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TOPIC: AUTOMATION IN SUSTAINABLE HOUSING: A DOUBLE-EDGED APPROACH TO RESIDENTIAL DESIGN

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My deepest appreciation to God Almighty for seeing me through the years I spent at the citadel of learning, the University of Benin. For all the nights where The Holy Spirit, suiting words and assurance, were what kept me going. To my Parents, Mr and Mrs Nosakhare Idiaru, who made sure I had all that was needed to make my studies at the university comfortable and enjoyable. To my amazing project supervisor, whose guidance and contribution made the process of this project a walkover, I am deeply grateful. To my siblings, better known as my second parents, who kept on encouraging and coming in, in whatever way they could. To my friends and roommates who ease the burden of the stress and workload that came with pursuing a degree in a federal university in Nigeria, with their amazing sense of humour. The story of my tertiary learning would be incomplete without you all.

ABSTRACT

Sustainability in housing is a phrase that has become a norm in the mouths of not just members of the building industry but also of all individuals with a sense of prudence and comfort. The tendency to beg the question “can housing really be sustainable?” Given that a lot of environmentally unfriendly processes are embarked on to produce the necessary elements used in construction and housing, a lot of work has to be done during the years of the structure to refund the ecological make up that was lost to create it in the first place. This leads to the need to create residential buildings that are not just aesthetically pleasing but also protect the core for which sustainability stands

The growing global concern for environmental sustainability and the increasing strain on natural resources have placed the built environment at the forefront of conversations surrounding climate resilience, energy efficiency, and responsible development. In Nigeria and many other developing economies, the challenge of creating housing that is environmentally sustainable while remaining economically accessible and socially inclusive has become increasingly urgent. At the same time, advances in digital technology and intelligent building automation are reshaping the possibilities within residential design by offering new mechanisms for improving energy performance, operational efficiency, and occupant comfort. This study explores the intersection between sustainable housing and automated residential systems, critically examining whether automation serves as an innovative tool that enhances sustainability or whether it introduces complexities that threaten affordability, equity, and long-term resilience in the Nigerian context.

The research adopts a mixed-method approach, combining quantitative data collected through structured questionnaires administered digitally via Google Forms with qualitative insights from semi-structured interviews with architects, engineers, residential developers, and automation technology practitioners. This methodology provided a comprehensive understanding of both user experiences and professional perspectives regarding automation and sustainability in the residential sector.

The findings reveal that while awareness of sustainable housing principles is growing, adoption is still largely limited due to economic constraints and infrastructural challenges. Passive environmental design strategies such as natural ventilation, shading, and solar integration are widely recognised as realistic and impactful within the Nigerian climatic and economic context. Conversely, automated systems such as intelligent lighting, energy

monitoring, and adaptive cooling are acknowledged as valuable improvements capable of providing 10–30% performance efficiency; however, they remain accessible primarily to higher-income households due to high installation costs, maintenance requirements, unreliable power supply, and limited technical expertise.

The research, therefore, identifies significant barriers to widespread automation adoption and highlights the risk that automation may deepen existing social inequalities if implemented without structural support. Nevertheless, respondents and professionals agree that the most promising pathway forward is a hybrid model that integrates robust passive design principles as the foundation of sustainability, while incorporating selective automation where feasible to optimise performance and long-term building adaptability.

The study concludes by recommending policy reform, professional capacity development, public awareness initiatives, and incremental integration frameworks that enable responsible adoption of automated systems without compromising affordability or resilience. The proposed conceptual framework demonstrates how balanced integration can support Nigeria's pursuit of sustainable, resilient, and future-ready residential environments, contributing to academic discourse and offering practical guidance for architects, policymakers, and housing developers.

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Sustainability is the incorporation of ecological well-being, social fairness and economic liveliness in order to create thriving, healthy, diverse and resilient communities for the current generation and the next. It emphasises efficient use of resources, environmental friendliness, durability, and affordability. Traditionally, sustainability in architecture relied on passive design strategies, strategic orientation, material choices, and efficient planning. However, the growing complexity of urban living, climate change, and technological advancement has introduced automation as an additional pathway to sustainability.

Automation generally refers to the use of technology, such as machines, software, or control systems, to perform tasks or processes with minimal human intervention (IBM, 2025), while building automation refers to the automatic control, regulation, monitoring, and optimization of critical building systems such as HVAC (heating, ventilation, and air conditioning), lighting, shading, and security through a centralized management system. These systems use sensors, controllers, and software to ensure efficient operation, resource savings, and occupant comfort (Kieback & Peter, n.d.).

The intersection of automation and sustainability in residential design represents one of the most transformative directions in contemporary architecture. Automation, driven by smart technologies such as sensors, artificial intelligence (AI), and the Internet of Things (IoT), Automated housing systems, including smart meters, automated ventilation, programmable thermostats, energy monitoring, water-saving systems, and integrated renewable energy sources, have revolutionised how buildings are designed, operated, and experienced. Within the discourse of sustainable housing, automation is positioned as a strategic tool for achieving energy efficiency, resource conservation, and improved living standards. These technologies, when combined with architectural design, can significantly reduce resource consumption while improving occupant well-being. For example, automated lighting systems reduce unnecessary energy use, while smart water systems detect and eliminate leaks.

Globally, automation is becoming synonymous with futuristic and sustainable housing. In countries like Japan, Germany, and Singapore, smart housing projects are being adopted as models for urban development. However, in tropical and developing regions such as Nigeria, the integration of automation into sustainable housing remains underexplored. Most housing projects prioritise affordability and speed of construction over technological sophistication.

The few attempts at automation are often imported models that fail to consider local conditions such as erratic power supply, socio-economic realities, and cultural housing preferences.

Thus, while automation holds the potential to redefine residential design in Nigeria and similar contexts, it requires critical analysis. It is not sufficient to adopt foreign models; instead, automation must be contextualised to local realities to ensure that it enhances rather than undermines sustainability.

1.2 RESEARCH GAP

Although global discourse has extensively studied the integration of automation into sustainable housing, most studies originate from developed nations where infrastructure, affordability, and technology adoption differ significantly from the Nigerian context. The majority of literature emphasises the benefits of automation, such as reduced energy consumption and increased efficiency, without equally addressing its challenges in regions with infrastructural and economic limitations.

In Nigeria, research on sustainable housing tends to focus on passive design, durable materials, and renewable energy, but rarely on automation. Where automation is mentioned, it is often in the form of imported technologies that do not consider the realities of unstable electricity, high costs, and limited technical expertise. This lack of localised research leaves a significant gap in understanding how automation can realistically contribute to sustainable housing in Nigeria.

Furthermore, while there are studies on the environmental performance of buildings, there is little empirical research on the social and economic implications of automated housing in low- and middle-income contexts. For example, automation could improve comfort and reduce waste but also create dependency on technologies that are expensive to maintain, vulnerable to breakdowns, or culturally incompatible.

Another gap is the lack of balanced perspectives in existing literature. Much of the research presents automation as an unquestioned benefit, neglecting its risks and potential downsides. This creates a one-sided narrative that fails to capture the “double-edged” reality of automation. In Nigeria, where sustainable housing is urgently needed, an uncritical adoption of automation could lead to unaffordable or unsustainable housing systems.

This study aims to bridge these gaps by providing a contextualised and critical analysis of automation in sustainable housing. It will evaluate both opportunities and drawbacks, emphasising how automation can either strengthen or undermine sustainability in Nigerian residential design.

1.3 RESEARCH PROBLEM

Despite the global push for smart and sustainable housing, Nigeria faces challenges that complicate the integration of automation into residential design. The key problems include:

1. The absence of localised frameworks for integrating automation into sustainable housing.
2. Over-reliance on imported technologies that are ill-suited for Nigeria's socio-economic and infrastructural realities.
3. High costs of automated systems, making them inaccessible to low- and middle-income households.
4. Dependence on erratic power supply and unstable internet connectivity, which undermines system functionality.
5. Lack of technical expertise for installation, maintenance, and repair of smart housing systems.
6. Environmental concerns over electronic waste generated from obsolete automated devices.

1.4 RESEARCH OBJECTIVES

- To analyse the current state of automation in sustainable housing globally and within Nigeria.
- To identify the potential benefits of automation in enhancing sustainability in residential design.
- To critically evaluate the challenges, risks, and limitations of automation in the Nigerian housing context.

- To compare automation with traditional passive strategies in terms of affordability, effectiveness, and adaptability.
- To propose a framework for integrating automation into sustainable housing that balances efficiency, affordability, and resilience.

1.5 RESEARCH QUESTIONS

1. What is the current state of sustainable housing practices in Nigeria, and how is automation being applied?
2. Which aspects of residential design can automation improve in terms of energy efficiency, water management, and comfort?
3. What challenges limit the adoption of automation in sustainable housing in Nigeria?
4. How do the costs and maintenance requirements of automated systems affect their long-term sustainability?
5. What role does infrastructure (electricity, internet) play in the success or failure of automation in Nigerian housing?
6. How does automation compare with passive design strategies in terms of affordability and effectiveness in tropical climates?
7. What risks does automation pose in terms of dependency, obsolescence, and environmental impact?
8. How do residents perceive and adapt to automation in housing—do they see it as beneficial or burdensome?
9. How can automation be contextualised to suit Nigerian socio-economic and climatic realities?
10. What framework can architects and policymakers adopt to balance the promises and risks of automation in sustainable housing?

1.6 SIGNIFICANCE OF STUDY

This study contributes significantly to the discourse on sustainable architecture in Nigeria. For architects, it provides a balanced framework for integrating automation into housing designs without neglecting passive and low-tech strategies. For policymakers, it highlights the infrastructural, economic, and regulatory conditions necessary to make automation feasible and sustainable. For residents, it raises awareness of the opportunities and limitations of automated housing, empowering them to make informed decisions.

Academically, the study fills a research gap by presenting automation not as an unquestioned solution but as a double-edged approach with both potential benefits and risks. Practically, it contributes to developing housing models that are sustainable, context-sensitive, and accessible. Ultimately, this research advances the broader goal of creating sustainable housing in Nigeria that is both technologically advanced and socially inclusive.

1.7 LIMITATIONS OF THE STUDY

This study is subject to several limitations that may influence the interpretation, reliability, and general applicability of its findings. A primary constraint lies in the relatively small and specialised sample size available for research, which may restrict the extent to which the results can be generalised beyond the specific study population. Additionally, the accuracy and representativeness of the data may be affected by the possibility that some respondents may not provide responses with full candour or may have limited exposure to automation technologies, thereby influencing the validity of survey and interview feedback. Furthermore, the study may encounter practical constraints such as limited time, insufficient financial resources, and restricted access to participants. The duration of the research also introduces the potential for participant attrition, whereby individuals engaged in initial phases may be unavailable or unwilling to continue through subsequent stages. Considering that fully automated residential systems are still emerging within Nigeria, available case studies may be limited to partially automated or hybrid housing models, which may affect the depth of comparative analysis. In addition, obtaining accurate energy performance and maintenance records may pose challenges due to inconsistent documentation practices within the housing sector.

While acknowledging these limitations is essential for methodological transparency and academic integrity, the study has been carefully designed to mitigate their effects through the adoption of structured sampling procedures, cross-verification (triangulation) of data sources, and analytical rigour to enhance the credibility, reliability, and practical value of the research outcomes

1.8 DELIMITATIONS

This research will primarily concentrate on residential developments, particularly small- to medium-scale projects situated in Benin City and Lagos, where public awareness of sustainable housing practices is steadily increasing. It will exclude commercial and institutional buildings, focusing instead on domestic design applications.

The inquiry will emphasise design integration, user perception, and contextual adaptation, rather than the technical or software engineering dimensions of automation. Both premium smart homes and affordable housing prototypes will be examined to capture a broad socio-economic spectrum, ensuring a balanced understanding of automation's potential role in sustainable residential architecture.

CHAPTER 2

LITERATURE REVIEW

2.0 OVERVIEW OF THE CHAPTER

This chapter examines existing research, theories, concepts, and scholarly discussions related to sustainable housing and the integration of automation into residential design, with special attention to the Nigerian context and comparisons with other developing regions. It discusses the evolution of sustainability principles, the development of automation technologies, global and local perspectives on smart housing, and comparative insights between passive and technology-driven systems. It also identifies the theoretical foundations of this research and emphasises the gaps in current knowledge that justify the present study.

2.1 CONCEPT OF SUSTAINABLE HOUSING

Sustainable housing represents an environmentally responsible, socially supportive, and economically viable approach to residential development. According to Mensah and Acheampong (2019), sustainability involves balancing the environmental, social, and economic pillars of development to meet present needs without compromising future generations. In architectural design, sustainable housing integrates strategies that minimise resource consumption, reduce ecological impact, and promote long-term building performance. Such housing reframes buildings as socio-ecological systems rather than isolated artefacts.

Lehmann (2018) argues that sustainable housing prioritises passive design strategies, energy efficiency, durable materials, and lifecycle thinking. These strategies include maximising natural lighting, strategic building orientation, cross-ventilation, low-carbon material selection, water efficiency, and renewable energy integration. Sustainable housing developments also emphasise indoor comfort and occupant well-being, recognising buildings as living environments rather than static enclosures.

In the Nigerian context, Akinyemi (2020) notes that sustainable housing practices have largely remained theoretical due to limited policy enforcement, high implementation costs, and low environmental awareness. As a result, most housing relies on conventional construction technologies rather than performance-driven principles. This raises critical questions about the viability of sustainable housing practices in developing economies and the role technology could play in improving adoption.

In developing economies, the social and economic pillars intensify the design challenge. Akinyemi (2020) observes that sustainability discourse in sub-Saharan Africa must foreground affordability, incremental construction practices and cultural acceptability. In Nigeria specifically, housing shortages, informal settlement dynamics and limited enforcement of building regulations mean that sustainable design often remains aspirational (Adeleye, 2021). Consequently, sustainable housing in Nigeria must reconcile ideal performance goals with realities of cost, supply chains, and local construction capacity.

Architecturally, this reconciliation means prioritising measures that deliver the greatest performance for the lowest recurring cost: basic passive design, shading, vernacular materials adapted to modern codes, and low-tech renewable solutions. This pragmatic orientation frames the later discussion about where automation legitimately augments sustainable housing rather than supplanting basic resilience.

2.2 AUTOMATION IN RESIDENTIAL DESIGN

Automation refers broadly to the application of control technologies, sensors, and computerised systems to perform tasks with minimal human intervention (IBM, 2025). In residential design, automation, often referred to as smart home technology, includes systems such as automated lighting, temperature control, security monitoring, climate controls (smart thermostats), motorised shading, energy-management platforms that coordinate PV generation with battery storage and loads, which are building-scale systems that influence energy performance and occupant experience (Techopedia, n.d.).

Automation enhances residential performance by enabling real-time environmental monitoring and responsive control. According to Oladokun and Emmanuel (2020), automated residential systems improve energy efficiency, operational precision, and user comfort while enabling efficient management of power and resource consumption. Architecturally, automation shifts the focus from fixed form to responsive performance. Buildings equipped with automation can modulate enclosure behaviour (e.g., operable windows actuated by indoor air quality sensors), balance solar gains (automatic shading algorithms), or shift non-critical loads to times of high renewable generation. Such capabilities open avenues for optimisation that passive systems alone cannot achieve, particularly in dense urban contexts where control over microclimate and occupancy use can significantly affect operational energy (Lehmann, 2018).

However, the literature underlines two essential cautions. First, automation is only as sustainable as its energy source and maintenance regime: automated systems that rely on grid electricity in unreliable supply contexts can paradoxically increase embodied and operational carbon (Bagale & Shah, 2017). Second, automation introduces complexity in software, firmware and supply chains that can outpace local maintenance capacity, thus risking rapid obsolescence (Oladokun & Emmanuel, 2020). An architect's role, therefore, extends to specifying resilient, serviceable automation that can be locally supported. The authors emphasise that adoption in Nigeria remains limited due to high procurement costs, unreliable power supply, limited technical expertise, and perceived complexity of maintenance.

Globally, smart homes represent major advancements in housing innovation. UN-Habitat (2021) reports that automated residential buildings are becoming central components of smart cities, enabling data-driven operation and integration with renewable energy systems. In contrast, Bagale and Shah (2017) suggest that without context-based adaptation, advanced automation systems may increase financial burdens for low-income users, undermining sustainability objectives.

2.3 GLOBAL PERSPECTIVES ON SMART AND SUSTAINABLE HOUSING

High-income regions have piloted holistic integrations of automation and sustainability: district energy management, smart grids, and predictive control strategies. Countries such as Japan, Germany, and the United States lead in integrating automation into sustainable residential design. Germany and the Netherlands are often cited for integrated retrofits that combine envelope improvements with intelligent control; Japan demonstrates robotics and automation tailored to ageing populations; and parts of North America have advanced home energy management platforms tightly coupled to demand response markets. Mature markets achieve optimised energy performance through intelligent HVAC controls, automated shading, and smart solar grids (UN-Habitat, 2021). In Europe, building automation contributes significantly to carbon-reduction goals by utilising predictive energy-use patterns and adaptive controls integrated into architectural systems (Lehmann, 2018).

Conversely, in developing countries, particularly in sub-Saharan Africa, smart residential technologies remain concentrated among high-income groups. Research findings suggest that smart housing is often perceived as a luxury, rather than a sustainability solution, due to affordability constraints and infrastructure limitations (Akinyemi, 2020). This creates a duality in the global housing landscape where smart, sustainable housing thrives in technologically advanced nations while remaining aspirational in lower-income regions.

These contrasting realities highlight the need for hybrid sustainable strategies that adapt automation technologies to context-appropriate levels rather than replicating expensive foreign models.

Key lessons for developing contexts include:

- **Simplicity and interoperability:** Solutions using open standards reduce vendor lock-in and are easier to service locally.
- **Energy pairing:** Automation must be paired with distributed renewables (solar + battery) to avoid reliance on fragile grids.
- **Local capacity building:** Successful projects invest in local technician training and supply chains, reducing lifecycle costs and improving adoption rates (Lehmann, 2018; UN-Habitat, 2021).

Translatability depends on adaptation: technical packages must be right-sized, cost-reduced and designed for the social realities of the local market.

2.4 AUTOMATION IN DEVELOPING ECONOMIES: CHALLENGES AND OPPORTUNITIES

The adoption of automation in residential housing within developing countries is challenged by multiple socio-economic and infrastructural barriers. High installation and maintenance costs, inconsistent electricity supply, inadequate digital literacy, and the scarcity of technical support personnel limit effective deployment, perception of automation as a luxury (Akinyemi, 2020; Oladokun & Emmanuel, 2020). Specific to Nigeria, intermittent power supply, limited after-sales services for imported automation components, and fragmented regulatory frameworks constrain scale (Adeleye, 2021).

Nevertheless, automation presents significant opportunities. Integration with standalone solar systems and micro-grids can reduce energy dependency on unstable national power networks (Lehmann, 2018). Additionally, locally developed low-cost automation technologies and simplified user interfaces (e.g., motion sensors, time switches) provide performance benefits without high complexity, and could enable affordable system integration. The literature emphasises policy levers: subsidies for retrofits, tax incentives for energy-efficient systems, standards for minimum energy performance and training programmes for local technicians

(Akinyemi, 2020; UN-Habitat, 2021). These institutional supports are often prerequisites for widespread automation adoption in resource-constrained settings.

These potentials indicate that automation can support sustainable development goals when implementation strategies prioritise affordability, resilience, and long-term maintainability, rather than importing complex systems unsuited to local realities.

2.5 COMPARATIVE ANALYSIS: PASSIVE DESIGN VS AUTOMATED SYSTEMS

Passive design focuses on optimising environmental performance using natural resources such as sunlight, ventilation, thermal mass, and building orientation, without mechanical systems. Automated systems, on the other hand, use digital sensors, responsive controls, and energy-management technology to enhance building performance.

The literature treats passive and automated strategies not as rivals but as complementary tools. Passive design reduces baseline demand; automation refines performance and manages transients. When applied sequentially, passive measures provide resilience and reduced dependence on automation; when automation is added, it yields incremental gains at lower marginal cost (Lehmann, 2018). Advantages of passive strategies include low maintenance, independence from continuous power, and simplicity qualities, especially valuable in the Nigerian context where grid stability is uneven (Ogunbiyi et al., 2020). Automated systems, conversely, deliver precision control and the ability to schedule, monitor and adapt building operation in real time.

Passive Design	**Automated Systems**
Low-cost, resilient, easy to maintain	Higher initial cost, requires expertise
Independent from power supply	Dependent on stable electricity
Long-term performance stability	Risk of system failure or obsolescence
Lower energy consumption baseline	Reduces operational waste dynamically
Less precision control	Very high accuracy and monitoring capacity

Trade-offs are clear: adding automation increases initial capital costs, introduces servicing requirements, and can create single points of failure (software bugs, network outages). Yet in mid- to high-density housing or multi-unit buildings, automation can unlock efficiencies, for example, centralised energy management or shared storage that passive approaches cannot provide alone (Oladokun & Emmanuel, 2020). Lehmann (2018) argues that the most effective design approach is a **hybrid strategy** that combines passive measures to reduce baseline energy loads with automation for fine-tuned performance. Such integration supports sustainability goals by maximising efficiency while managing cost and operational resilience.

2.6 SOCIO-ECONOMIC, CULTURAL AND ETHICAL IMPLICATIONS

Automation intersects with the social dimensions of housing. Economically, automation risks creating a two-tier housing market: those able to pay for smart efficiency versus those excluded from its benefits (Bagale & Shah, 2017). Culturally, automation may clash with local practices of informal adaptation and incremental modification; users accustomed to hands-on control may distrust opaque automated systems.

Ethical concerns include data privacy (home occupancy patterns are sensitive), security vulnerabilities (poorly secured IoT devices can be entry points for malicious actors), and the environmental footprint of manufacturing and replacing automated hardware (Oladokun & Emmanuel, 2020). The literature urges architects to incorporate privacy-by-design, specify secure, updateable firmware, and select devices with low embodied carbon profiles where possible.

2.7 MAINTENANCE, LIFECYCLE AND WHOLE-LIFE COSTING

A recurring critique is the neglect of lifecycle thinking when evaluating automation's sustainability. Upfront savings reported in pilot studies often fail to account for maintenance, replacement cycles and software licensing costs (Lehmann, 2018). In Nigeria, where local maintenance markets for automation are nascent, lifecycle costs can overwhelm owners after installation. Architects and developers must therefore evaluate whole-life cost models, favouring modular, repairable equipment and local supply strategies that reduce long-term risk (Akinyemi, 2020).

2.8 CASE STUDIES AND APPLIED PROJECTS — EVIDENCE AND LEARNING (SELECTED)

Empirical studies from Nigeria remain limited but instructive. Oladokun and Emmanuel (2020) surveyed residents' willingness to adopt smart home technologies in urban Nigeria, finding willingness tied primarily to perceived cost-benefit and assurances around maintenance. Studies on passive strategies (Ogunbiyi et al., 2020) demonstrate clear performance improvements from orientation and ventilation design in Nigerian dwellings, improvements that automation can augment but not replace.

Across developing countries, pilot projects combining solar PV and simple automation (load shifting, timed water-heating control) have improved reliability and reduced diesel generator reliance in mixed-income housing (UN-Habitat, 2021). These examples illustrate that targeted, modest automation paired with renewable energy and strong maintenance planning achieves better sustainability outcomes than broad, high-cost smart systems.

2.9 THEORETICAL FRAMEWORK

Three theoretical perspectives strongly inform the present study:

1. **Technology Acceptance Model (TAM)**
   Developed by Davis (1989), TAM explains technology adoption based on two determinants: perceived usefulness and perceived ease of use. In housing, TAM predicts that residents adopt automation when they perceive clear usefulness (energy savings, comfort) and manageable effort to operate. In housing, these factors determine whether residents accept automated systems as valuable and manageable.
2. **Unified Theory of Acceptance and Use of Technology (UTAUT)**
   1. According to Venkatesh et al. (2003), UTAUT expands TAM by incorporating social influence and facilitating conditions, critical in communal cultures. This framework explains willingness to adopt automation in residential settings were cultural context influences perception. Adoption is influenced by performance expectancy, effort expectancy, social influence, and facilitating conditions.

3. **Systems Theory**

   Bertalanffy (1968) describes buildings as interconnected systems where architectural, mechanical, and human subsystems interact. This theory supports understanding automation not as an isolated system but as part of an integrated design ecosystem. These frameworks collectively enable analysis of adoption drivers and constraints, while also guiding design decisions that reconcile user behaviour, technology affordances and systemic capacities.

2.10 SMART HOUSING, IOT AND SYSTEMS INTEGRATION — TECHNICAL ARCHITECTURE AND DESIGN POTENTIALS

The Internet of Things (IoT) and advances in embedded sensors have accelerated the penetration of smart functions into the domestic realm (UN-Habitat, 2021). IoT provides distributed sensing, temperature, humidity, occupancy, and irradiance that, when fused through edge controllers or cloud platforms, enables nuanced control strategies: predictive ventilation, adaptive shading based on solar forecasts, and demand-side management responsive to variable tariffs or solar generation.

From an architectural viewpoint, several affordances stand out:

1. **Performance Feedback:** IoT enables post-occupancy measurement of actual energy and comfort performance, creating feedback loops for iterative design improvement (Lehmann, 2018).

2. **Adaptive Envelopes:** Motorised or responsive façade elements can dynamically alter solar and daylighting conditions without drastic changes to building form.

3. **Behavioural Nudging:** Interfaces (dashboards, mobile apps) can encourage occupant behaviours that reduce consumption, such as timely reminders, visualisation of energy flows, or automatic optimisation that reduces cognitive load.

Studies note, however, that to be effective in low-resource contexts, IoT implementations must prioritise robustness: low-bandwidth operation, offline fallback modes, and local serviceability (Akinyemi, 2020). The literature thus advocates lightweight IoT architectures, locally maintainable controllers, open protocols, and modular hardware, over black-box proprietary ecosystems that lock owners into expensive maintenance cycles (Bagale & Shah, 2017).

2.11 CONTRADICTIONS, DEBATES AND UNRESOLVED QUESTIONS

The literature contains several contested ideas:

- **Automation as enabler vs risk:** Proponents argue automation is essential for deep decarbonisation and occupant well-being; critics warn of rebound effects, vendor lock-in and maintenance liabilities (Lehmann, 2018; Bagale & Shah, 2017).
- **Top-down technology transfer vs local innovation:** Some researchers advocate importing sophisticated systems; others emphasise localised, low-cost innovation tailored to social contexts (Akinyemi, 2020). The debate hinges on whether performance requires high tech or intelligent adaptation of basic principles.
- **Equity implications:** Automation may improve efficiency but widen inequality unless paired with policy measures that make benefits accessible at scale.

These tensions frame the research imperative: to specify how automation can be integrated into sustainable housing in Nigeria so that benefits are realised without creating new vulnerabilities.

2.12 RESEARCH GAP

Numerous studies discuss sustainable housing and smart automation independently, but little research explores their combined application within developing nations from an architectural perspective. Existing studies rarely address design-integration frameworks or propose adaptive hybrid models suited to socio-economic and infrastructural realities in Nigeria. Therefore, this research fills a critical knowledge gap by examining automation as a supportive, rather than substitutive, component of sustainable housing, rammed through architectural design thinking.

2.13 SUMMARY OF THE CHAPTER

This chapter has reviewed literature on sustainable housing principles, automation technologies, global smart-housing trends, adoption challenges in developing economies, and the comparative role of passive and automated systems. It has also presented theoretical frameworks that underpin adoption behaviour and systemic design integration. The research gap identified provides a justification for exploring automation in sustainable housing within the Nigerian context, guiding the methodology presented in Chapter Three.

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Chapter 3

Research Methodology

3.0 INTRODUCTION

The purpose of this chapter is to explain in detail the methodological procedures that will guide the study on Automation in Sustainable Housing: A Double-Edged Approach to Residential Design. Methodology provides the structural framework through which research validity, reliability, transparency, and replicability are achieved (Creswell & Creswell, 2018). This chapter describes the research design, study population, sampling techniques, research instruments, procedures for data collection and analysis, and the ethical considerations that underpin the study. It also outlines the justification for methodological choices based on the research aim, objectives, and research questions. The methodology is designed to support a rigorous academic inquiry that captures perceptions, challenges, opportunities, and contextual realities shaping automation in sustainable housing within the Nigerian built environment.

3.1 RESTATEMENT OF THE RESEARCH PROBLEM

Residential buildings represent a major sector of global energy consumption and environmental degradation, accounting for over 30% of total energy use worldwide (International Energy Agency, 2022). While automation and smart technologies hold the potential to enhance resource efficiency, reduce operational cost, and improve comfort within sustainable housing systems, their relevance within developing regions such as Nigeria remains unclear due to infrastructure limitations, affordability constraints, and limited technological capacity. Existing research tends to examine automation and sustainability independently rather than integrating both perspectives within a single architectural framework. Therefore, there is a need to investigate how automation can support sustainability in residential architecture without intensifying socioeconomic inequality or dependency on unstable infrastructure.

3.2 RESEARCH AIM AND OBJECTIVES

The primary aim of the study is to examine how automation can be integrated into sustainable housing as a complementary rather than conflicting component of residential architectural design in Nigeria and other developing contexts.

The objectives are:

1. To assess the current state of sustainable housing and environmental performance principles in residential design in Nigeria.
2. To evaluate the extent of adoption and application of automation technologies in residential buildings.
3. To identify perceived benefits and challenges associated with automation within sustainable housing.
4. To compare passive design principles and automated systems in relation to cost, energy performance, resilience, and user experience.
5. To examine resident perceptions of smart housing technologies and sustainability priorities.
6. To propose an integrated framework that balances passive strategies and targeted automation to enhance sustainability outcomes.

3.3 RESEARCH QUESTIONS

The research will be directed by the following questions:

1. What is the current state of sustainable housing practice in Nigeria?
2. How is automation currently applied in residential housing within Nigeria and similar developing economies?
3. What challenges restrict automation adoption in residential architecture in developing contexts?
4. What are residents' perceptions of automation in housing and its relationship to comfort, cost, and usability?
5. How do passive design systems compare with automated systems in terms of sustainability performance?

6. How can a hybrid model integrating both strategies be developed to support sustainable housing?

3.4 RESEARCH PHILOSOPHY

The research adopts a pragmatist philosophical paradigm, which supports the use of mixed methods and assumes that knowledge is constructed through real-world experience and problem-centred inquiry (Creswell, 2014; Saunders, Lewis & Thornhill, 2019). Pragmatism is appropriate because sustainability and automation involve multiple perspectives, economic, social, cultural, environmental, and technological, and cannot be understood through a single methodological lens. Rather than prioritising either positivist or interpretivist positions, pragmatism encourages methodological flexibility and the use of the most effective tools for answering research questions.

3.5 RESEARCH APPROACH

The study will adopt a Mixed-Methods Research Design, incorporating both quantitative and slightly qualitative approaches. A mixed-methods structure is appropriate for this study because it allows numerical data to be complemented with experiential, perceptual, and contextual insights relating to residents' awareness, acceptance, and opinions on housing automation within sustainability frameworks.

The quantitative component will involve the distribution of structured questionnaires to selected residents, housing professionals, and facility managers within selected Nigerian urban residential developments. The combination of these methods enhances the breadth and depth of analysis. Descriptive research enables the systematic assessment of conditions as they exist, while exploratory research allows deeper exploration of emerging concepts like automation adoption. Survey design is appropriate because it supports broad data collection from diverse stakeholders within the built environment (Kothari, 2014)

3.6 POPULATION OF THE STUDY

The population of this research refers to the complete group of individuals, professionals, or entities from which relevant information about sustainable housing and automation may be obtained. According to Creswell and Creswell (2018), a research population comprises all individuals who possess the characteristics relevant to a study's objectives.

The population for this research consists of:

- Residents living in both conventional and modern housing developments;
- Built environment professionals (architects, quantity surveyors, builders, and engineers);
- Stakeholders involved in smart home technology deployment and sustainability policy regulation.

The study will target residential estates and emerging smart developments within selected urban centres in Nigeria. The population size is estimated based on available residential records and professional association registries. Because the final population size is large and diverse, sampling will be used to select a manageable and representative subset.

3.7 SAMPLE SIZE AND SAMPLING TECHNIQUE

Sampling refers to the process of selecting a subset of a population to represent the entire population in research (Kothari, 2014). Since the entire population cannot practically be surveyed due to financial, spatial, and time limitations, a purposive sampling technique will be employed to select respondents with direct exposure to housing issues and technologies. (purposive sampling technique will) Purposive sampling is suitable because it ensures that participants possess relevant experience or knowledge about residential housing conditions and automation technologies.

The sample size for the questionnaire will be determined using Cochran's sample size formula, which supports accurate estimation when the population size exceeds 10,000 potential participants. A target sample of approximately 120–150 respondents is considered adequate to achieve statistically reliable results. For interviews, a smaller sample of 8–12 key informants will be selected based on expertise.

The sample frame, therefore, consists of:

- Residents living in contemporary or developing housing estates
- Registered architects and architectural firms
- Student building professionals
- Engineers and building system specialists
- All members of the building industry
- Smart housing and automation technology suppliers

3.8 RESEARCH INSTRUMENTS

The study will make use of questionnaires as the major research instruments:

Questionnaire

A structured questionnaire will be developed and divided into sections addressing:

- Demographic data of respondents
- Awareness and understanding of sustainable housing principles
- Knowledge and perception of residential building automation
- Perceived benefits and drawbacks of automation technology
- Willingness to adopt automated sustainable housing

The questionnaire will contain closed-ended questions

3.9 DATA COLLECTION PROCEDURES

Data collection refers to the systematic process used to gather responses required to answer the research questions and achieve the stated objectives. According to Creswell and Creswell (2018), data collection must be structured, transparent, and logically sequenced to enhance research credibility and replicability. For this study, data will be collected using digital questionnaire distribution via Google Forms.

The Google Forms survey link will be distributed electronically through email, WhatsApp, Telegram groups for residents, professional networks. Digital distribution allows a wider reach across Lagos, Abuja, and Benin City without geographical limitations and offers improved organisation of responses through automated data capture. A cover letter explaining the study purpose, ethical rights, and voluntary participation will accompany each survey instrument. Respondents will be given two to three weeks to complete the survey, with reminders issued weekly to improve response turnout.

3.10 METHOD OF DATA ANALYSIS

Data analysis involves systematically organising, interpreting, and examining collected data to identify patterns, relationships, and insights relevant to the research objectives. Analysis methods depend on the type of data collected and support meaningful interpretation of results (Creswell & Plano Clark, 2018).

For this study, quantitative data from questionnaires will be analysed using descriptive and inferential statistics. Descriptive statistics such as frequencies, mean rankings, and percentages will summarise demographic information and perception trends. Inferential statistical tools such as correlation analysis and cross-tabulations may be used to explore relationships between variables such as automation adoption and affordability or user perception and comfort.

Data will be analysed using SPSS (Statistical Package for the Social Sciences) or PSPP, which is a free alternative for statistical computation. These tools enable accurate data processing, graphical representation through charts and tables, and reliable interpretation of results.

3.11 VALIDITY AND RELIABILITY OF RESEARCH INSTRUMENTS

Validity will be ensured by subjecting the instruments to expert review by academic supervisors and experienced researchers in architecture and sustainability.

3.12 Ethical Considerations

Ethical considerations ensure that research respects human rights, protects respondent privacy, and maintains academic integrity. According to the American Psychological Association (2020) and Creswell (2014), ethical compliance must govern consent procedures, data handling, and reporting transparency.

Key ethical procedures include:

- **Informed Consent:** Participants will be provided with detailed information about the study purpose, procedures, benefits, and rights before participation.
- **Voluntary Participation:** Respondents may withdraw at any time without penalty.
- **Confidentiality and Anonymity:** Personal identifiers will not be disclosed. Data will be reported collectively.
- **Data Security:** Digital data will be stored in password-protected drives accessible only to the researcher.
- **Non-maleficence:** The study poses no physical, psychological, or reputational harm to participants.
- **Academic honesty:** Only authentic sources will be cited, and no fabrications or manipulations will occur.

Ethical conduct is fundamental to this research. Participation will be voluntary, and respondents will be informed about the purpose and scope of the study prior to participation. Confidentiality and anonymity will be guaranteed by excluding personal identifiers. Data collected will be used exclusively for academic purposes, and consent will be obtained from participants and institutional authorities where necessary.

3.13 Methodological Limitations

Every methodological approach has inherent limitations that may affect generalizability or execution. Expected limitations include:

- Limited sample access due to digital distribution reliance
- Variations in internet access that may hinder participation
- Possible non-response bias from participants unfamiliar with automation

- Limited availability of professionals for interviews due to scheduling constraints
- Study scope limited to three Nigerian cities, which may not fully represent the national context

These limitations will be managed through broad distribution channels, reminder follow-ups, and inclusion of multiple respondent groups to enhance representativeness.

3.14 Research Methodology Workflow Model

The research workflow will follow a structured sequence:

1. Identification of research problem and purpose
2. Review of relevant literature
3. Development of survey and interview instruments
4. Data collection using Google Forms and interviews
5. Integration and interpretation of findings
6. Reporting results and drawing conclusions

This sequence ensures procedural clarity and supports study replicability.

3.15 SUMMARY

This chapter has presented the research methodology designed to investigate the integration of automation into sustainable housing within Nigeria. It has outlined the research philosophy, mixed-method approach, descriptive survey design, population and sampling framework, data collection instruments, and procedures for statistical and thematic analysis. Ethical provisions and expected methodological limitations have also been discussed. The methodology provides a rigorous foundation for generating reliable, valid, and contextually relevant findings that support the research objectives and the advancement of sustainable architectural practice.

Chapter 4

DATA PRESENTATION, ANALYSIS AND FINDINGS

4.0 Introduction

This chapter presents the analysis and presentation of data obtained from the questionnaire survey administered for this study titled “Automation in Sustainable Housing: A Double-Edged Approach to Residential Design.” The analysis focuses on respondents’ awareness, perception, and experiences regarding the integration of automation in sustainable residential housing, particularly within the Nigerian context. The findings are organised in line with the research objectives and research questions outlined in Chapter One. Data is presented using descriptive statistical tools such as frequencies, percentages, tables, and charts to ensure clarity and ease of understanding.

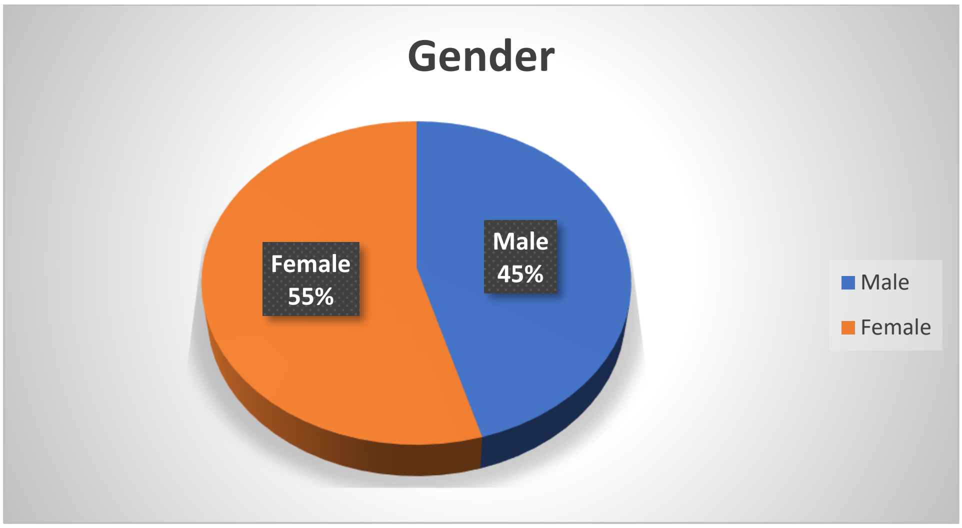
4.1 Socio-Demographic Characteristics of Respondents

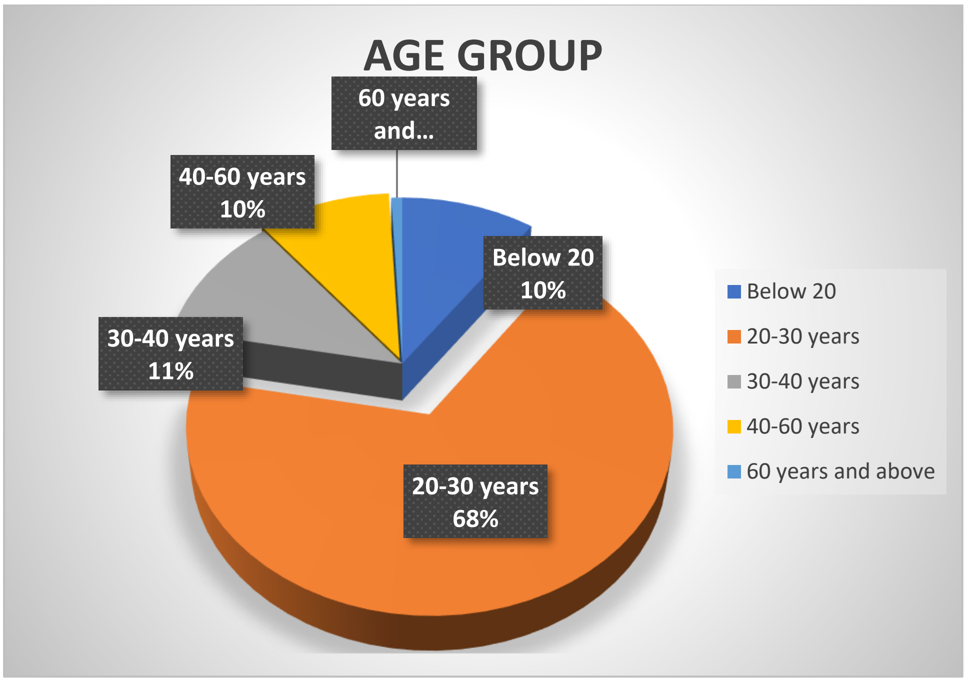
This section provides an overview of the background information of respondents, which is essential for understanding the context of the responses obtained.

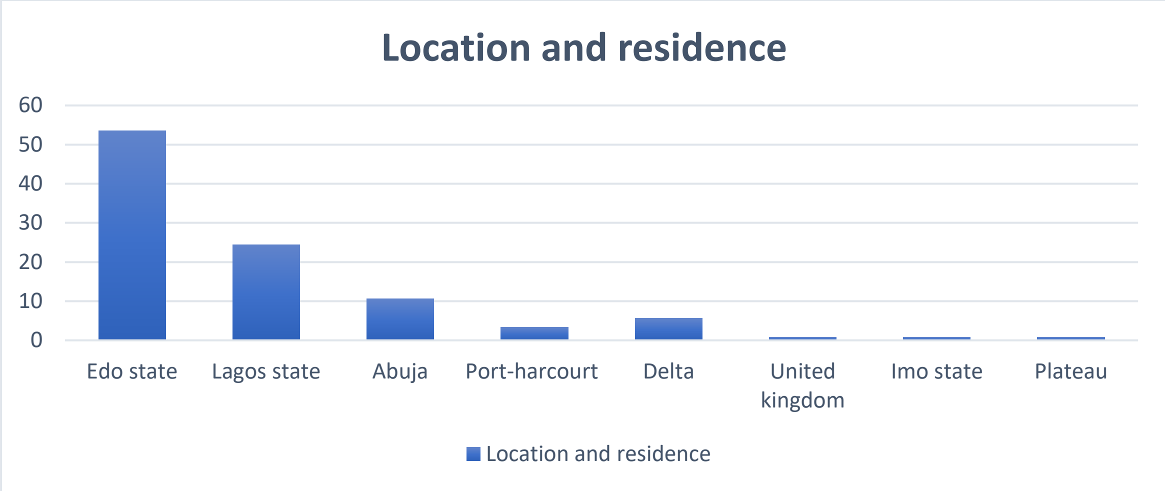
Variables examined include:

- Gender
- Age group
- Occupation
- Educational background
- Home ownership status

These characteristics help establish the diversity of the respondents and ensure that the data reflects varying social and economic perspectives relevant to residential housing design.




AGE GROUP
60 years and...
40-60 years 10%
Below 20 10%
30-40 years 11%
20-30 years 68%
Below 20
20-30 years
30-40 years
40-60 years
60 years and above


Location and residence
60
50
40
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Edo state
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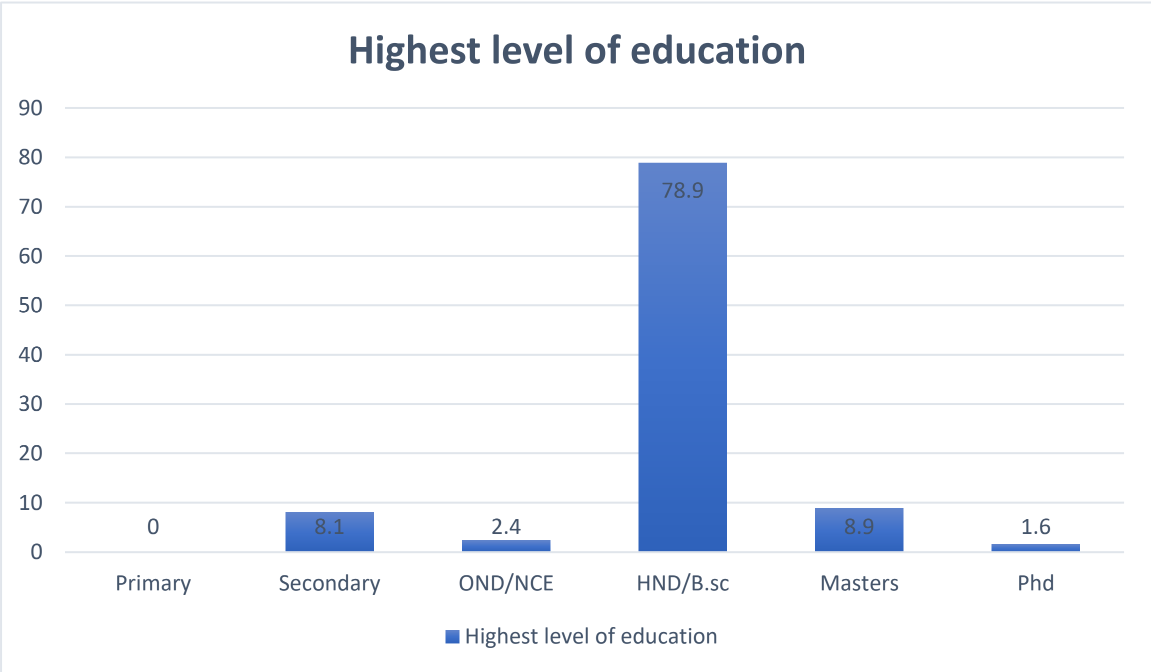
Abuja
Port-harcourt
Delta
United kingdom
Imo state
Plateau
Location and residence


Highest level of education
90
80
70
60
50
40
30
20
10
0
0
8.1
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78.9
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1.6
Primary
Secondary
OND/NCE
HND/B.sc
Masters
Phd
Highest level of education

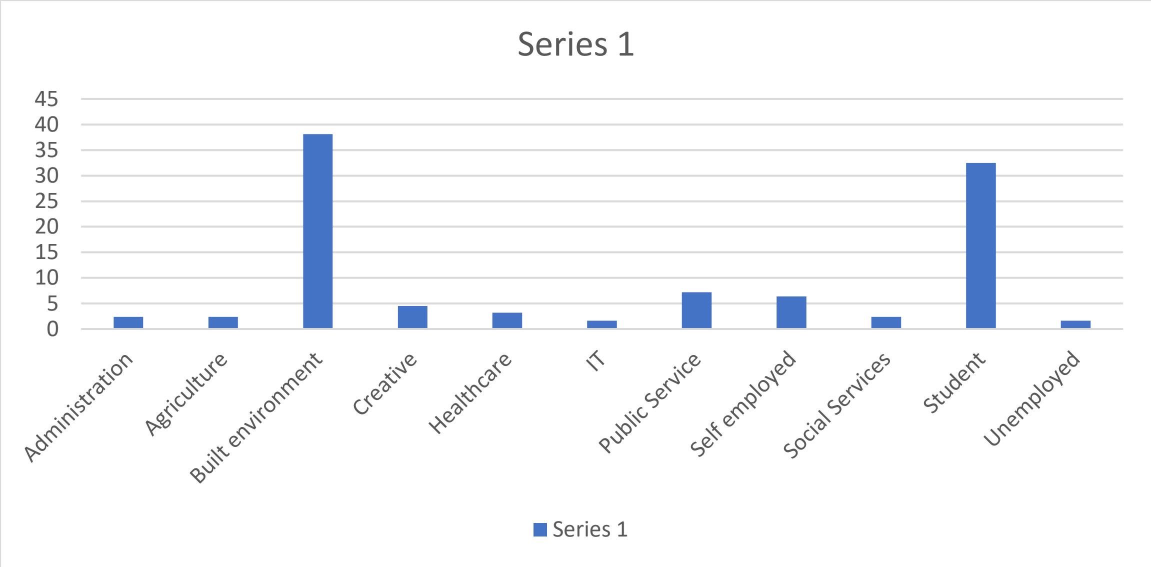


Table 4.1 presents the distribution of respondents based on selected demographic variables.

Interpretation:

The demographic distribution indicates that respondents were drawn from varied residential and professional backgrounds, providing a balanced perspective on housing experiences and technological exposure.

4.2 Awareness of Automation in Residential Housing

This section examines the level of awareness among respondents regarding automation and smart technologies in residential buildings.

Respondents were asked whether they were familiar with concepts such as:

- Smart lighting systems
- Automated security systems
- Smart energy management systems
- Automated climate control

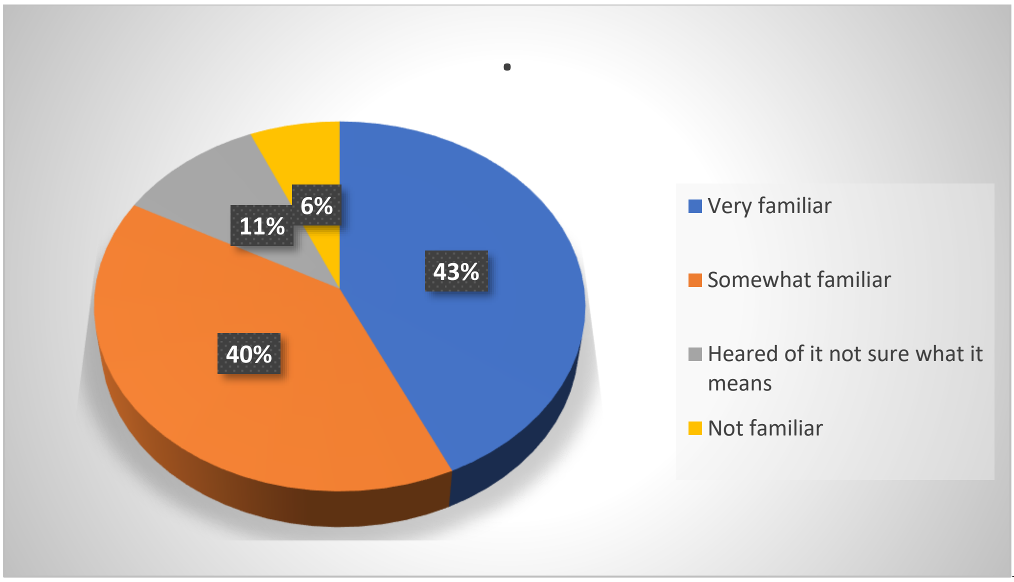


Fig 4.2 illustrates respondents' awareness levels.

Findings:

The responses indicate that a significant proportion of participants are aware of at least one form of residential automation. Awareness appears to be higher for security and lighting systems, while more advanced automation technologies show comparatively lower familiarity.

4.3 Application of Automation in Residential Housing

This section analyses the extent to which automation has been applied in respondents' residences.

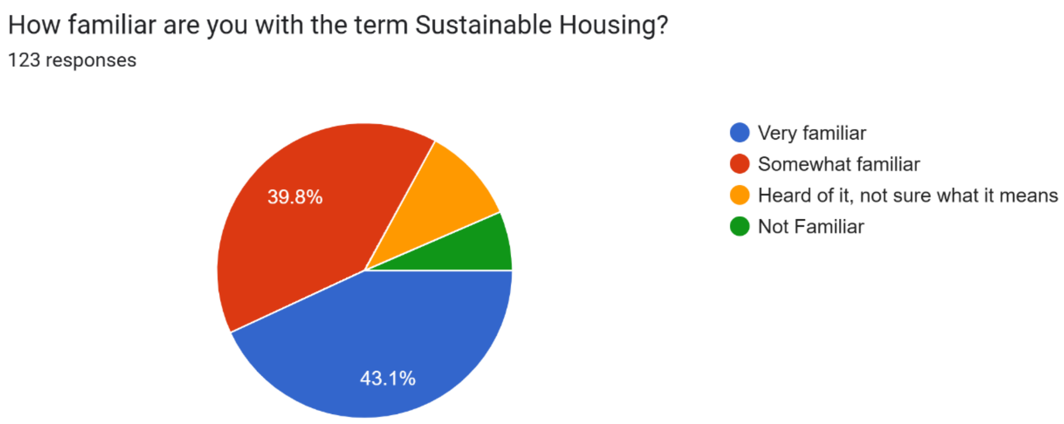
Respondents indicated whether they currently use or have access to:

- Automated lighting
- Security and surveillance systems
- Smart meters or energy-monitoring devices
- Automated shading or ventilation systems

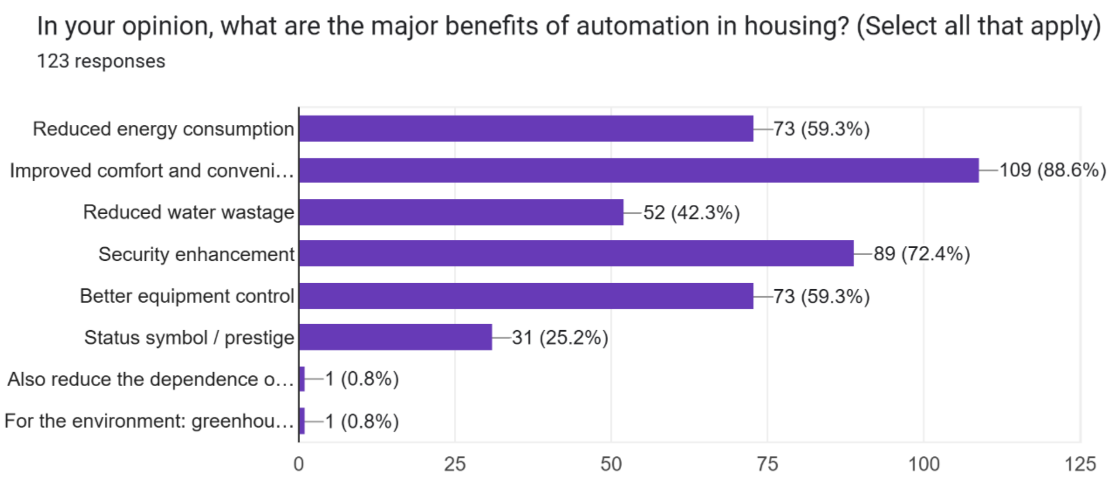
Table 4.3 summarises the level of application of automated systems.

Findings:

The data suggests that while some automated features have been adopted, full integration of



automation in residential housing remains limited. Adoption is largely concentrated on systems perceived as improving safety and convenience rather than energy performance or sustainability.



4.4 Perceived Benefits of Automation in Sustainable Housing

This section evaluates respondents' perceptions of the advantages associated with automation in residential design.

Key benefit indicators assessed include:

- Improvement in indoor comfort
- Energy efficiency

- Enhanced security
- Convenience and ease of control
- Contribution to sustainable living

Responses were measured using a Likert scale ranging from *Strongly Agree* to *Strongly Disagree*.

Findings:
Most respondents expressed positive perceptions of automation in relation to comfort and security. However, opinions were more moderate regarding its contribution to long-term sustainability, suggesting a gap between perceived comfort benefits and environmental awareness.

4.5 Challenges in the Adoption of Automation

This section presents findings on the barriers limiting the adoption of automation in sustainable housing.

Identified challenges include:

- High initial installation cost
- Unreliable power supply
- Maintenance and technical expertise requirements
- Fear of system failure
- Limited awareness and training

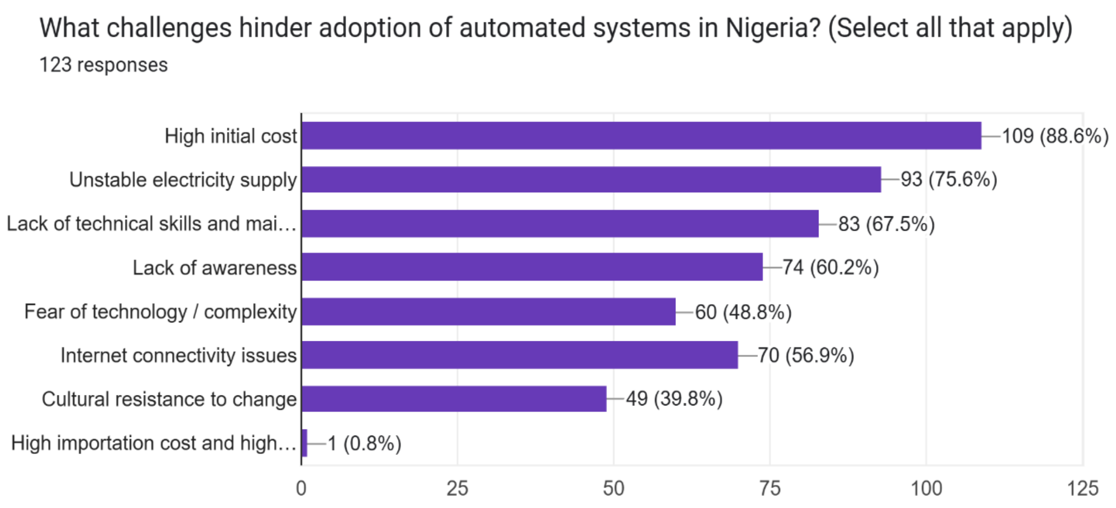


Table 4.5 ranks challenges based on frequency of response.

Findings:

High initial cost and unreliable power supply emerged as the most significant barriers. These challenges reflect broader infrastructural and economic constraints common in developing economies.

4.6 Comparison Between Passive Design Strategies and Automated Systems

This section compares respondents' perceptions of passive design strategies and automated systems in achieving sustainable housing.

Criteria considered include:

- Cost effectiveness
- Energy efficiency
- Reliability
- Ease of maintenance
- Suitability for local conditions

Findings:

Passive design strategies were generally perceived as more affordable and reliable, especially in areas with unstable infrastructure. Automated systems, on the other hand, were valued for comfort optimization and convenience but were seen as less accessible. The findings suggest a preference for a hybrid approach combining both strategies.

4.7 Summary of Key Findings

The major findings of this chapter can be summarized as follows:

- Awareness of residential automation exists, but application remains limited.
- Automation is primarily adopted for security and convenience.
- Cost and infrastructure challenges significantly affect adoption.
- Passive design strategies are perceived as more suitable for the local context.
- A combined approach integrating passive and automated strategies is viewed as the most sustainable option.

Chapter Summary

This chapter has presented and analysed the data obtained from the field survey, highlighting respondents' perceptions, experiences, and challenges related to automation in sustainable housing. The findings provide a factual basis for the discussion in the next chapter, where these results will be interpreted and compared with existing literature

CHAPTER FIVE

DISCUSSION OF FINDINGS

5.0 Introduction

This chapter discusses the findings presented in Chapter Four in relation to the objectives and research questions of the study titled *Automation in Sustainable Housing: A Double-Edged Approach to Residential Design*. The discussion interprets the results within the context of sustainable residential design, existing literature, and the realities of housing development in Nigeria and similar developing economies. Emphasis is placed on understanding not only the benefits of automation but also its limitations, thereby reinforcing the "double-edged" nature of automated systems in sustainable housing.

5.1 Discussion on Awareness of Automation in Residential Housing

The findings indicate that awareness of automation in residential housing exists among respondents, particularly in relation to security systems and basic lighting controls. This suggests that automation is not an entirely unfamiliar concept within the study area. However, awareness appears to be uneven, with more advanced systems related to energy management and environmental control receiving less recognition. This pattern reflects the tendency for residential automation in developing contexts to be driven primarily by immediate functional needs such as safety rather than long-term sustainability goals.

From an architectural perspective, this uneven awareness highlights a gap between technological availability and informed design integration. While automation technologies are increasingly present in the market, their sustainable application in residential design remains poorly understood by users. This supports the argument that awareness alone does not guarantee effective adoption, especially when automation is not embedded within a broader sustainability framework.

5.2 Discussion on the Application of Automation in Residential Buildings

The limited application of automated systems observed in the findings suggests that the adoption of automation in residential housing is still at an early stage. Where automation exists, it is largely confined to standalone systems rather than fully integrated building solutions. This reflects a fragmented approach to residential automation, where technologies are added incrementally rather than planned as part of the architectural design process.

This outcome underscores the importance of design-led integration of automation. When automation is treated as an afterthought, its potential contribution to energy efficiency and environmental performance is significantly reduced. The findings suggest that the role of the architect is critical in ensuring that automation complements building form, orientation, and passive strategies rather than operating in isolation.

5.3 Discussion on Perceived Benefits of Automation in Sustainable Housing

Respondents generally associated automation with improved comfort, convenience, and security. These perceived benefits align with global literature that identifies user comfort and operational efficiency as key drivers of smart housing adoption. However, the relatively moderate perception of automation's contribution to sustainability indicates that respondents may not fully associate automation with environmental performance.

This finding suggests a disconnect between user experience and sustainability outcomes. While automation can optimise energy use, its environmental benefits are not always visible to occupants. As a result, automation is often valued for lifestyle enhancement rather than ecological responsibility. For sustainable housing to be effective, automation must be designed and communicated as a tool for environmental stewardship rather than solely as a convenience feature.

5.4 Discussion on Challenges Affecting the Adoption of Automation

The challenges identified, particularly high installation costs and unreliable power supply, are consistent with broader infrastructural and economic constraints in Nigeria. These factors significantly limit the feasibility of automation in low and middle-income housing developments. The reliance of automated systems on stable electricity and technical maintenance further compounds these challenges.

From a sustainability standpoint, these findings raise important questions about resilience and equity. A system that fails during power outages or requires specialised maintenance may undermine the very principles of sustainability it seeks to promote. This reinforces the argument that automation, while beneficial, can become counterproductive if applied without consideration of local conditions.

5.5 Discussion on Passive Design Versus Automated Systems

The comparative findings highlight a strong favouring of passive design strategies because of their cost-effectiveness, dependability, and suitability with local climatic conditions. Passive design was seen as more resilient, especially in areas with unreliable infrastructure. Automated systems, although valued for accuracy and flexibility, were considered less accessible to a wider segment of the population.

This contrast highlights the complementary roles of passive and automated approaches. Passive design establishes a stable foundation for sustainability, while automation enhances performance where conditions permit. The findings, therefore, support the notion that automation should not replace passive strategies but rather build upon them in a carefully balanced manner.

5.6 Implications for Residential Design Practice

The findings have significant implications for architectural practice. They suggest that sustainable housing in developing contexts should prioritise passive design principles while selectively incorporating automation based on affordability, infrastructure, and user capacity. Architects must adopt a context-responsive approach, recognising that the success of automation depends not only on technology but also on social, economic, and environmental factors.

The study reinforces the need for architects to act as mediators between technology and human needs, ensuring that automation enhances rather than complicates residential living. Design decisions must therefore be guided by long-term sustainability, resilience, and inclusivity.

5.7 Chapter Summary

This chapter has discussed the findings of the study, highlighting the complex role of automation in sustainable housing. While automation offers significant benefits in terms of comfort and efficiency, its limitations, particularly in developing economies, cannot be overlooked. The discussion confirms that automation functions as a double-edged tool in residential design, capable of enhancing sustainability when applied appropriately, but potentially undermining it when introduced without adequate contextual consideration. These insights provide a foundation for the conclusions and recommendations presented in the next chapter.

CHAPTER 6

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.0 Introduction

This chapter presents the final stage of the study titled *Automation in Sustainable Housing: A Double-Edged Approach to Residential Design*. It summarizes the major findings of the research, outlines the conclusions drawn from the study, and provides recommendations for architectural practice, housing development, and policy considerations. The chapter also highlights possible directions for further research on the integration of automation in sustainable residential design.

6.1 Summary of the Study

The study examined the role of automation in sustainable housing and evaluated its potential benefits and limitations within the context of residential design in Nigeria. The research was motivated by the increasing global interest in smart technologies and automated systems in buildings, alongside the growing need for environmentally responsible housing solutions.

Sustainable housing emphasizes the efficient use of resources, environmental responsibility, and improved living conditions for occupants. Automation, on the other hand, introduces technological systems capable of regulating building functions such as lighting, security, ventilation, and energy consumption. While these systems can enhance building performance and user comfort, their application within developing economies presents both opportunities and challenges.

To investigate this relationship, the study explored several key issues, including the level of awareness of automation in residential housing, the extent of its adoption, the perceived benefits of automated systems, and the challenges associated with their implementation. The research also examined the relationship between automated technologies and traditional passive design strategies commonly used in sustainable architecture.

A questionnaire survey was employed to collect primary data from respondents, including residents and individuals familiar with housing conditions within the study area. The responses were analysed using descriptive statistical methods such as frequency distributions, percentages, and comparative evaluation. The findings provided insight into how automation is currently perceived and applied in residential environments.

The results indicated that although awareness of automation technologies exists, their practical application in residential buildings remains limited. Automated systems are more commonly associated with security and convenience rather than sustainability or environmental performance. Additionally, several barriers were identified, including high installation costs, unreliable power supply, limited technical expertise, and concerns regarding maintenance.

Despite these challenges, respondents acknowledged the potential of automation to improve comfort, energy efficiency, and overall building performance when properly integrated into residential design. The findings also revealed that passive design strategies are widely regarded as more accessible and reliable within the local context. Consequently, the study suggests that sustainable housing solutions should combine passive design principles with carefully selected automation technologies.

6.2 Conclusions

Based on the analysis and discussion of findings, several conclusions can be drawn from this study.

First, automation in residential housing remains an emerging concept within the Nigerian housing sector. Although awareness of smart technologies is gradually increasing, widespread adoption has yet to occur due to infrastructural, economic, and technical limitations.

Second, the perceived benefits of automation are largely centred on comfort, convenience, and security. While these features contribute positively to residential living, the environmental and sustainability benefits of automation are not always fully recognized by users. This indicates the need for greater awareness regarding the role of automated systems in energy management and environmental performance.

Third, the study confirms that automation can function as both a solution and a challenge within sustainable housing development. When properly implemented, automation can optimize building performance and reduce resource consumption. However, when applied without consideration for local conditions such as unstable electricity supply and maintenance capacity, automated systems may introduce new vulnerabilities.

Fourth, passive design strategies continue to play a fundamental role in sustainable residential architecture, particularly in regions with limited infrastructure. Passive solutions such as natural ventilation, building orientation, shading devices, and thermal mass remain reliable and cost-effective approaches for improving indoor environmental quality.

Finally, the findings suggest that the most effective approach to sustainable housing lies in a balanced integration of passive design principles and appropriate automation technologies. Rather than replacing traditional architectural strategies, automation should complement them by enhancing building performance where feasible.

6.3 Recommendations

Based on the conclusions drawn from this study, the following recommendations are proposed for architects, housing developers, policymakers, and researchers.

1. Integration of Passive and Automated Design Strategies

Architects should prioritize passive design strategies as the foundation of sustainable housing while incorporating automation selectively to enhance building performance. This hybrid approach ensures that buildings remain functional and comfortable even in the absence of technological systems.

2. Context-Sensitive Application of Automation

Automation technologies should be adapted to local conditions rather than imported without modification. Design decisions should consider factors such as energy infrastructure, affordability, climate conditions, and user familiarity with technology.

3. Improved Awareness and Education

There is a need for greater public awareness regarding the potential role of automation in sustainable housing. Educational initiatives, professional training, and architectural workshops can help promote a better understanding of smart building technologies and their environmental benefits.

4. Development of Affordable Automation Technologies

Manufacturers and developers should focus on producing cost-effective automation solutions that are accessible to a wider segment of the population. Affordable technologies will make it easier to integrate automation into mainstream residential development.

5. Policy Support and Regulatory Framework

Government agencies should establish policies that encourage sustainable housing practices, including incentives for energy-efficient technologies and smart building systems. Regulatory frameworks can also guide the responsible implementation of automation in residential developments.

6. Strengthening Local Technical Capacity

Training programs should be developed to equip professionals and technicians with the skills required to install, operate, and maintain automated building systems. This will help reduce dependency on external expertise and improve the reliability of such systems.

6.4 Suggestions for Further Studies

Although this research has contributed to the understanding of automation in sustainable housing, several areas remain open for further investigation.

Future studies may focus on:

1. The long-term environmental performance of automated residential buildings in tropical climates.
2. Comparative studies between fully automated housing developments and passive design-based housing estates.
3. The economic feasibility of automation technologies in low-income housing.
4. The role of renewable energy systems in supporting automated residential environments.
5. The integration of artificial intelligence and adaptive building systems in sustainable architecture.

Further research in these areas will help deepen knowledge on the role of automation in shaping the future of residential design, particularly in developing economies.

6.5 Concluding Remark

Sustainable housing remains one of the most pressing challenges in contemporary architectural practice. While automation offers new possibilities for improving building performance and occupant comfort, its successful integration requires careful consideration of social, economic, and environmental factors. The findings of this study demonstrate that automation should not be viewed as a replacement for traditional architectural strategies but rather as a complementary tool that can enhance sustainable residential design when applied responsibly and thoughtfully.

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APPENDICES

APPENDIX A

Questionnaire

Title:

Automation in Sustainable Housing: A Double-Edged Approach to Residential Design

Dear Respondent,

You are invited to participate in a research study examining the role of automation in sustainable residential housing. The purpose of this questionnaire is to gather information about the awareness, perception, and adoption of automated technologies in residential buildings, as well as the benefits and challenges associated with their use.

Your responses will contribute to a better understanding of how automation can influence sustainability, comfort, and efficiency in housing design. All information provided will be treated with strict confidentiality and will be used solely for academic purposes.

Thank you for your participation.

Section A: Background Information

1. Gender
   □ Male
   □ Female
2. Age
   □ Below 20
   □ 20-30
   □ 30-40
   □ 40-60
   □ 60 and above
3. Occupation
   □ Student

□ Civil servant

□ Professional

□ Self-employed

□ Others

4. Type of residence

□ Detached house

□ Semi-detached house

□ Apartment

□ Other

Section B: Awareness of Automation

5. Are you familiar with automated systems in residential buildings?

□ Yes

□ No

6. Which automated systems are you aware of?

□ Smart lighting

□ Automated security systems

□ Smart energy meters

□ Automated ventilation systems

Section C: Application of Automation

7. Do you currently use any automated system in your home?

□ Yes

□ No

8. If yes, which of the following systems do you use?

□ Security systems

□ Smart lighting

□ Climate control systems

□ Energy management systems

Section D: Perceived Benefits

Indicate your level of agreement with the following statements:

Statement	SA	A	N	D	SD
Automation improves comfort in residential buildings	□	□	□	□	□
Automation enhances energy efficiency	□	□	□	□	□
Automation improves security in homes	□	□	□	□	□

Section E: Challenges of Automation

What challenges limit the adoption of automation in residential buildings?

□ High installation cost

□ Unstable electricity supply

□ Lack of technical expertise

□ Maintenance difficulties