



## AN EXPLORATORY POST-OCCUPANCY ASSESSMENT OF SMART BUILDING TECHNOLOGIES IN OWNER-OCCUPIED HOUSING IN A DEVELOPING URBAN CONTEXT

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### ABSTRACT

This study examined the awareness, adoption patterns, and post-occupancy performance of smart home technologies in owner-occupied residential buildings. A questionnaire survey was administered to 68 homeowners, and the data were analyzed using descriptive and inferential statistical methods, including frequency distribution, chi-square analysis, and ANOVA. The findings revealed relatively high awareness of smart home technologies, with 67.6% of respondents indicating prior knowledge of smart homes. However, awareness of specific smart features varied considerably, suggesting uneven technical understanding of integrated smart systems. Smart technology adoption was predominantly retrofit-based, with 62.0% of installations introduced after occupancy rather than during the design or construction stages. This indicates limited incorporation of smart infrastructure considerations during initial building development. User satisfaction with installed smart systems was generally high, as 82.2% of respondents reported being satisfied or very satisfied with their systems. In contrast, perceptions regarding energy reduction were more varied: only 35.0% reported significant or very significant energy savings, while 21.7% perceived no reduction in energy consumption. This divergence suggests that homeowners may value smart technologies more for convenience, security, automation, and improved occupant interaction than for demonstrable energy-efficiency outcomes. Inferential analysis revealed no statistically significant relationship between educational qualification and timing of smart technology adoption, nor between building type and perceived energy reduction. The study concludes that smart home adoption is driven more by user experience and convenience than verified energy-performance outcomes, highlighting the need for better system integration and design-stage planning. Future studies should incorporate objective post-occupancy energy data to complement perception-based assessments.

**Keywords:** Smart Home Technologies, Post-Occupancy Performance, Retrofit Adoption, Energy Perception, User Satisfaction, Smart System Integration

### INTRODUCTION

The integration of digital technologies into the built environment has led to the emergence of smart buildings characterized by interconnected systems that enable automated monitoring, control, and optimization of building performance. These systems comprising smart energy meters, automated lighting, adaptive ventilation, and intelligent security operate through sensor networks, Internet of Things (IoT) architectures, and data-driven control algorithms to enhance operational efficiency and occupant experience (Froufe et al., 2020; Olawumi & Chan, 2020). Within residential buildings, such smart building technologies (SBTs) are expected to improve measurable performance outcomes, including energy consumption efficiency, indoor environmental quality, and user satisfaction (Adekunte et al., 2025; Ghansah et al., 2021; Owusu-Manu et al., 2021). From an engineering perspective, the performance of smart buildings is not solely dependent on technology availability but on the interaction between system design, user behavior, and operational conditions. Post-occupancy evaluation (POE) provides a structured framework for assessing this interaction by linking building system performance with occupant feedback and usage patterns (Nkpiete & Esau, 2021). However, while POE has been extensively applied to conventional residential buildings in Nigeria, its application to smart residential systems particularly in evaluating how user engagement influences system effectiveness and energy performance remains underexplored.

Nigeria's urban residential sector faces persistent challenges such as high energy demand, inadequate indoor comfort, and unreliable infrastructure (Kennedy et al., 2024). Rapid urbanization and housing deficits, particularly in cities such as Kaduna Metropolis, have increased the need for improved residential building performance, especially within owner-occupied housing, which constitutes a significant portion of the housing stock. Previous post-occupancy studies in Nigeria have shown that occupants' satisfaction with building features is a key indicator of housing performance, as demonstrated in evaluations of public housing in Ogun State (Ibem et al., 2013). Similar studies in Lagos and other Nigerian cities have used occupant surveys to identify strengths and weaknesses in housing quality and user satisfaction (Jiboye, 2012; Nubi & Adegemile, 2007). Recent research suggests that the adoption of smart and energy-efficient technologies may contribute to improved residential performance, although adoption in developing contexts is often constrained by cost, limited technical knowledge, and infrastructural challenges (Kennedy et al., 2024). Furthermore, where adoption is discussed, it is rarely linked to quantifiable indicators such as perceived energy reduction levels, satisfaction indices, or timing of system integration (design, construction, or retrofit stages).

Despite the increasing awareness of smart home technologies in Nigeria, their level of adoption in residential buildings remains relatively low, and empirical data on occupants' experiences after installation are scarce Shen et al., (2017) and Li et al., (2020). This gap highlights the need for a system-

oriented investigation that connects technology adoption (independent variables), user interaction behavior (mediating factors), and performance outcomes (dependent variables such as satisfaction and energy efficiency) (Indrawati et al., 2017). In addition, most studies are concentrated in developed contexts, where infrastructure, technical expertise, and economic conditions differ significantly from those in developing regions. As a result, findings from global literature may not be directly transferable to the Nigerian housing context, where cost constraints, awareness gaps, and infrastructural limitations influence both adoption and performance.

To address this gap, this study develops a simplified conceptual framework in which: Adoption characteristics (awareness level, type of smart features, timing of adoption); User and building factors (demographics, building type, usage patterns) jointly influence, Post-occupancy performance outcomes (occupant satisfaction and perceived energy efficiency). This framework assumes that the benefits of smart technologies are moderated by how and when systems are implemented, as well as how occupants interact with them after installation. This study is grounded in the assumption that the performance benefits of smart building technologies

are influenced by the timing and mode of their implementation, as well as by the nature of user interaction after installation. Accordingly, the study adopts a system-oriented approach to examine the adoption and post-occupancy performance of smart building technologies in owner-occupied residential buildings in Kaduna Metropolis, Nigeria, by quantifying adoption patterns and timing, evaluating performance through measurable indicators such as occupant satisfaction and perceived energy reduction, and analyzing how user characteristics and building attributes interact with adoption factors to influence overall performance outcomes. The findings are expected to support architects, homeowners, policymakers, and built-environment professionals in making informed decisions regarding the implementation of smart technologies in Nigerian residential buildings.

Furthermore, to guide this system-based analysis, the study adopts a simple conceptual model (Fig.1), that links smart technology adoption characteristics and user building factors to post-occupancy performance outcomes through user system interaction.

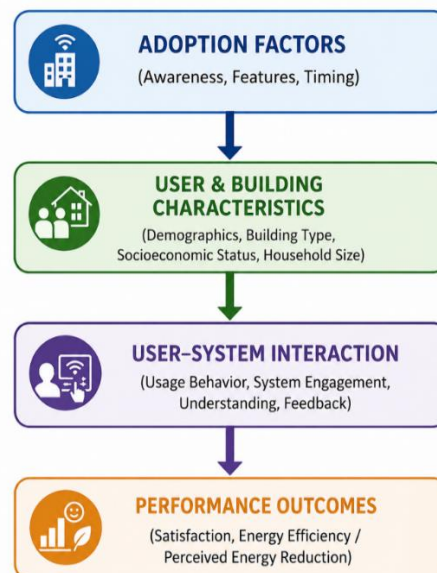


Figure 1: Conceptual Model

## MATERIALS AND METHODS

### Sample Size & Sampling Technique

This study employed a quantitative survey design targeting owner-occupier of residential buildings with installed or accessible smart building technologies. A total of 68 respondents participated in the study. Given the absence of a comprehensive sampling frame for homeowners using smart technologies within the study area, a non-probability convenience sampling technique was adopted. This approach enabled efficient access to eligible respondents within the limited timeframe and exploratory scope of the research. The sample size is considered adequate for exploratory post-occupancy evaluation studies, where the objective is to identify patterns and relationships rather than to generalize findings to a wider population. However, it is acknowledged that convenience sampling introduces potential selection bias and limits the external validity of the results. According to Nworgu (2015), Johnny, et al., (2020), survey research design aims to systematically collect and describe data concerning

the characteristics, features, or facts about a given population. Consequently, the findings of this study should be interpreted as indicative rather than representative of all residential buildings in the study area.

### Data Description

The data used for this study was gotten from primary sources and administered to owner-occupiers of residential homes by means of structured questionnaires. Such information as awareness, adoption and perception and the timing of adoption of smart home technologies were captured. Specifically, adoption was either done during the stages of design, construction, or retrofit to determine whether implementation occurred during initial construction or as a retrofit. All perceptions were measured on a 5-point Likert scale. The dataset comprises a total of 68 responses, with variables measured primarily on nominal (e.g., gender, building type) and ordinal (e.g., satisfaction levels) scales.

### Research Instrument

The research instrument was a structured questionnaire designed to capture both demographic characteristics and user experiences with smart building technologies. The instrument was divided into sections covering socio-demographic data, awareness and adoption patterns, and post-occupancy performance. To improve clarity and interpretability, key constructs were operationally defined as follows-

**Occupant Satisfaction:** defined as the respondent's overall evaluation of smart building systems in terms of comfort, convenience, usability, and perceived effectiveness. This was measured using a 5-point Likert scale ranging from *Very Dissatisfied (1)* to *Very Satisfied (5)*

**Perceived Energy Efficiency:** defined as the respondent's assessment of the extent to which smart technologies contribute to reducing household energy consumption. This was measured using a 5-point scale ranging from *Not at all (1)* to *Very significantly (5)*.

The questionnaire items were developed based on established literature on smart building adoption and post-occupancy evaluation, ensuring alignment with previously validated constructs.

### Data Collection

Ethical approval for the study was obtained prior to data collection. The questionnaire was administered to owner-occupiers of residential buildings within the study area. Due to the specific requirement that respondents must own and occupy their homes (to assess post-occupancy performance), a combination of physical administration and online distribution (via Google Forms) was utilized. Participation was voluntary, and respondents were assured of the confidentiality of their responses. Data collection took place over a period of 2 and half weeks. A total of 68 questionnaires were completed, retrieved and deemed suitable for analysis after data cleaning.

### Statistical Analysis

The Statistical Package for Social Sciences (SPSS) software was used to code, input, and analyze the recovered questionnaires after data collecting was finished. According to the goals of the study, the analysis was carried out in three stages:

#### Descriptive Statistics

Descriptive analysis was employed to summarize the demographic characteristics of the respondents and their responses to key variables (Kennedy et al., 2024). For categorical data (e.g., gender, educational qualification, and timing of adoption), frequencies and percentages were computed.

For ordinal data (e.g., Likert-scale satisfaction scores), the Median was used as the preferred measure of central tendency, as it is more appropriate for ordered categorical data than the mean. The Standard Deviation was reported to indicate the spread or variability of responses around the central value, providing insight into the level of agreement or diversity of opinion within the sample. The results of this analysis are presented in Tables 1 through 4, utilizing frequency distribution tables and bar charts for visual representation.

#### Inferential Statistics

To address the research objectives regarding relationships between variables, inferential statistical tests were conducted.

The choice of test was determined by the nature of the variables involved:

#### Chi-Square Test of Independence

A chi-square test was conducted to examine the association between two categorical variables: educational qualification and the timing of smart appliance adoption (design stage, construction, and retrofit). This test was used to determine if the adoption period was dependent on the educational background of the respondent. The significance level was set at  $p < 0.05$ . The results, including the chi-square value ( $\chi^2$ ), degrees of freedom (df), and significance level ( $p$ ), are reported in Table 7.

#### One-Way Analysis of Variance (ANOVA)

A one-way ANOVA was employed to compare the mean scores of perceived energy reduction across more than two independent groups, specifically the different types of residential buildings (e.g., bungalow, duplex). This test was used to determine if there was a statistically significant difference in how residents of different building types perceived the energy-saving benefits of their smart systems. The F-statistic and significance level ( $p$ ) are reported in Table 8.

For all inferential tests, a significance threshold of  $p < 0.05$  was used to determine statistical significance.

#### Instrument Reliability and Validity

To ensure the robustness of the measurement instrument, internal consistency reliability was assessed using Cronbach's Alpha for Likert-scale items related to satisfaction and perceived energy efficiency. The coefficient value obtained is ( $\alpha = 0.76$ ) as regards the reliability test.

In addition, content validity was established through:

- i. A review of relevant literature on smart housing and post-occupancy evaluation
- ii. Careful structuring of questions to align with the study objectives

These steps ensured that the instrument adequately captured the constructs of interest.

#### Data Limitations and Measurement Considerations

This study relies primarily on self-reported data, which may be subject to response bias and may not fully reflect actual system performance. In particular, measures of energy efficiency are based on perceived reductions rather than objective energy consumption data.

While self-reported measures are widely used in post-occupancy evaluation studies to capture user experience, they inherently limit the ability to assess actual performance outcomes. Therefore, the results of this study should be interpreted as reflecting perceived performance rather than measured energy efficiency.

Future studies are encouraged to incorporate objective performance indicators, such as smart meter readings or utility consumption records, and to adopt mixed-method approaches to enhance data triangulation and improve the robustness of findings.

## RESULTS AND DISCUSSION

### Descriptive and Summary Statistics

This subsection consists of the following: Table 1 reflects respondents' Demography, Table 2, the Building Category and Table 3- Table 5, the Awareness and Adoption Timing of Smart technologies in owner occupied houses.

**Table 1: Descriptive Statistics on Demography**

Variables	Frequency	Valid percent	Median	Standard dev.
Gender				
Male	38	55.9	2.00	0.500
Female	30	44.1		
Age Group				
Below 31 years	2	2.9	4.00	
	1,158			
31 to 40 years	12	17.6		
41 to 50 years	14	20.6		
51 to 60 years	21	30.9		
Above 60 years	19	27.9		
Educational Qualification				
Primary	1	1.5	5.00	1.152
Secondary	4	5.9		
OND/NCE	6	8.8		
HND/BSc	15	22.1		
MSc	30	44.1		
PhD	12	17.6		
Occupation				
Civil servant	21	30.9	4.00	2.622
Public servant	1	1.5		
Retired	15	22.1		
Private sector	31	45.6		
Monthly Income				
Below 100,000	15	22.1	3.00	1.167
100,001 to 200,000	11	16.2		
200,001 to 300,000	20	29.4		
300,001 to 400,000	21	30.9		
Above 400,000	1	1.5		
Location				
Urban	33	48.5	2.00	0.583
Peri urban	32	47.1		
Rural	3	4.4		

A total of 68 respondents participated in the survey. Female respondents constituted 55.9% (n = 38), while males accounted for 44.1% (n = 30). Most respondents were aged 51 years and above, representing 58.8% of the sample, whereas respondents below 31 years constituted only 2.9% (n = 2). The respondents were generally highly educated, with MSc holders accounting for 44.1% (n = 30), followed by HND/BSc holders at 22.1% (n = 15), while PhD holders represented

17.6% (n = 12). In terms of occupation, private-sector employees formed the largest category at 45.6% (n = 31), followed by civil servants at 30.9% (n = 21). Most respondents earned between ₦200,001 and ₦400,000 monthly, while respondents were almost evenly distributed between urban (48.5%) and peri-urban (47.1%) locations.

**Table 2: Descriptive Statistics on Building Category and Age of Building**

Variables	Frequency	Valid percent	Median	Standard dev.
Building Category				
Duplex	20	29.4	3.00	1.228
Storey building	7	10.3		
Bungalow	36	52.9		
Four bedrooms flat	1	1.5		
Three bedrooms flat	1	1.5		
Semi-detached bungalow	3	4.4		
Age of Building				
Less than 5 years	5	7.4	3.00	0.896
5 to 10 years	17	25.0		
11 to 20 years	28	41.2		
Above 20 years	18	26.5		

The demographic profile (tables 1 and 2) suggests that smart home adoption within owner-occupied residential buildings is currently more prevalent among educated and economically stable households capable of financing technology upgrades

and understanding their operational benefits. The moderate variability observed across age and educational categories further indicates a reasonably diverse respondent base, while the relatively low variability in gender and location reflects

consistency within these characteristics. Bungalows constituted the dominant building type, accounting for 52.9% (n = 36), followed by duplexes at 29.4% (n = 20). Storey buildings represented 10.3% (n = 7), while other housing categories recorded minimal representation. The predominance of bungalows is significant from a system-performance perspective because single-level residential structures generally simplify smart system installation, maintenance access, and wireless connectivity. Most buildings were between 11 and 20 years old (41.2%, n = 28), while 26.5% (n = 18) were above 20 years old. Buildings below 5 years accounted for only 7.4% (n = 5). This indicates that most respondents occupy relatively older residential

buildings that were not originally designed with integrated smart infrastructure.

The age profile of the buildings helps explain the predominance of retrofit-based smart technology adoption observed in the study. Older residential buildings typically require post-construction installation of smart systems, which may create compatibility and interoperability challenges between existing building infrastructure and newer automated technologies. Consequently, the effectiveness of smart systems may depend not only on the installed technology but also on the adaptability of existing building services and electrical systems.

**Table 3: Descriptive Statistics on Awareness and Adoption of Smart Technology in Owner-Occupied Houses**

Variables	Frequency	Valid percent	Median	Standard dev.
Yes	46	67.6	1.00	0.471
No	22	32.4		
If yes, your main source(s) of information are:				
Architects/Builders	11	22.4	3.00	1.359
Friends or family	11	22.4		
Television/radio	7	14.3		
Internet/social media	15	30.6		
Personal experience	5	10.2		

From table 3, majority of respondents (67.6%, n = 46) had heard of smart homes or smart building technologies before the survey, while 32.4% (n = 22) had no prior awareness.

**Table 4: Descriptive Statistics on Awareness and Adoption of Smart Technology in Owner-Occupied Houses (Parts of a Smart Home)**

Variables	Frequency	Valid percent	Median	Standard dev.
Automated lighting	2	2.9	6.00	3.136
Smart security systems	11	16.2		
Smart energy meters	9	13.2		
Automated ventilation /cooling	4	5.9		
Remote control of appliances	5	7.4		
Aware of all of the above	15	22.1		
Not aware of any	13	19.1		
Smart security systems & smart energy meters	1	1.5		
Smart security systems & remote control of appliances	1	1.5		
Smart energy meters & Automated ventilation/ cooling	1	1.5		
Smart energy meters & remote control of appliances	1	1.5		
Automated lighting, smart security systems, smart energy meters & automated ventilation/ cooling	1	1.5		
Automated lighting, smart security systems, smart energy meters & automated ventilation/ cooling	1	1.5		
Automated lighting, smart security systems, automated ventilation/ cooling, remote control of appliances	3	4.4		

Most respondents (67.6%, n = 46) had heard of smart homes or smart building technologies prior to the survey, while 32.4% (n = 22) had no prior awareness (Table 4). Internet/social media was the major source of information (30.6%, n = 15), followed by architects/builders and friends/family at 22.4% each (Table 4). Awareness of specific smart features varied considerably across respondents. While 22.1% (n = 15) reported awareness of all listed smart features, 19.1% (n = 13) were not aware of any. Smart security systems were the most recognized individual feature (16.2%, n = 11), followed by smart energy meters (13.2%, n = 9). These

findings suggest that awareness is often conceptual rather than technical, as many respondents appear familiar with the idea of smart homes without fully understanding integrated smart building operations.

When respondents rated their awareness level, the majority (57.4%, n = 39) described themselves as moderately aware, while only 5.9% (n = 4) considered their awareness very high. The moderate awareness level may partly explain the incremental pattern of smart technology implementation observed in the study.

**Table 5: Descriptive Statistics on Awareness and Adoption of Smart Technology in Owner-Occupied Houses (Overall Awareness)**

Variables	Frequency	Valid percent	Median	Standard dev.
Very low	8	11.8	3.00	0.982
Low	7	10.3		
Moderate	39	57.4		
High	10	14.7		
Very high	4	5.9		
When were your smart appliances introduced?				
During design stage	9	18.0	3.00	0.787
During construction stage	10	20.0		
After occupation (renovation/ retrofit)	31	62.0		
Rate your overall satisfaction with your installed smart systems				
Very dissatisfied	1	1.8	4.00	0.769
Dissatisfied	2	3.6		
Neutral	7	12.5		
Satisfied	37	66.1		
Very Satisfied	9	16.1		
To what extent do these features reduce energy consumption?				
Not at all	13	21.7	3.00	1.279
Slightly	6	10.0		
Moderately	20	33.3		
Significantly	15	25.0		
Very Significantly	6	10.0		

Regarding adoption timing, most smart technologies were introduced after occupation through renovation or retrofit (62.0%, n = 31), while only 18.0% (n = 9) were incorporated during the design stage. This indicates that smart home adoption within the study area is driven more by post-occupancy modification than by integrated smart-ready building design. The dominance of retrofit adoption may be linked to factors such as limited awareness during initial construction, cost considerations, and the relatively older age of the buildings studied. From an engineering perspective,

retrofit implementation may limit system interoperability and operational efficiency because many existing residential buildings were not originally configured for automated integration.

Overall, the findings suggest a progression pattern in which awareness influences adoption mode, which subsequently shapes user experience and perceived building performance (Fig. 2). This relationship may be conceptualized as:

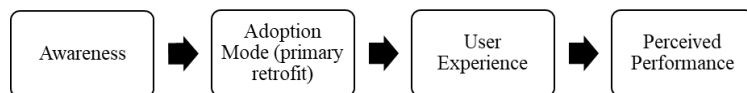


Figure 2: Progression Pattern Reflecting Influence of Awareness on Adoption

This conceptual linkage indicates that the level of awareness among homeowners affects how smart technologies are adopted, while the mode of adoption influences occupants'

experiences and their perception of system performance after installation.

**Extent of Smart Feature Implementation**

**Table 6: Frequency and Percentage of Smart Appliance Introduction Timing**

Introduction Stage	Frequency	Valid Percent
During design stage	9	18.0%
During construction	10	20.0%
After occupation (retrofit)	31	62.0%
Total	50	100.0%

The findings indicate that about 62.0% of smart appliances were introduced after occupation through renovation or retrofit, while 20.0% were introduced during construction and only 18.0% were incorporated during the design stage (Table 6).

This pattern confirms that smart home adoption within the study area is predominantly retrofit-driven (Fig.3). The finding reflects the reality that many existing residential buildings were constructed before smart technologies became widely accessible or affordable. Consequently, homeowners adopt smart systems incrementally as post-occupancy

upgrades. Although retrofit adoption increases accessibility to smart technologies, it may also create operational limitations. Unlike integrated smart-ready buildings, retrofit installations often face challenges associated with wiring compatibility, network coordination, equipment integration, and system interoperability. These factors may affect the long-term operational efficiency of smart systems.

The findings therefore highlight the need for greater incorporation of smart infrastructure considerations during the architectural design and construction stages. Early integration would improve coordination between electrical

systems, communication networks, sensors, and building services, thereby enhancing overall building performance.

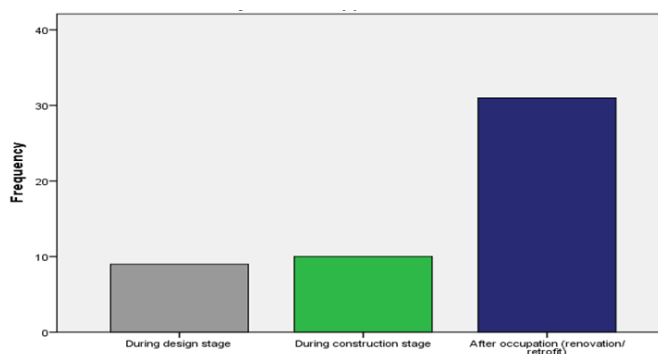


Figure 3: Introduction Stage of Smart Appliances

**Impact on Post-Occupancy Performance**

**Table 7: Satisfaction with Smart Systems**

Satisfaction Level	Frequency	Valid Percent
Very dissatisfied	1	1.8%
Dissatisfied	2	3.6%
Neutral	7	12.5%
Satisfied	37	66.1%
Very Satisfied	9	16.1%
Total	56	100.0%

Post-occupancy performance was evaluated using user satisfaction and perceived energy reduction. The low dissatisfaction rate (5.4%) suggests that when smart features are properly installed and functioning, users tend to appreciate their value. However, the presence of neutral responses (12.5%) indicates that some users may not be fully experiencing the benefits (Table 7).

Most respondents expressed satisfaction with their installed smart systems, with 82.2% reporting that they were either satisfied or very satisfied. The findings suggest that smart technologies contribute positively to residential comfort, convenience, automation, remote accessibility, and security. However, satisfaction should not be interpreted solely as evidence of high technical or energy-performance outcomes.

Rather, the findings indicate that occupants value smart technologies largely for enhanced user experience and improved interaction with building systems. This aligns with post-occupancy evaluation literature which emphasizes that occupant satisfaction in smart environments is multidimensional and extends beyond energy efficiency alone.

From a system-performance perspective, the findings suggest that many installed technologies currently function more as convenience-oriented smart devices than as fully integrated building energy-management systems. Consequently, positive user experiences may coexist with modest or inconsistent energy-performance outcomes.

**Table 8: Perceived Extent of Energy Reduction**

Satisfaction Level	Frequency	Valid Percent
Not at all	13	21.7%
Slightly	6	10.0%
Moderately	20	33.3%
Significantly	15	25.0%
Very significantly	6	10.0%
Total	60	100.0%

One-third of respondents (33.3%) perceived 'Moderate' energy consumption reduction, while 25.0% reported 'Significant' savings. An equal percentage (10.0%) of respondents perceived that energy consumption was either 'Slightly' or 'Significantly' reduced. Notably, 21.7% indicated that smart features reduced energy consumption 'Not at all,' suggesting considerable divergence in user experience.

Although many respondents perceived moderate or significant energy savings, perceptions varied considerably across households. While some occupants perceived moderate or significant reductions in energy consumption, 21.7% reported no perceived reduction at all (Table 8).

Importantly, the study assessed perceived rather than objectively measured energy savings. Therefore, the findings should not be interpreted as direct evidence of actual building energy-performance improvement. Perceptions of energy reduction may be influenced by occupant expectations, behavioural patterns, system usage, and awareness levels.

The findings suggest that current smart home adoption within the study area is driven more strongly by convenience, security, and lifestyle enhancement than by verified energy optimization outcomes. In addition, the variability in responses indicates differences in system integration quality, user interaction, and operational practices across households. The divergence between high user satisfaction and mixed

perceptions of energy reduction represents an important finding of the study. It suggests that homeowners may value smart technologies primarily for convenience and controllability even where measurable energy benefits are uncertain.

Future studies should therefore incorporate objective post-occupancy performance indicators such as electricity consumption records (kWh), sensor data, or smart meter analysis to complement perception-based assessments.

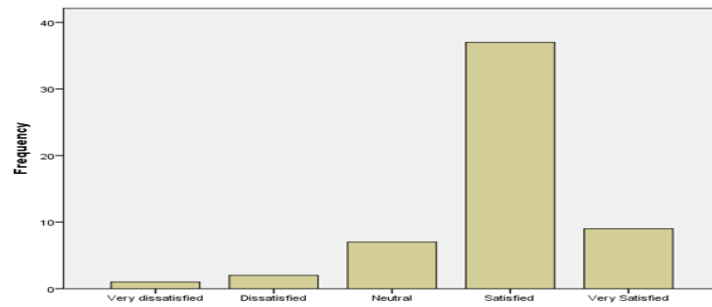


Figure 4: Rate of Overall Satisfaction with Installed Smart System

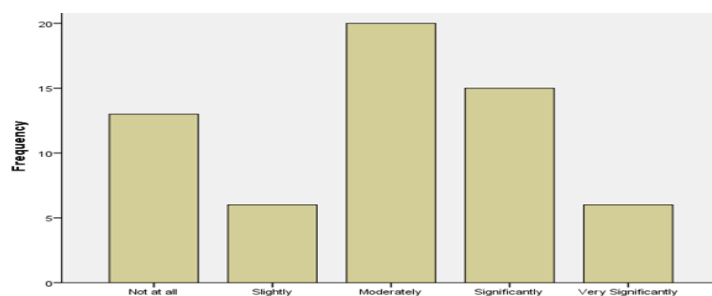


Figure 5: Extent of Reduction of Energy Consumption

**Inferential Statistics on Smart Energy Adoption with Educational Qualification and Time of Adopting Smart Energy**

A chi-square test of independence revealed no statistically significant relationship between educational qualification and timing of smart technology adoption,  $\chi^2 (10, N = 50) = 10.96$ ,  $p = 0.361$ . Although MSc holders appeared more likely to adopt smart technologies through retrofit installation, the relationship was not statistically significant.

The findings suggest that retrofit adoption may be influenced more by broader economic and infrastructural conditions than

by educational attainment alone. Even highly educated homeowners may postpone smart technology integration until after occupancy due to financial considerations, evolving technology availability, or limited smart-ready construction practices.

Cramer’s V (0.331) indicated a moderate effect size, suggesting that practical relationships may still exist despite the absence of statistical significance. However, the large proportion of cells with expected counts below five requires cautious interpretation of the results.

**Table 9: Chi-Square Results between Education and Time of Adopting Smart Energy**

Items	Value	Df	Asymp.Sig (2-sided)
Pearson Chi-Square	10.959	10	0.361
Likelihood Ratio	10.536	10	0.395
Cramer's V	0.331		0.361
N	50		

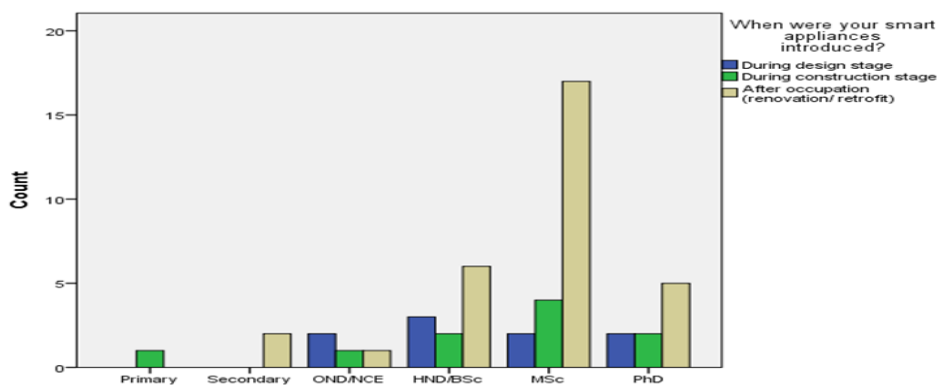


Figure 6: Association Between Educational Qualification and Energy Adoption Timing

### Inferential Statistics on Building Type and Energy Perception

The ANOVA results showed no statistically significant differences between residential building type and perceived energy reduction,  $F(5, 54) = 1.26, p = 0.295$ .

**Table 10: ANOVA Results from the Comparison of Building Type and Energy Reduction**

Source	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	10.081	5	2.016	1.259	0.295
Within Groups	86.503	54	1.602		
Total	96.583	59			

The findings imply that perceived smart system performance may be relatively transferable across different residential building forms. This suggests that operational outcomes may depend less on housing typology and more on factors such as installation quality, system integration, user behavior, and occupant interaction with smart technologies.

The relatively larger within-group variability compared with between-group variability further indicates inconsistency in user experiences across households. This reinforces the importance of proper installation practices, user education, and integrated building-system coordination in achieving improved smart building performance.

Overall, the study demonstrates that smart home adoption within owner-occupied residential buildings is emerging primarily through retrofit implementation driven by convenience, security, and lifestyle enhancement rather than exclusively by energy-efficiency objectives. While awareness of smart technologies is relatively high, detailed understanding of integrated smart building systems remains uneven. The findings further emphasize the importance of integrated design-stage planning, professional coordination, and objective post-occupancy performance evaluation in improving the long-term effectiveness of smart residential technologies.

### RECOMMENDATIONS

Based on the findings and limitations of this study, the following recommendations are proposed. Future studies should include larger samples with greater demographic diversity to improve the generalizability of findings and allow more detailed subgroup analysis. The use of random or probability sampling methods is recommended in future research to enhance representativeness and support stronger statistical inference. Future studies should incorporate actual energy consumption records, such as utility bills or smart meter data, alongside self-reported perceptions to provide a more accurate assessment of the performance of smart building technologies. Studies conducted over longer periods are recommended to examine how user satisfaction, adoption patterns, and perceived energy benefits change over time. Future research may combine questionnaire surveys with interviews or case studies to better understand the factors influencing awareness, adoption, and user satisfaction with smart housing technologies.

Further studies should examine individual smart building features and systems separately to identify which technologies provide the greatest benefits in residential buildings. Additional research comparing different housing types, regions, and socio-economic groups is recommended to better understand contextual factors affecting the adoption and effectiveness of smart building technologies in Nigeria.

### Implications for Engineering Practice

The findings of this study have implications for engineering practice in the development of smart residential buildings. There is a need to integrate automation, energy-monitoring,

and control systems during the early design stage rather than at the construction stage noting the uneven adoption of smart building technologies indicated in the study. To ensure that residential structures are designed to accommodate intelligent systems, there should be close collaboration among civil, electrical and building services engineers for effective implementation of smart systems. The results also highlight the importance of improving professional training and technical standards related to smart building technologies to support wider adoption and enhance the operational efficiency of residential buildings in Nigeria.

### CONCLUSION

This study examined the awareness, adoption patterns, and post-occupancy performance of smart home technologies in owner-occupied buildings. The findings revealed that awareness of smart home technologies was relatively high, with 67.6% of respondents indicating prior knowledge of smart homes. However, awareness of specific smart features and integrated system functions remained uneven, suggesting that many homeowners possess general familiarity with smart technologies without fully understanding their operational capabilities. The study further revealed that smart technology adoption is predominantly retrofit-based, as 62.0% of smart systems were introduced after occupation rather than during the design or construction stages. This finding reflects the reality that many existing residential buildings were not originally designed with integrated smart infrastructure. Consequently, smart technologies are often implemented incrementally as post-occupancy upgrades rather than as fully coordinated building systems.

User satisfaction with installed smart systems was generally high, with 82.2% of respondents reporting that they were satisfied or very satisfied with their systems. Nevertheless, perceptions regarding energy reduction were more varied, with only 35.0% reporting significant or very significant energy savings, while 21.7% perceived no energy reduction at all. This indicates that occupants may value smart technologies primarily for convenience, security, automation, and improved interaction with building systems rather than for measurable energy-efficiency outcomes alone. The inferential analysis revealed no statistically significant relationship between educational qualification and timing of smart technology adoption, as well as no significant differences between building type and perceived energy reduction. These findings suggest that smart system performance and adoption patterns may depend more on factors such as system integration quality, user interaction, retrofit constraints, and installation practices than on demographic or housing characteristics alone. Overall, the study highlights that the effectiveness of smart residential technologies depends not only on the presence of smart devices but also on the manner in which systems are integrated into existing buildings and utilized by occupants. The findings therefore emphasize the need for greater incorporation of smart infrastructure considerations during

the design stage of residential buildings to improve interoperability, operational efficiency, and long-term system performance. Finally, the study relied primarily on occupants' perceptions of performance rather than objective energy-consumption measurements. Future studies should therefore incorporate post-occupancy performance indicators such as electricity consumption records, smart meter data, and sensor-based monitoring systems to provide more robust evaluation of the actual energy-performance impacts of smart home technologies.

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