Journal of Sustainable Construction Materials and Technologies
Web page info: https://jscmt.yildiz.edu.tr
DOI: 10.47481/jscmt.1184338

JSCMT
Journal of Sustainable Construction Materials and Technologies

Research Article

Energy demand reduction for Nigeria housing stock through innovative materials, methods and technologies

Oluwafemi AKANDE[1,*], Chioma EMECHEBE[1], Jonam LEMBİ[1], Joy NWOKORİE[2]

[1]Department of Architecture, Federal University of Technology, Minna
[2]Department of Architecture, Federal Polytechnic Nekede, Owerri

ARTICLE INFO

Article history
Received: October 4, 2022
Revised: May 14, 2023
Accepted: June 01, 2023

Keywords:
Energy Demand, energy efficiency, Nigeria, residential housing

ABSTRACT

Energy utilisation has recently become a highly sought-after commodity on a global scale. This situation is not limited to Nigeria, where the national grid's supply of electricity has been severely inadequate. This has hampered the country's ability to meet the mounting needs of its large population and expanding economy. Aside from the global challenges of rising energy costs and environmental disasters, a number of factors such as a lack of interest in indigenous building technologies and materials have contributed to the Nigerian construction industry's slow pace of meeting energy demand and achieving energy efficiency. This study investigates the possibility of achieving energy conservation through innovative materials, methods, and technology to increase energy efficiency and minimise energy demand in Nigeria's residential housing. The objective is to determine the variables that influence energy usage in residential house design, select methods and technologies to reduce energy demand, and assess the best materials and processes. A quantitative approach to data collection was used by distributing questionnaires to respondents in the Minna metropolis. A hundred and forty (140) questionnaires were distributed, and 117 of them were returned. Secondary data were obtained from literature reviews, journal articles, and conference papers. According to the findings, the most energy efficient residential buildings would result from the appropriate use of innovative materials, methods, and technology to reduce the energy demand of the building. In order to decrease energy demand, the study suggests that built environment professionals should focus largely on changing energy-consuming devices and their end uses for energy efficiency. It concluded that, in order to reduce overlap between the applications of these elements and better meet the needs of building occupants in terms of energy usage in Nigeria, energy demand should be considered from the design stage.

Cite this article as: Akande, O., Emechebe, C., Lembi, J., & Nwokorie, J. (2023). Energy demand reduction for Nigeria housing stock through innovative materials, methods and technologies. *J Sustain Const Mater Technol*, 8(3), 1–17.

1. INTRODUCTION

Globally, due to rising population and income, energy consumption will increase by 15% from 2021 to nearly 660 quadrillion Btu in 2050 [1]. The Global Energy Review evaluates the trajectory of carbon dioxide emissions and energy consumption in recent years, and almost 55% of all electricity consumed worldwide is used for building

***Corresponding author.**
*E-mail address: akande.femi@futminna.edu.ng

operations [2]. The building and construction sectors combined form the highest CO_2 emissions recorded, accounting for 30% of total global final energy consumption and 38% of total global energy sector CO_2 emissions [3]. Energy demand from buildings and building construction continues to rise, driven by improved access to energy in developing countries, growing demand for air conditioning in tropical countries, greater ownership and use of energy-consuming appliances, and rapid growth in global building floor area [4].

Several studies [5-8] conducted in several regions of Africa, Europe, and Asia suggest that successful energy demand reduction is possible when approached from the correct angles. Buildings are responsible for significant energy use because individuals spend most of their waking hours indoors [9]. An energy-efficient design and technical characteristics that allow for good living standards and comfort with little energy use define a low-energy building [10]. In Africa, millions lack primary access to electricity due to rising energy demand, which challenges nations to maintain GDP development, forcing them to use polluted fuels to cook and light their houses. Estimate by [11] shows that 770 million people worldwide lack access to electricity, with 75% residing in sub-Saharan Africa. The majority of businesses in this area rely on fossil fuels, which are expensive and exacerbate climate change.

In Nigeria, population growth has rapidly increased reliance on fossil fuels due to a massive energy crisis that has plagued the country for over 20 years. In addition, industrial and commercial activity has been severely restricted, significantly increasing energy poverty. Based on the report by Nigerian Council for Renewable Energy, power disruptions cost Nigeria 126 billion naira ($984.38 million) yearly [12]. Nigeria experienced severe energy poverty due to the country's high demand and absence of a well-established energy supply network. Nearly 90 million Nigerians, according to [13] will not have access to grid energy in the coming years beyond 2020; while those that do will only have it for fewer than 12 hours each day. Despite the country's abundance of conventional energy resources, the leading cause of Nigeria's energy crisis is an insufficient supply of distribution to match the country's growing population. Additionally, due to unemployment and the inability to pay energy bills, literature has demonstrated the considerable effects of energy poverty on vulnerable households [14].

Energy poverty is a problem caused by the increasing energy demand and has become increasingly challenging to assess and characterize precisely. According to [15] the accepted definition of energy poverty is defined as the situation in which a household finds it difficult or impossible to secure adequate heating in the home at an affordable price. Similarly, it is when a household is unable to ensure a sufficient level and quality of domestic energy services for its social and material needs [16]. Against this backdrop, this paper investigates the possibility of achieving energy conservation in residential housing estates through innovative materials, methods, and technology with a view to increase residential housing energy efficiency and minimise energy demand in Nigeria housing stock. Its objectives are to: (i) identify factors influencing energy consumption in residential housing design. (ii) determine energy conservation strategies for energy use reduction in residential housing and (iii) assess suitable materials, methods, and technologies for reducing energy demand in residential housing provision.

2. LITERATURE REVIEW

Nigeria is projected to have a population of 195.87 million people and a GDP of $397.27 billion in 2021 [17]; however, its average annual energy consumption is only 144 kWh per person. The energy demand required for proper economic growth is lacking when taking into account the 16 GW installation capacity (which is made up of 75% gas and 13.5% hydro), at production of about 33%, with a transmission capacity of 2.9 GW and transmission losses of 22% from generation to distribution, and with only about 55% of the population known to have access to electricity [18 -19]. The assumption for the size of Nigeria's energy demand is that it is based on the country's high population, an annual GDP growth rate of about 2.2%, a high rate of power shortages, an energy consumption that is roughly twice to thirty times lower than that of its peers on the continent, and a World Bank ranking of 131 for ease of doing business [19-22]. Therefore, it is estimated that Nigeria requires more than 63,000 MW to address the gap in energy demand. This is based on estimations, assertions, and available data.

The demand for grid-powered energy distribution in Nigeria is estimated to be around 3200 MW [22-23]. There is a general view that many families in the nation have insufficient access to electricity since several elements, including a home's energy access, location in relation to electricity infrastructure, and administrative capability, have been neglected [24]. An average Nigerian household spends 27% of its income on energy, primarily on cooking, lighting, and cooling (91% of energy is used for cooking, 6% for lighting, and 3% for other electrical appliances); 72% of homes use fossil fuel because it is readily available; 69% do so out of convenience; 58% do so out of efficiency; and 52% do so out of cost [25].

Furthermore, Nigeria's energy poverty is extremely of concern [26] with some reports describing the electricity's performance records as abhorrent [27]. Hence, it is essential to conduct ongoing research on the energy situation in order to identify potential solutions to the issue. Additionally, several Nigerians lack access to the national grid, creating a very worrisome scenario that impacts the nation's residents and economic development. Various forms of research have been carried out to investigate Nigeria's potential for clean and dependable energy. According to [28] cited by [29] clean energy is the solution to Nigeria's severe energy crisis, particularly in rural areas. Ajayi and Ajayi [30] pointed out that by-products from fossil fuels are dangerous for both the environment and people. Aliyu *et al.* [31] posited that renewable energy technology must be aggressively pursued to address Nigeria's ongoing energy shortage and advance. Hence, considerable possibilities for sustainable electricity production in Nigeria should include renewable resources like clean energy.

Migration from the country's rural parts, where only 34% of people have access to power, to the nation's already highly energy-demanding urban centres, where 86% do, has also contributed to Nigeria's rising population and energy consumption [17, 32]. To ensure energy efficiency in Nigeria's building industry, deliberate efforts are required to halt the grid's energy supply which is insufficient, unstable and unbalanced [33]. Although, the decline over time has been due to the dominance of fossil fuels, which are well-known to be non-sustainable, non-renewable, and unfriendly to the environment.

Energy Efficiency Evaluation and Adoption Strategies

Reducing the use of energy-intensive building materials and technology is one of the sustainable methods for improving energy efficiency in residential buildings in Nigeria [34]. Any residential buildings that consume less energy than a typical one is energy efficient. It is generally accepted that low-energy buildings should use much less energy to deliver the same service [35]. Energy consumption optimization and making the most use of the energy that is available are not novel concepts. For instance, humans in ancient times struggled to build structures with adequate thermal comfort. The critical issue was keeping a house cool in the summer and warm in the winter [36]. There is no universally accepted definition of a low-energy house due to the vast disparity between national regulations; "low-energy" developments in one nation might not comply with "normal practice" in another. One primary federal and worldwide initiative to reduce greenhouse gas emissions with reasonable economic costs is improving energy efficiency [37].

Between 2000 and 2016, Germany's total energy consumption (or primary energy, not temperature-corrected) fell by 6%, from around 344 to 322 million or mega tonnes of oil equivalent (MTOE) in 2016 [38]. To a considerable extent, heat gains from occupants, equipment, lighting, and solar radiation are employed in low-energy buildings to maintain a comfortable indoor climate [39]. Low-energy buildings typically use high insulation, energy-efficient windows, low levels of air infiltration, and heat recovery ventilation to reduce the energy required for heating and cooling. They may also use passive solar building design methods or active solar technologies [36]. There are two key approaches to ensuring that buildings are using energy efficiently. The technological approach is the first, and the behavioral method is the second [40].

Adopting sustainable technologies is the technological strategy for increased energy efficiency to help meet growing energy demands without harming the environment [41]. Any technology that reduces energy more efficiently than conventional systems can be considered sustainable [42]. Therefore, Smith [43] offers a variety of sustainable methods. They comprise solar thermal energy, low-energy cooling methods, geothermal energy, wind energy, photovoltaics, and bioenergy. Green roofs and renewable technologies like solar panels and solar hot water systems are examples of further sustainable technologies [44-45].

Green roof technology is generally considered a passive strategy for lowering building energy demand [41]. The following are some examples of technological approaches: (i) Introduction of solar architecture and solar passive systems, which include energy-efficient light bulbs, refrigerators, water pumps, fans, and other devices. (ii) The utilization of contemporary, energy-efficient heating and cooling systems. (iii) Incentives for buying energy-efficient items have been used to influence customer behavior to advance energy efficiency. (iv) Reducing the amount of electrical energy used to heat water in the home through Renewable Energy Technologies (RETs), such as a solar heater.

Energy efficiency is all about performance and product improvements that reduce the energy needed for service delivery and other activities like lighting, cooling, heating, manufacturing, and cooking. Activities like indiscriminate electricity use by urban dwellers, gas flaring, inefficient, traditional three-stone fuel wood stoves, buying reasonably used appliances, and low fuel efficiency vehicles fall under this category [46]. Devices that ensure little energy is wasted are created and constructed to help achieve energy efficiency in electrical systems.

Automatic power factor controllers, electronic ballasts, energy-efficient lighting controls, energy-efficient motors, energy-efficient transformers, maximum demand controllers, occupancy sensors, soft starters with energy savers, and variable speed drivers are some gadgets that help with energy efficiency. Energy efficiency appliances, sensor-based modeling, and thermal insulators on panels, walls, and floors to help regulate the indoor thermal environment are a few technologies that can reduce overall energy use and achieve energy conservation [47-48].

Innovative Materials, Methods and Technologies

When it comes to the envelope performance, the elements of the materials, thermal mass, geometrical surface-to-volume ratio, shading devices, and the building orientation, the usage of the OTTV idea in place of glass has been quite established [49]. Innovative approaches to reducing energy demand include the use of programmable thermostats in homes with settings that are appropriate for the local weather at any given time, the use of renewable energy sources, and the intentional use of CFL bulbs [50].

Adjusting external shading devices to control interior lighting and thermal comfort, using wireless sensors through automated control panels to reduce energy usage, and using reflective roofing materials and modern building insulation [51].

It has been shown that using bioclimatic design to insulate a building's mass appropriately is the first step in improving energy efficiency [52]. This is accomplished by starting with a compact building shape, appropriate orientation, applying passive shading techniques, using high thermal resistant insulators for external walls within acceptable dimensions, and reducing air leakages through an airtight design through proper detailing [53-54]. Additionally, to save energy, it has been found that using earthen walls, insulating concrete forms, Low-e windows, plant-based polyurethane foam (the fiberglass insulation), plastic composite lumber, recycled steel, straw bales, structural insulation panels in structural systems, and vacuum insulation panels can all help create low energy buildings [48]. A design that closely connects to the heating influence of the sun on the house and effective insulation of the thermal mass is credited with contributing to energy conservation in the built environment.

Solar Energy Technologies

Solar energy is an excellent prospective option for producing clean electricity because it is unrenewable and pollutant-free. Several developing nations, including Nigeria, experience trouble utilizing the resources despite the enormous amount of solar energy that strikes the globe's surface. Mohammed [55] claims that several industrialized nations experienced electrical stability after investing in solar. Investing in solar energy collection technologies can assist developing countries in ending energy poverty and reducing greenhouse gas emissions (GHG). Solar photovoltaic, solar thermal, and concentrated solar power conversion are the three main processes that turn solar energy into electricity [3]. These innovations are machines that transform solar energy into usable energy. In the following section, these technologies are briefly discussed, focusing on photovoltaic technology because it is the most widely used solar technology in Nigeria and the rest of the world.

Solar Photovoltaic

This device uses photovoltaic effects when exposed to solar radiation to produce energy. When exposed to solar radiation, photons become stimulated and release electrons that are then captured by wires to produce direct electricity that must be converted to alternating current using converters [56]. The generated energy can be delivered to a load or stored using a storage device like a battery. As long as the device is exposed to sunlight, it will continue to produce energy.

Hydro

The process of releasing energy to turn mechanical turbines and produce electricity is known as hydropower energy generating [57]. The water's volume and descent velocity affect how much power is made. Hydropower is the first and only renewable energy source supplying electricity to Nigeria's national utility grid [3].

Energy Demand Reduction Conceptual Framework

A conceptual framework (Figure 1) was developed to study the concepts derived from the theoretical framework found in the literature in connection to energy demand reduction. This is to accomplish demand reduction in energy consumption in housing provision in Nigeria. The approach implies that climatic conditions, building design, and building operations impact the energy demand in housing. These three factors could worsen and increase the demand for energy in housing if they are not adequately considered while designing housing provisions. This would unavoidably call for innovative techniques (Figure 1) that might lower housing energy use. The framework is built on a model that illustrates several strategies for reducing energy usage.

Figure 1 depicts the study's hypothesis that energy reduction strategies center on technological, building-specific, and behavioral methods that, when integrated and sufficiently considered, would call for an innovative strategy to reduce energy consumption in buildings. Sustainable construction, which includes eco-friendly methods and integration of renewable energy, is a component of the technological approach. The building attributes had bioclimatic designs, year of construction, window type, and building materials. The behavioral method focuses on the occupant's behavior, which includes comfort-seeking, perceived norms, mixed habits, and conscious and unconscious drivers. Using smart home hubs, LED lighting, smart thermostats, energy-efficient insulation, smart plugs, and power strips, cool roofing, high-efficiency heat pumps, and smart HVAC systems are all part of the innovative and green energy reduction strategy.

3. RESEARCH METHODOLOGY

The research methodology used in this study is a quantitative method that specifies the investigation into a social or human problem regarding the responses to specific questions. A cross-sectional survey approach using a questionnaire's respondents' statistical data as the primary instrument. The respondents who live in Minna City comprise the sample population of users. Data collected from pertinent literature and published articles from journals, conferences, and national newspapers were combined using the qualitative technique.

Study Area

The research is conducted in Minna, Nigeria's north-central geopolitical zone. Minna connects Abuja, Kano, Ibadan, and Lagos and covers an area of 76,363 square kilometers. It is geographically located between the Latitude and Longitude coordinates of 9.58 and 6.54 east

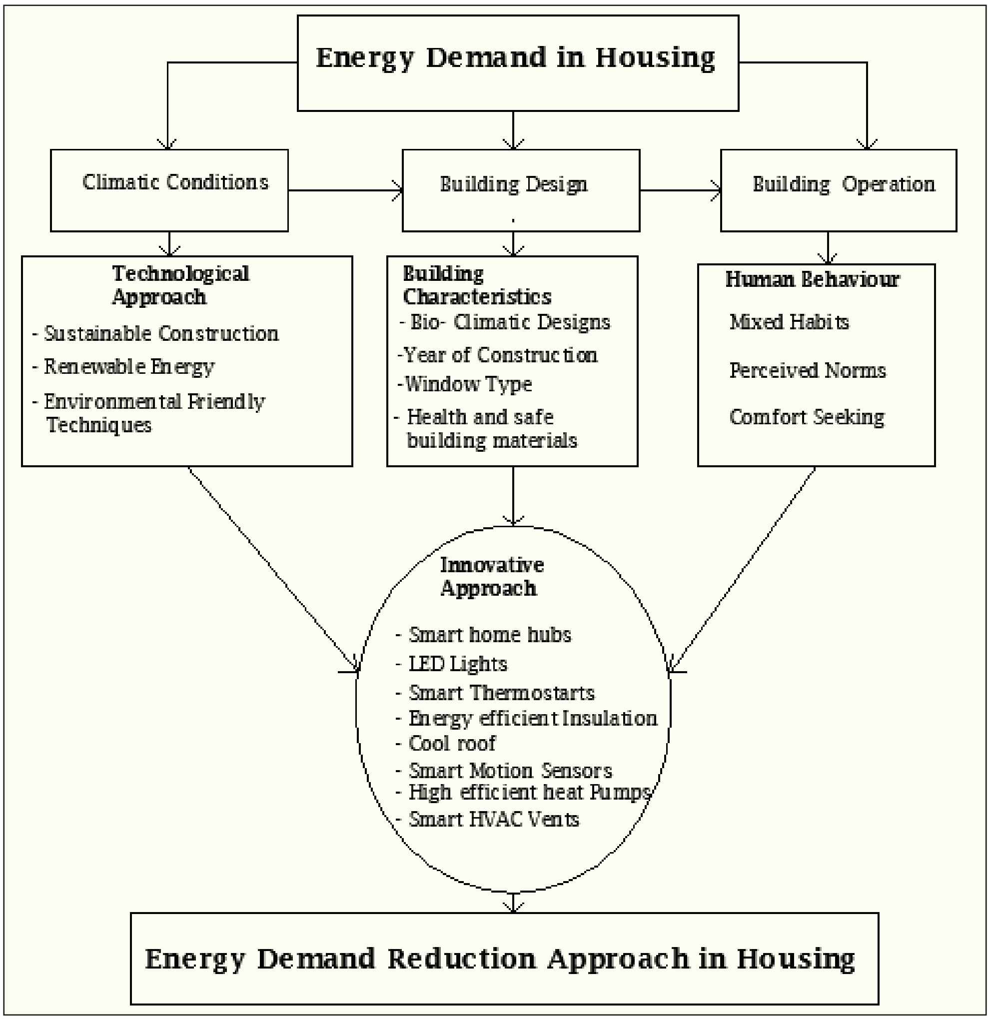

Figure 1. Conceptual framework of energy demand reduction approach in housing.

of the Greenwich Meridian, respectively (Figures 2 and 3). Minna is emerging as one of Nigeria's fastest-growing cities, with a population density of 56 people per square kilometer. Minna's residential land use exhibits three characteristics: high, medium, and low densities, with a combination of these densities except for the low density, which is delimited. Several densely populated communities can be found in the inner city. It has an estimated land area of 1,000

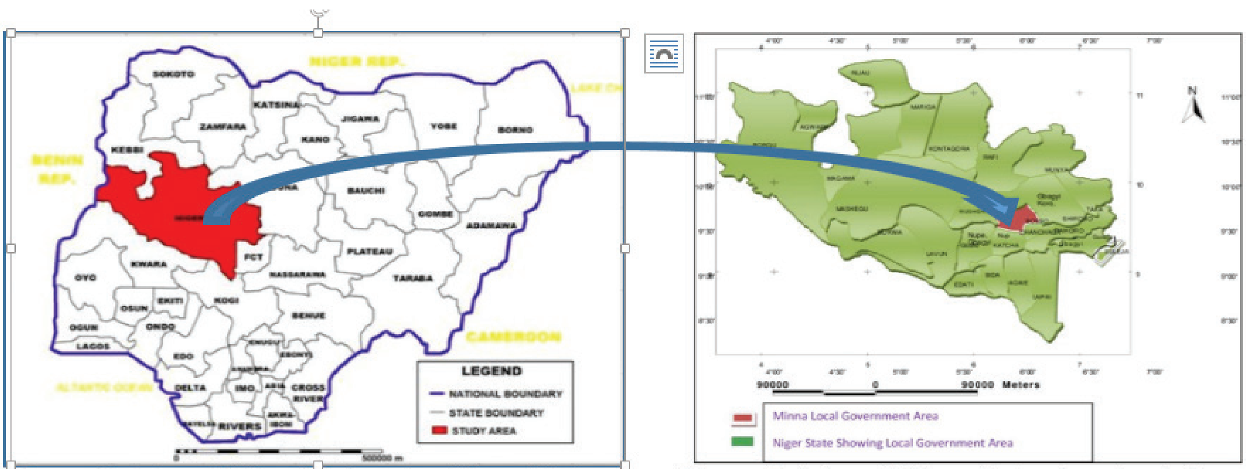

Figure 2: Map of Nigeria showing Niger State Figure 3: Map of Niger State showing Minna

square kilometers [58]. Minna's population has increased dramatically, from 192,437 in 1991 to almost 300,000 in 2006 [59]. Sulyman *et al.* [60] stated that there is a lack of energy supply in the Minna metropolis, and electricity usage accounts for 25.0% of total energy consumption in the city, typically used for lighting and cooking.

The Survey

The study used a quantitative survey approach using a questionnaire as an instrument is considered efficient and effective by [61] in sampling a wide population. The questionnaire was recognized as the most appropriate instrument the respondents could easily reach in the most inexpensive, efficient, and popular way to obtain essential information. Within the study area, it was reported by [58] that domestic energy increased by 72.6% in 2012, resulting in a significant demand for energy supply. The questionnaire was distributed to the residents in the study area. Before administering the questionnaire, a pilot study was conducted in which some respondents were interviewed using the intended, structured questionnaire to check that the respondents comprehended the questions.

Sample size

The sample size is determined by the study's need for reliable and authentic findings to establish conclusions [62]. According to [63], the size of the sample is more a question of convenience and a compromise among various criteria (e.g., expenses and precision) as supported by [64]. The sample size for this study was determined using the formulas from [65] and [66], which are as follows:

$$ss = \frac{Z^2*(p)*(1-p)}{C^2}$$

Where:

Z = Z value (e.g., 1.96 for 95% confidence level)
P = percentage picking a choice, expressed as decimal (.5 used for sample size needed)
C = confidence interval, expressed as decimal

In surveys, it is a common practice to aim for a 95% confidence level or a precision level of 5%. As a result, a 95% confidence level was assumed, as is customary in other research [65] while z = 1.96 for a 95% confidence level (i.e., significance threshold of = 0.05). Based on the requirement to balance precision, available resources, and the utility of the research findings, a confidence interval (c) of 10% was deemed sufficient for this investigation. To calculate the sample size for a particular degree of accuracy, Czaja and Blair [66] proposed that the worst-case percentage of picking a choice (p) be assumed, which is 50% or 0.5. The sample size was estimated using the following assumptions:

$$ss = \frac{1.96^2 \text{ x } 0.5\ (1 - 0.5)}{0.1^2}$$

$$ss = 96.04$$

The sample size for the questionnaire survey will be 96 respondents. However, the calculated value requires further modification for limited populations. As a result, the formula for calculating finite populations was taken from [66] as follows:

$$\text{new ss} = \frac{ss}{1 + \frac{ss - 1}{pop}}$$

Where: Pop = population

$$\text{new ss} = \frac{96.04}{1 + \frac{96.04 - 1}{300{,}000}}$$

$$\text{new ss} = 96.00$$

This formula can be used to determine the finite populations, and it can be seen that 96 samples are the bare minimum needed. The nonresponse rate, typical with questionnaire surveys, was nevertheless considered vital when determining the sample size. Therefore, it was crucial to modify the sample size to consider nonresponse. The suitable sample size to be surveyed was consequently determined using the method adapted from [67] based on the assumption of a cautious response rate of 85% as proposed by [68] for in-person (i.e., Face to Face) surveys:

$$\text{survey ss} = \frac{\text{new ss}}{\text{response rate}}$$

$$\text{survey ss} = \frac{95}{0.85} = 113$$

In order to conduct the survey, a minimum of 113 respondents with an 85% response rate were required.

4. RESULTS AND DISCUSSION

One hundred and forty (140) questionnaires were sent out in total, and 117 of them were returned giving an 83% response rate. A reliability score of 0.826 and a frequency of 85 male and 36 female respondents were recorded. The reliability value of 0.826 and the response rate percentage were deemed satisfactory for the study. Most respondents are 25-34 years old, while others are 55 years and above. Half (50.4%) of the respondents live in rented houses, while 49.6 % live in owned houses, as shown in Table 1.

Table 1. Demography information of the Respondents

Characteristics	Frequency	Percentage	Characteristics	Frequency	Percentage
Gender			Number of bedrooms		
Male	85	70.2	1	36	29.8
Female	36	29.8	2	32	26.4
			3	28	23.1
			4	25	20.7
Age			Number of occupants		
15-24	23	19	1	17	14
25-34	45	37.2	2	23	19
35-44	31	25.8	3	17	14
44-54	14	11.6	4	64	52.9
55 and above	8	6.6			
Do you own or rent the building			Occupation		
Rent	61	50.4	Self-employed	33	27.3
Own	60	49.6	Regular salary	62	51.2
			Casual/daily wage	10	8.3
			Student	11	9.1
			Unemployed	3	2.5
			Retired	2	1.7

The majority (27.4%) of the respondents receive a monthly income of N100,000 ($131.18) and above, closely followed by 25.6% having an income of N20,000 ($26.24) - N50,000 ($65.59). About 22.2% earned N81,000 ($106.26) - N100,000 ($131.18) while just 10.25% earned N51,000 ($57.06) - N80,000 ($105.19) while 17.95% earned below N20,000 ($26.30) (see Figure 2 recorded according to the number of the respondents in each category). This shows that the majority of the users battle with poor income to meet up with the energy demand.

It has been observed that there is a lot of energy consumption on use of 2 out of 6 appliances: Refrigerators and fans. Figure 3 illustrates that most respondents constantly leave their refrigerators, ceiling, and standing fans on. This is due to the importance of both devices

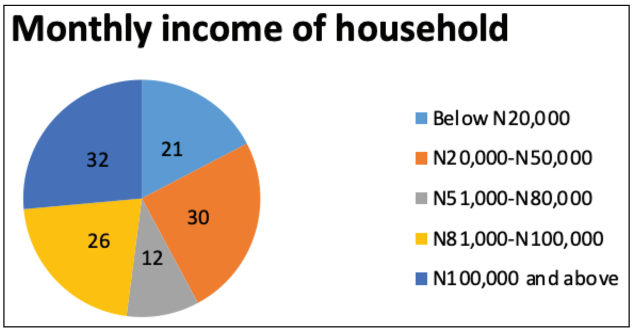

Figure 2. Shows the Monthly income of the Respondents.

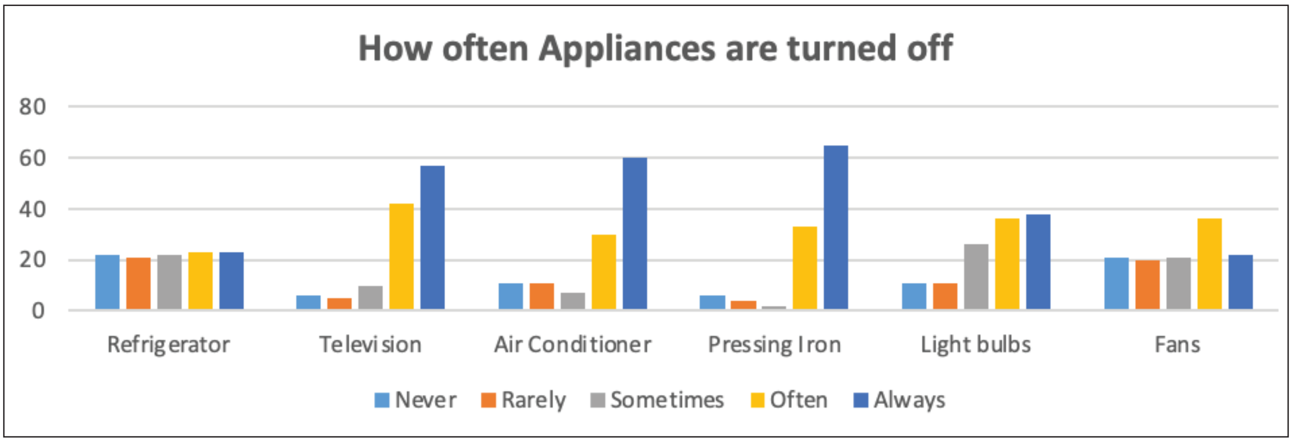

Figure 3. Showing human behavior on ways of energy conservation in the household.

For sustaining the occupants' comfort. This finding reflects the opinion of [10] on the overreliance on more mechanical and electrical devices to produce thermal heating, which results in more energy consumption and acts as a barrier to low energy—the respondents' solutions for reducing energy waste while in use are presented in Figure 4. According to the figure, 88%, 85%, and 88% of the users of appliances such as phones, laptops, and rechargeable fans responded to switching off their gadgets when fully charged. In comparison, 33%, 36%, and 33% of phones, laptops, and rechargeable fans do not switch off when fully charged. This result corroborates the views of [69], who opined that a sharp growth in the number of electrical appliances has been one of the main factors driving rising electricity consumption in homes, especially when they are not turned off when they are ultimately charged or not in use.

Figure 5 reveals the year of construction of the building. Forty-five percent of the respondents' facilities were constructed between 2000 and 2010, while the fewest were dwellings completed in 1990 or earlier. Structures built in the 1990s typically combine local and modern elements, whereas buildings constructed in the 20th century have a preponderance of modern materials. In the view of [70] occupants of buildings built in earlier years relied significantly on wood and coal to keep them warm, cook their food, and light their homes, which results in using less energy. However, in the modern age, the discovery of electricity ushered in a new age of technology that claims to provide comfort in any building by invariably incorporating high energy-consuming technologies. Though the new age technology has significantly impacted how people live, it has increased fossil fuel-based energy prices over the past two decades. This has created more awareness of the need to preserve energy and practice energy efficiency in modern buildings.

According to Table 2, 84.3% of respondents utilize hollow sandcrete blocks for their building's walls, compared to 8.3% who use stone and 7.4% who use mud blocks. This demonstrates that sandcrete hollow blocks are the material most frequently used for wall construction in residential constructions. This finding aligns with [71] who indicated that most residential buildings in Nigeria's hot-dry climate rely on sandcrete hollow blocks to build respective of their climatic environment. Meanwhile, only a small number of

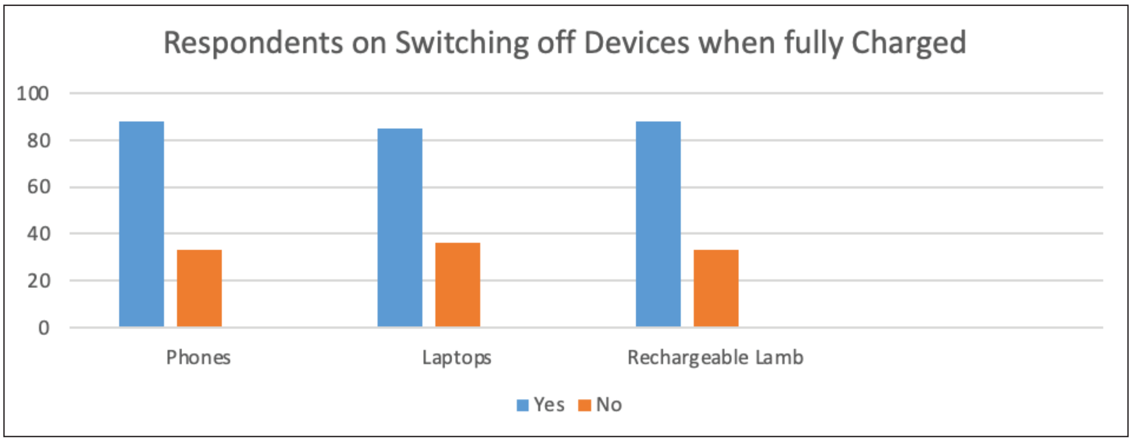

Figure 4. Showing human behavior on switching off devices when fully charged.

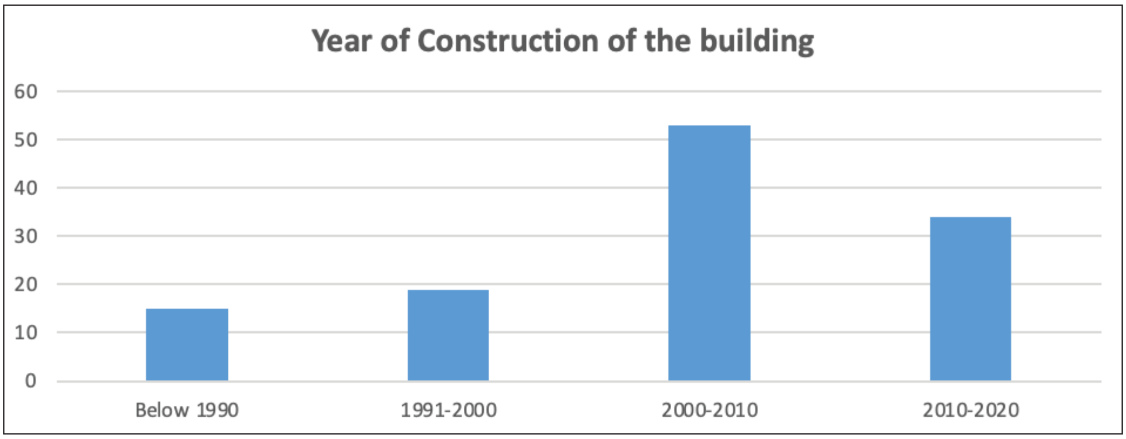

Figure 5. Showing the year of construction of the building.

Table 2. External materials (walls) used in construction

Variable		Frequency	Percentage
What building material was used for the wall of your building	Stone	10	8.3
	Sandcrete hollow blocks	102	84.3
	Mud blocks	9	7.4
	Wood	0	0
	Others	0	0

houses employ mud and stone blocks. While [72] and [73] argued that sustainable residential building construction in Nigeria is the goal of the low-energy architecture idea. Lembi *et al.* [74] further emphasize that traditional building materials are a significant resource for architecture which could take the form of clay bricks, compressed earth blocks, rammed earth, and other types of earthen construction. Thus, it could be argued that utilizing these materials, which are readily and naturally available, would lower the amount of fossil fuel energy used.

Figure 6 and Table 3 show the usage of the window types by the respondents. Casement windows are used in 31.4% of residences, sliding windows in 38.5%, louvers in 17.4%, and projecting windows in 12.4%. This result shows that the majority of residences utilized sliding windows more than any other type of windows. It could be argued that inappropriate window types in residential houses, such as sliding windows and projected windows in the tropics, could result in more energy use for adequate ventilation as these would limit the extent of the openings required for a more significant percentage of airflow needed for natural ventilation. Although [75] argued that up to 25% of a home's total heat loss through windows can come from window units and frames, losses from heat conduction and convection airflows between the panes, and heat loss from heat radiation. In contrast to this argument, this view only applies to buildings in temperate regions or climates where residential buildings need window types to limit the rate of heat loss.

Figure 7 illustrates the type of ventilation in the sampled household. The data shows that the household uses 33% natural, 27% mechanical, and 61% of the available ventilation types. This shows the household depends mainly on mechanical ventilation for adequate comfort due to poor designs. Knowing that the study location records high temperatures and hot seasons will result in the use of more energy by the household to seek adequate comfort, thereby causing an increase in energy demand. Wargocki [76] speculated that health risks may occur when ventilation rates in residential properties fall below 0.4 air changes per hour.

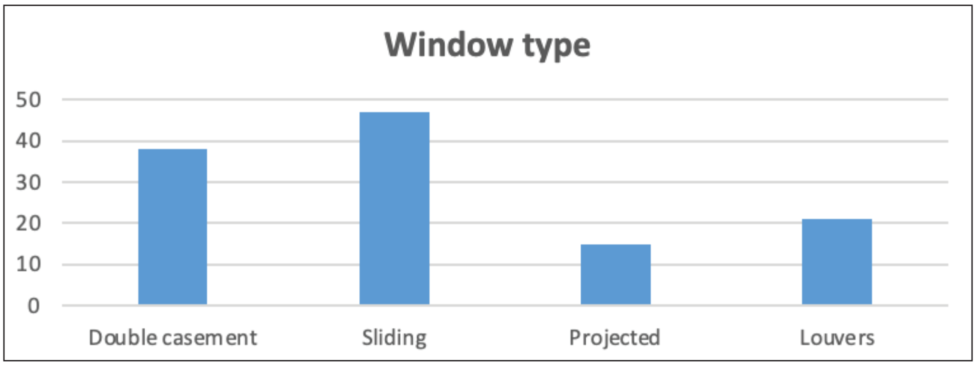

Figure 6. Chart showing window types used in the households.

Table 3. Energy conservation strategies suitable for energy use reduction for appliances

Variable		Frequency	Percentage
Window types	Double casement	38	31.4
	Sliding	47	38.5
	Projected	15	12.4
	Louvers	21	17.4

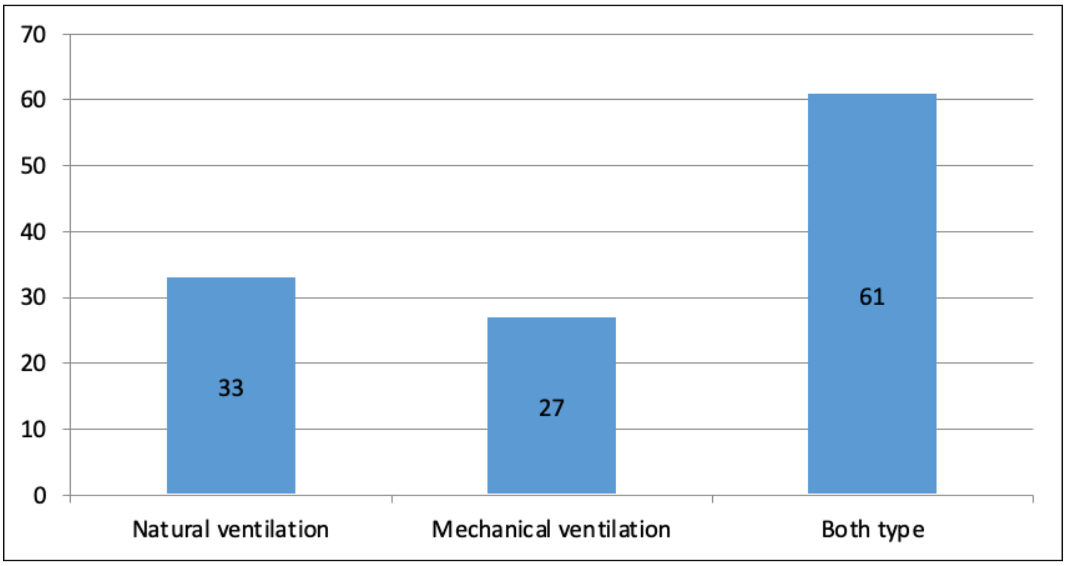

Figure 7. Chart showing ventilation types in the households.

Sherman and Matson [77] proposed that energy use is a factor of building attributes. According to the study, a typical residence's average yearly ventilation energy demand is approximately 61 GJ (almost 50% of total space conditioning energy usage); the cost-effective savings potential is approximately 38 GJ. This means that housing requires a lot of energy to offer acceptable comfort for the residents, and adequate measures to ensure proper ventilation must be in place from the design stage to minimize energy use.

Energy Conservation Strategies

Regarding energy conservation strategy, 49.4% of the respondents use ceiling fans in their bedrooms, 31.6% use air conditioning, and 19% use standing fans. As for sitting rooms, 49% of the respondents use ceiling fans in their living rooms, while 28.9% use air conditioning and 22.1% use standing fans. Lastly, 73.6% of respondents use energy-saving bulbs, 18.1% use incandescent light bulbs, and 8.3% use standard fluorescent tubes in their houses (Table 4). From the findings, it is instructive that most respondents use energy-saving bulbs for lighting. However, the use of air-conditioning would result in higher consumption of energy for cooling, as opined by [78], who expressed that air conditioners use the most electricity excluding lighting. In addition to the energy conservation strategies employed by the respondents, 80% unplugged their refrigerators, while only 19.8% never unplugged their refrigerators.

Meanwhile, 72.7% of the respondents switched off their phones when they were fully charged, while only 27.3% did not switch off their phones. 70.2% of the respondents switched off their laptops when fully charged, while only 29.8% did not switch off their computers. 72.7% of the respondents switched off their rechargeable lamps when fully charged, while only 27.3 did not switch off their rechargeable lights (See Table 5). To adequately use energy in buildings, Monacchi *et al.* [79] recommended prepaid billing as an easy technique to raise energy awareness and convert appliances into pay-as-you-go devices which could result in average savings of 11% regardless of grid disconnections. This step could regulate household behavior

Table 4. Energy conservation strategies suitable for energy use reduction for appliances

Variable		Frequency	Percentage
What cooling devices are used in the bedroom	Air condition	50	31.6
	Ceiling fan	78	49.4
	Stand fan	30	19
What cooling devices are used in the living room	Air condition	43	28.9
	Ceiling fan	73	49
	Standing fan	33	22.1
Types of lighting devices/systems used in the house	Standard fluorescent tubes	12	8.3
	Energy saving bulbs	106	73.6
	Incandescent light bulbs	26	18.1

Table 5. Strategies of household energy conservation in residential housing design

Variable		Frequency	Percentage
How often do you unplug your refrigerator	Never	24	19.8
	Rarely	23	19
	Sometimes	24	19.8
	Often	25	20.7
	Always	25	20.7
How often do you unplug your television	Never	6	5
	Rarely	5	4.1
	Sometimes	10	8.3
	Often	43	35.5
	Always	57	47.1
How often do you unplug your AC	Never	11	9.1
	Rarely	11	9.1
	Sometimes	8	6.6
	Often	30	24.8
	Always	60	49.6
How often do you unplug your Pressing iron	Never	5	4.1
	Rarely	3	2.5
	Sometimes	1	0.8
	Often	33	27.3
	Always	66	54.5
How often do you unplug your light bulbs	Never	11	9.1
	Rarely	11	9.1
	Sometimes	26	21.5
	Often	36	29.8
	Always	37	30.6
How often do you unplug your fans	Never	21	7.4
	Rarely	20	16.5
	Sometimes	21	17.4
	Often	36	29.8
	Always	23	19.0
Do you switch off your phones when it fully charged	Yes	88	72.7
	No	33	27.3
Do you switch off your laptops when it is fully charged	Yes	85	70.2
	No	36	29.8
Do you switch off your rechargeable lamp when it is fully charged	Yes	88	72.7
	No	33	27.3

regarding unnecessary energy consumption arising from users' behavior, and it would prompt users to turn off appliances to avoid racking up large utility bills.

Table 6 shows some design parameters that aid in reducing energy demand in residential housing. 39.7% of the respondents admitted having high airflow in their bedrooms, while 9.9% and 12.4% recorded very low and low airflow, respectively. 38% of the respondents admitted having high airflow in their living rooms, while 3.1% and 4.2% recorded very low and low airflow, respectively. 27.3% of the respondents attest to using more natural ventilation, while 22.3% use mechanical ventilation. 38.5% of the respondents use sliding windows, while 12.4% use projected windows. Adequate ventilation is a key measure to reducing energy demand in buildings. As suggested by [80] several strategies for reducing energy consumption include features in buildings such as appropriate design strategies, proper placement of fresh air intakes, efficient air distribution in rooms through improved ventilation efficiency, and using ventilation for night cooling.

Table 6. Design parameters for reducing energy demand in residential housing

Variable		Frequency	Percentage
Quality of airflow in the bedroom	Very low	12	9.9
	Low	15	12.4
	Moderate	40	33.1
	High	48	39.7
	Very high	6	5
Quality of airflow in the living room	Very low	5	4.1
	Low	16	3.2
	Moderate	45	37.2
	High	46	38
	Very high	9	7.4
Quality of airflow in the kitchen	Very low	12	9.9
	Low	20	16.5
	Moderate	57	47.1
	High	28	23.1
	Very high	4	3.3
Types of ventilation in the bedroom	Natural ventilation	33	27.3
	Mechanical ventilation	27	22.3
	Both	61	50.4
Window types	Double casement	38	31.4
	Sliding	47	38.5
	Projected	15	12.4
	Louvers	21	17.4

The amount of space in the bedroom and living room is shown in Table 7, along with its impact on natural lighting, thermal comfort, light brightness, and natural ventilation. Natural ventilation in living rooms stands at 38% moderate and 35.5% high, while natural lighting in living rooms moves to be moderate and high with a 38% reduction in energy use. Living rooms have intermediate thermal comfort (40.5%) and high thermal comfort (23.1%). The bedroom had extremely high natural ventilation (9.1) and low natural ventilation (5.8% airflow).

The living room's light brightness was 6.6% extremely high and 19.8% extremely poor conservation. These are the frequencies and percentages of the Minna, Nigeria, housing stock sampled for energy efficiency.

From Table 8, saving monthly costs and reducing greenhouse gas emissions appear to be the most important

Table 7. Contributing factors to energy reduction/conservation strategy

Questions relative to the contributing elements to energy conservation tactic	Very low (1)		Low (2)		Moderate (3)		High (4)		Very high (5)	
	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Level of space in the living room (Natural lighting)	12	9.9	9	7.4	46	38.0	46	38.0	8	6.6
Level of space in the living room (Thermal comfort)	9	7.4	27	22.3	49	40.5	28	23.1	8	6.6
Level of space in the living room (Light brightness)	24	19.8	36	29.8	37	30.6	16	13.2	8	6.6
Level of space in the bedroom (Natural ventilation)	7	5.8	14	11.6	46	38.0	43	35.5	11	9.1
Level of space in the living room (Natural ventilation)	7	5.8	10	8.3	50	41.3	50	41.3	4	3.3

Table 8. Perception of energy use reduction in the residential buildings

Questions relative to the perception of energy use reduction in the residential buildings	Not important (1)		Least important (2)		Neutral (3)		Important (4)		Very important (5)	
	Frequency	%	Frequency	%	Frequency	%	Frequency	%	Frequency	%
Response to having a less negative impact on the environment	14	11.6	18	14.9	24	19.8	35	28.9	30	24.8
Response to saving monthly operating cost	12	9.9	10	8.3	14	11.6	38	31.4	47	38.8
Response to adding value to the house	11	9.1	11	9.1	23	19.0	36	29.8	40	33.1
Response to minimizing the effect of climate change	13	10.7	9	7.4	25	20.7	39	32.2	35	28.9
Answer to reducing greenhouse gases	12	9.9	8	6.6	17	14.0	51	42.1	33	27.3

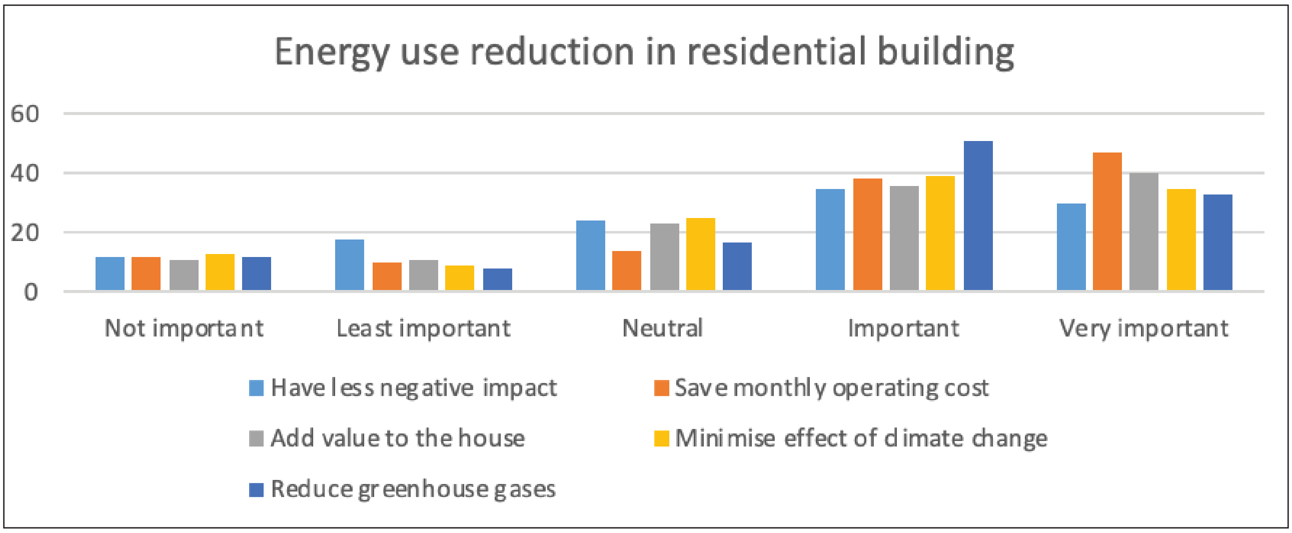

Figure 8. Chart showing perception of energy use reduction in the residential building.

aspects of energy reduction benefits, with less negative impact being the least important overall.

Recommendations

1. Energy use demand should be considered right from the design stage in helping to reduce the synergy between applying these elements and even more innovation to bridging the gap of building occupants' need for energy in Nigeria.
2. Professionals and researchers in the field can focus primarily on directly influencing the demand by modifying the energy-using devices or their end use for energy efficiency.
3. To help reduce the energy demand load, there is a need to employ both the energy efficient and energy conservative approach of saving monthly costs and minimizing the effect of climate change with a definite action on innovative materials, methods, and technology.
4. There should be more clay bricks for wall construction to reduce thermal heat in housing interiors, double casements for windows to allow maximum free air flow and practical applications of energy-saving appliances.
5. There should be a constitutional amendment in Nigeria by laws of power generation to allow the individual state to generate its power and consume with the prospect of selling out to another neighboring state.

Contribution to knowledge

The study advances knowledge by encouraging the reduction of energy demand through energy-efficient building strategies to enhance energy performance in housing provision and innovative building design to address energy consumption in housing design, especially in mass housing provision in Nigeria.

5. CONCLUSION

Reducing energy demand in Nigeria's housing stock is essential. The demand for energy in the country, though, cannot be particularly articulated, but it can be ascertained that it is high, and the need for a measure of meeting those needs is expedient. Therefore, design parameters with indications of energy conservation must be implemented on various building codes and requirements to achieve the desired reduction in household energy demand. Energy efficiency and energy conservation are vital in driving a reduction in Nigeria's energy demand. In line with this, the professionals and researchers in the field can focus primarily on directly influencing the demand by modifying the energy-using devices or their end use for energy efficiency. Or focus more on the indirect influences of "what causes users to need energy." The various elements discussed in this study would guide homeowners, designers, and builders on how to be innovative with materials, technologies, and methods to reduce energy demand. The study's findings will aid in the economic improvement of the users by reducing energy demand and ensuring adequate energy supply. This will significantly help in energy savings in residential buildings. This can be achieved using cost-effective technologies and an innovative and behavioral approach. Energy use in the residential sector can be significantly reduced.

Areas of Future Research

This study is an ongoing contribution to the body of knowledge rather than a final answer. As a result, future research should focus on the following:

- To improve more on the technological approach to reduce energy demand and make the supply more sustainable,
- To develop passive design features and to promote an adequate environment that will be comfortable for the users and reduce energy demand,
- To alert the users on the occupants' behaviour regarding energy use to achieve energy reduction,
- To sensitize the users on the benefits of the Innovative approach of using renewable energy in households to conserve energy.

ETHICS

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

CONFLICT OF INTEREST

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

DATA AVAILABILITY STATEMENT

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

FUNDING

There was no specific grant for this research from the public

REFERENCES

[1] IEA (International Energy Agency) (2021). Global Energy Review 2021: *Assessing the effects of economic recoveries on Energy demand and CO_2 emission in 2021.*

[2] Irfani, F.U. M., Hooi, H. L., Djoni, H., Kenny, D. I., & Ramadani, P. (2022). Population density and energy consumption: A study in Indonesian provinces. *Heliyon*, 8, (9) 2405-8440. [CrossRef]

[3] Yusuf, A, & Akande O. K. (2023). Drivers, enablers, barriers and technologies (debt) for low-energy public housing delivery in Nigeria. *Journal of Advanced Research in Applied Sciences and Engineering Technology*, *29*(3), 115–127. [CrossRef]

[4] Global Alliance for Buildings and Construction (2020). *Global status report for buildings and construction towards a zero-emissions, efficient and resilient buildings, and construction sector.* https://wedocs.unep.org/bitstream/handle/20.500.11822/34572/GSR_ES.pdf

[5] González, P.J., & Yousif, C. (2015). Prioritising energy efficiency measures to achieve a zero net-energy hotel on the ısland of Gozo in the Central Mediterranean. *Buildings, 83, 50-59.* [CrossRef]

[6] Ibrahim, I.A. (2017). Green architecture challenges in the middle east within different rating systems. *Energy Procedia,* 115, 344-352. [CrossRef]

[7] Jonesa, R., Fuertesa, A., Goodhewb, S., & Wilde, P. (2017). The actual performance of aspiring low energy social houses in the United Kingdom. *Energy Procedia,* 105, 2181-2186. [CrossRef]

[8] Wang, F., Lin, H., Tu, W., Wang, Y., & Huang, Y. (2015). Energy modelling and chillers sizing of HVAC system for a hotel building. *Procedia Engineering,* 121, 1812-1818. [CrossRef]

[9] Hoof, J., Kort, H.S, Waarde, H., & Blom, M.M. (2010). Environmental interventions and the design of homes for older adults with dementia: an overview. *Am J Alzheimers Dis Other Demen* 25(3), 202-32. [CrossRef]

[10] Emechebe, L.C., Akande, O. K., Ahmed, S. & Lembi, J. J. (2021). Barriers to low energy for public housing delivery in Nigeria. *International Journal of Science Academic Research,* 7(2), 1785-1790

[11] IEA (International Energy Agency) (2019). Energy access outlook: from poverty to prosperity.

[12] Council for Renewable Energy, Nigeria (CREN). (2009). *Nigeria Electricity Crunch.* www.renewablenigeria.org

[13] Rural Electrification Agency (REA). (2022). Energy poverty in Nigeria. https://borgenproject.org/energy-poverty-in-nigeria-2/

[14] Taltavull de La Paz, P., Juárez Tárrega F., Su Z, & Monllor, P. (2022). Sources of energy poverty: a factor analysis approach for Spain. *Front Energy Res* 10, Article 847845. [CrossRef]
[15] European Fuel Poverty and Energy Efficiency [EPEE]. (2009). *European fuel poverty and energy efficiency project*. https://www.precarite-energie.org/IMG/pdf/EPEE_Project_presentation.pdf.
[16] Bouzarovski, S., & Bouzarovski, S. (2018). Energy poverty policies at the EU level. *Energy Poverty: (Dis) Assembling Europe's Infrastructural Divide*, 41-73. [CrossRef]
[17] USAID. (2021). Nigeria: Power Africa fact sheet. USAID. https://www.usaid.gov/powerafrica/nigeria
[18] World Bank. (2021). Nigeria to improve electricity access and services to citizens. https://www.worldbank.org/en/news/press-release/2021/02/05/nigeria-to-improve-electricity-access-and-services-to-citizens.
[19] Enerdata. (2021). *Nigeria Energy Information*. https://enerdata.net
[20] Mos, T., & Portelance, G. (2017). *Do African countries consume less (or more) electricity than their income level suggest?* https://www.cgdev.org/blog/do-african-countries-consume-less-or-more-electricity-than-their-income-levels-suggest
[21] Cervigni, R., Rogers, J., & Henrion, M. (2018). *Low carbon development: opportunities for Nigeria*. World Bank. https://documents1.worldbank.org/curated/en/290751468145147306/pdf/Low-carbon-development-opportunities-for-Nigeria.pdf
[22] Akanonu, P. (2019). *How big is Nigeria's power demand? Centre for the Study of the Economies of Africa*. Energy for Growth Hub. htt://energyforgrowth.org
[23] GIZ. (2015). *The Nigerian energy sector: an overview with a special emphasis on renewable energy, energy efficiency and rural electrification*. GIZ. https://www.giz.de/en/downloads/giz2015-en-nigerian-energy-sector.pdf
[24] Popoola, A.A., Adeleye, B.M. (2020). Access and limitations to clean energy use in Nigeria. In: Qudrat-Ullah, H., Asif, M. (eds) dynamics of energy, environment and economy. Lecture Notes in Energy, vol 77. Springer, Cham.
[25] Oyedepo, S.O. (2012). Energy efficiency and conservation measures: tools for sustainable energy development in Nigeria. *International Journal of Energy Engineering (IJEE)*, 2(3), 86-98.
[26] Edomah, N., Ndulue, G., & Lemaire, X. (2021). A review of stakeholders and interventions in Nigeria's electricity sector. *Heliyon, 7*(9), Article e07956.
[27] Ebhota, W. S., & Tabakov, P. Y. (2018). Power inadequacy, the thorn in economic growth of Nigeria. *International Journal of Applied Engineering Research, 13*(16), 12602-12610.
[28] Sambo, A. (2009). Strategic developments in renewable energy in Nigeria. *International Association for Energy Economics,* 16, 15-19.
[29] Chanchangi, Y.N., Adu, F., Ghosh, A. Sundaram, S., & Mallick, T.K. (2022). Nigeria's energy review: Focusing on solar energy potential and penetration. *Environ Dev Sustain* 25, 5755-5796. [CrossRef]
[30] Ajayi, O. O., & Ajayi, O. O. (2013). Nigeria's energy policy: Inferences, analysis and legal ethics toward RE development. *Energy Policy,* 60, 61–67. [CrossRef]
[31] Aliyu, A. S., Dada, J. O., & Adam, I. K. (2015). Current status and future prospects of renewable energy in Nigeria. *Renewable and Sustainable Energy Reviews, 48*, 336–346. [CrossRef]
[32] FMPWH (Federal Ministry of Power, Works and Housing). (2016). *Building energy efficiency guide for Nigeria.* https://energypedia.info/images/c/c7/Building_Energy_Efficiency_Guideline_for_Nigeria_2016.pdf.
[33] Ochedi, E.T., & Taki, A. (2019). Towards energy efficient buildings in Nigeria: Challenges and opportunities. *Journal of Engineering and Architecture* 7(2), 125-133. [CrossRef]
[34] Akande, O. K., Fabiyi, O., & Mark, I. (2015). Sustainable approach to developing energy efficient buildings for resilient future of the built environment in Nigeria. *American Journal of Civil Engineering and Architecture,* 3(4), 144-152.
[35] Rosen, M. A. (2008). *Towards energy sustainability: a quest of global proportion.* Forum of Public Policy online: A Journal of the Oxford Round Table. https://www.questia.com/library/journal/1G1-218606547/towards-energy-sustainability-a-quest-of-global-proportions
[36] Davor, H. (2015). *Low energy, passive and zero-energy houses.* Energy and Ecology. http://www.our-energy.com/low_energy_passive_and_zero_energy_houses.html
[37] Medina, A., Cámara, A., & Monrobel, J. R. (2016). Measuring the Socioeconomic and Environmental Effects of Energy Efficiency Investments for a More Sustainable Spanish Economy. (Sustainability), 8, 1039. [CrossRef]
[38] Lopez, E., Schlomann, B., Reuter, M., & Eichhammer, W. (2018). Energy efficiency trends and policies in Germany Fraunhofer institute for systems and innovation research ISI, Karlsruhe, Germany 28-29.
[39] Persson, J. (2014). Low energy buildings, energy use, indoor climate and market diffusion. *Unpublished thesis in chemical engineering, KTH Royal institute of technology school of chemical science and engineering*. Stockholm, Sweden.
[40] Uyigue, E., Agho, M., Edevbaro, A., Ogbemudia,O.G., Uyigue, O. P., & Okungbowa, G.O. (2009). *Energy efficiency survey in Nigeria: A guide for developing policy and legislation.* Community research and development centre (CREDC). *https://www.osti.gov/etdeweb/servlets/purl/21328691*

[41] Dadzie, J., Runeson, G., Ding, G., & Bondinuba, F. (2018). Barriers to adoption of sustainable technologies for energy-efficient building upgrade—semi-structured ınterviews. *Buildings, 8(4), 57.* [CrossRef]
[42] Syed, A. (2012). *Advanced building technologies for sustainability*. John Wiley & Sons.
[43] Smith, P. F. (2007). *Sustainability at the cutting edge: emerging technologies for low energy buildings.* Routledge.
[44] Wilkinson, S. J., & Reed, R (2009). Green roof retrofit potential in the central business district. *Property Management*, *27, 284-301.* [CrossRef]
[45] Boxwell, M. (2012). *Solar electricity handbook, simple practical guide to solar energy-designing and installing photovoltaic solar electric systems*. Green Stream Publishing.
[46] Oyedepo, S.O. (2012). *Energy and sustainable development in Nigeria: the way forward.* Energy Adeleye Sustainability and Society. http://www.energsustainsoc.com/content/2/1/15. [CrossRef]
[47] Ramya, L.N. (2015). Energy conservation- a case study. *International Journal of Applied Engineering Research,* 10(9): 8982-8985.
[48] Anderson, C. (2021). *Energy conservation: 10 ways to save energy*. https://www.energysage.com/energy-efficiency/10/ways-to-save-energy
[49] Garg, A. N., Kumar, A., Piprrlia, S., & Kumar, P. (2016). Optimizing building performance for energy efficiency in cooling. *International Journal on Emerging Technologies*, 7(1): 126-131.
[50] Bruce, N. (2021). *What are the different types of energy conservation techniques?* All things nature. https://www.allthingsnature.org/what-are-the-different-types-of Energy-conservation-technique.htm
[51] Lester, P. (2015). *Future home tech: 8 energy-saving solutions on the horizon.* Energy.gov. https://www.energy.gov/articles/future-home-tech-Energy-saving-solution-horizon
[52] Akande, O.K., & Olagunju, R.E. (2016). *Retrofitting and greening existing buildings: strategies for energy conservation, resource management and sustainability of the built environment in Nigeria. Journal of Sustainable Architecture and Civil Engineering,* 15(2), 6-12. [CrossRef]
[53] Hanania, J., Jenden, J., Stenhouse, K., & Donev, J. (2015). *Energy education. Energy efficient building design*. https://energyeducation.ca/wiki/index.php?title=Energy_efficient_building_design&oldid=710
[54] Zero energy project. (2021). *Affordable zero energy home design & construction in 12 steps*. Zero Energy Project. https://zeroenergyproject.org/build/twelve-steps-affordable-zero-energy-home-Construction-design
[55] Mohammed, Y. S., Mustafa, M. W., Bashir, N., & Ibrahim, I. S. (2017). Existing and recommended renewable and sustainable energy development in Nigeria based on autonomous energy and microgrid technologies. *Renewable and Sustainable Energy Reviews, 75*, 820–838. [CrossRef]
[56] Leggett, J. (2009). *The solar century: the past, present and world-changing future of solar energy*. Green Profile.
[57] Ikem, I. A., Ibeh, A. I., Nyong, O. E., Takim, S. A., & Osim-Asu, D. (2016). Integration of renewable energy sources to the nigerian national grid—way out of power crisis. *International Journal of Engineering Research, 5*(8), 694–700.
[58] Abd'Razack, N. (2012). An appraisal of household domestic energy consumption in Minna, Nigeria. *IOSR Journal of Environmental Science, Toxicology and Food Technology*, 2, 16-24. [CrossRef]
[59] National Population Commission (NPC). (2010). Federal Republic of Nigeria, (2006). population and housing census. priority table volume IV, population distribution by age and sex.
[60] Sulyman, A., Nelson, A., & Medayese, S. (2017). Ecological footprint of housing in Minna, Nigeria, 3(7), 68-84.
[61] Akande, O.K., Olagunju, R. E., Aremu, S. C., & Ogundepo, E.A. (2018). Exploring factors ınfluencing of project management success in public building projects in Nigeria. *YBL Journal of Built Environment, 6(1), 47-62.* [CrossRef]
[62] Akande, O.K. (2015) Factors influencing operational energy performance and refurbishment of UK listed church buildings: towards a strategic management framework. [Unpublished PhD thesis submitted to Anglia Ruskin University, Chelmsford, United Kingdom].
[63] Bulmer, M., & Warwick D.P. (1993). *social research in developing countries: surveys and censuses in the third world.* UCL Press.
[64] Bulmer, M. (1998). Introduction: the problem of exporting social survey research. american behavioral scientist, 42(2), 153–167. [CrossRef]
[65] Creative Research Systems. (2003). *The survey systems: sample size calculator.* http://www.surveysystem.com/sscalc.htm
[66] Czaja, R., & Blair, J. (1995). Designing surveys: a guide to decisions and procedures. *SAGE Publications.*
[67] Akadiri, P. (2011). *Development of a multi-criteria approach for the selection of sustainable materials for building projects.* Https://Www.Researchgate.Net/Publication/215568358_Development_Of_A_MultiCriteria_Approach_For_The_Selection_Of_Sustainable_Materials_For_Building_Projects
[68] Botani, D. (2021). *What is the acceptable response rate for survey research?.* https://www.researchgate.net/post/What-is-the-acceptable-response-rate-for-survey-research/60fbdf4b213b617c7a2f0aff/citation/download.

[69] Borg, S.P., & Kelly, N. (2011). The effect of appliance energy efficiency improvements on domestic electric loads in European households. Energy and Buildings, 43, 2240–2250. [CrossRef]

[70] Mohanty, B. (2004). Improving energy efficiency in the construction and building sector. In: End-use energy efficiency and promotion of a sustainable energy future Chapter: 4. United Nations.

[71] Akande, O.K. (2010). Passive design strategies for residential buildings in a hot dry climate in Nigeria. WIT Transactions on Ecology and the Environment, 128, 61-71. [CrossRef]

[72] Akande, O. K., Akoh, S., Francis B., Odekina, S., Eyigege, E., & Abdulsalam M. (2021). Assessing the potentials of low impact materials for low energy housing provision in Nigeria. *Journal of sustainable construction Materials and Technologies,* 6(4), 156-167. [CrossRef]

[73] Adebayo, A. A. (2005). *Sustainable construction in Africa. Agenda 21 for sustainable construction in developing countries Africa position paper.* https://www.irbnet.de/daten/iconda/CIB659.pdf

[74] Lembi, J.J., Akande, O.K., Salawu A., Emechebe, L.C. (2021). The drivers for low energy materials application for sustainable public housing delivery in Nigeria. *Landscape Architecture and Regional Planning*, 6(2), 19-24. [CrossRef]

[75] Nikolai, V, & Olga, G. (2014). Choosing the right type of windows to improve energy efficiency of buildings. *Applied Mechanics and Materials,* 633-634, 972-976. [CrossRef]

[76] Wargocki, P. (2013). The effects of ventilation in homes on health. *Int J Vent,* 12, 101-118. [CrossRef]

[77] Sherman, M, & Matson, N. (1997). Residential ventilation and energy characteristics. ASHRAE Transactions. 103.

[78] Chen, Yi-Tui. (2017). The factors affecting electricity consumption and the consumption characteristics in the residential sector—a case example of Taiwan. Sustainability, 9, Article 1484. [CrossRef]

[79] Monacchi, A., Elmenreich, W., D'Alessandro, S., & Tonello, A. (2013). Strategies for domestic energy conservation in Carinthia and Friuli-Venezia Giulia. IECON Proceedings (Industrial Electronics Conference). [CrossRef]

[80] Seppanen, O. (2008). Ventilation strategies for good indoor air quality and energy efficiency. *International Journal of Ventilation*, 6(4), 929-935.