer within the new climate regime: A "helicopter" view under the CDM. *Renewable and Sustainable Energy Reviews, 13(5), 1138–1143.* [CrossRef]

[56] Karakosta, C., Doukas, H., & Psarras, J. (2010). Technology transfer through climate change: Setting a sustainable energy pattern. *Renewable and Sustainable Energy Reviews*, 14(6), 1546–1557. [CrossRef]

[57] Jagadeesh, A. (2000). Wind energy development in Tamil Nadu and Andhra Pradesh, India Institutional dynamics and barriers—A case study. *Energy Policy*, 28(3), 157-168. [CrossRef]

[58] Ravindranath, N. H., & Balachandra, P. (2009). Sustainable bioenergy for India: Technical, economic, and policy analysis. *Energy,* 34(8), 1003–1013. [CrossRef]