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CLASSIFICATION OF GREEN BUILDING TECHNIQUES APPLICABLE TO THE FEDERAL CAPITAL CITY, ABUJA NIGERIA

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Abstract

This study applied a Descriptive-Survey Research Design with a mixed-method approach to assess the socio-economic and environmental impacts of green building techniques in Abuja, Nigeria. Data were gathered from primary and secondary sources, including structured surveys, semi-structured interviews, field observations, and literature reviews. A multi-stage sampling method identified key stakeholders such as developers, architects, government officials, and property owners, using the Krejcie and Morgan sample size [redacted] determination table for statistical accuracy. Quantitative data centered on financial metrics, cost analysis, and stakeholders' perceptions, while qualitative data provided insights through interviews and direct observations. Data analysis incorporated statistical methods, AMOS (Structural Equation Modeling), comparative analysis, and content analysis to evaluate sustainability indicators, economic

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viability, and policy frameworks. The study classified green building techniques in Abuja, focusing on five categories: Energy-Saving and Energy Utilization (ESEU), Water-Saving and Water Utilization (WSWU), Material-Saving and Material Utilization (MSMU), Indoor Environmental Quality (IEQ), and Site Planning and Land Surveying (SPLS). The findings highlighted the varying performance of 19 techniques in the ESEU category, with Off-Grid Systems (OSG) achieving an average performance of 37.8% and Traditional Grid Systems (TTSG) achieving higher performance levels in most techniques. In the WSWU category, several techniques like WSWU-2, WSWU-3, and WSWU-4 exhibited high performance, with a 100% adoption in TTSG. In the MSMU category, techniques like MSMU-9 and MSMU-10 achieved near-perfect performance in both OSG and TTSG, while others, such as MSMU-13, showed limited adoption. The IEQ category displayed a continuous variation in performance, with significant improvements in TTSG for techniques like IEQ-7 and IEQ-14, which recorded increases of 23.0% and 19.3%, respectively. Finally, in the SPLS category, the performance of techniques such as SPLS-17 and SPLS-26 was exemplary, with full implementation observed. The statistical analysis, including comparisons between OSG and TTSG systems, demonstrated that green building practices could significantly enhance energy efficiency, water conservation, and material utilization. However, challenges such as the limited adoption of renewable materials, inconsistent implementation of water-saving technologies, and inadequate policy frameworks were identified. The findings underline the need for policy improvements, capacity building, and greater public awareness to accelerate the widespread adoption of green building techniques in Abuja. The study's statistical findings were supported by a Cronbach's alpha of 0.943, indicating high reliability in the research instruments.

Introduction

The rapid urbanization of Abuja, the Federal Capital City of Nigeria, presents significant environmental and infrastructural challenges. As the city expands to accommodate increasing population and economic activities, the need for sustainable development becomes more urgent. Green building techniques have emerged as a critical approach to addressing these challenges, ensuring that the built environment is both resource-efficient and environmentally responsible (Olaniyan & Ogbu, 2022). These techniques encompass a wide range of strategies, including sustainable site planning, energy efficiency, water conservation, and the use of eco-friendly materials. Given Abuja's unique climatic and socio-economic conditions, classifying and implementing appropriate green building techniques is essential for promoting sustainability and resilience in urban development (Akinyemi et al., 2023).

One fundamental classification of green building techniques focuses on sustainable site development. This involves optimizing land use, reducing urban sprawl, and preserving natural ecosystems. In Abuja, regulatory agencies such as the Federal Capital Development Authority (FCDA) have introduced policies to encourage developers to incorporate sustainable landscaping, green roofs, and permeable paving to manage stormwater and enhance biodiversity (Green Building Council Nigeria, 2023). These site development strategies contribute to reducing the environmental footprint of buildings while improving urban livability.

Energy efficiency is another crucial category within green building techniques, particularly in the context of Abuja's growing energy demand. Techniques such as passive solar design, high-performance building envelopes, and the integration of renewable energy sources, such as solar photovoltaic systems, are increasingly being promoted (Eneh, 2023). The Nigerian Energy Efficiency Building Code (EEBC) has established guidelines to enhance energy performance in new and existing buildings, emphasizing measures such as efficient lighting, heating, ventilation, and cooling systems (Federal Ministry of Power, 2023). These strategies help reduce energy consumption and reliance on fossil fuels, which is critical for mitigating climate change and reducing operating costs for building owners.

Water conservation and management techniques also play a vital role in green building classification. Strategies such as rainwater harvesting, greywater recycling, and the use of water-efficient fixtures are particularly relevant in Abuja, where rapid urbanization has placed pressure on existing water resources (Ajayi & Okonkwo, 2023). The integration of sustainable water management practices in building design not only reduces demand on municipal water supply but also enhances resilience against water scarcity and climate variability. Additionally, policy frameworks are being developed to enforce water efficiency standards and promote responsible water use in the built environment.

The final classification of green building techniques focuses on the selection of sustainable materials. The use of locally sourced, recycled, and low-impact materials is gaining traction in Nigeria's construction industry. Materials such as compressed earth blocks, bamboo, recycled steel, and low-VOC (volatile organic compound) paints are being increasingly adopted for their environmental and health benefits (Adebayo & Yusuf, 2024). These materials reduce carbon emissions associated with transportation and manufacturing, while also enhancing indoor air quality and overall building performance. The Nigerian Green Building Rating System provides guidelines for material selection, ensuring that projects adhere to sustainability standards (Green Building Council Nigeria, 2024).

MATERIALS AND METHODS

Abuja is the planned capital city of Nigeria which was created in February 1976. Its creation was as a result of the intolerable living and working conditions, environment pollution, overcrowding, growing squalor, in adequate infrastructure and limitation of space in Lagos. Mabogunje, (1994). Abuja which has a population of over 1 million is located in the center of the country, Abuja FCT is the capital city of Nigeria and located in between latitude 8° 50′ 0″ N, and longitude 8° 7° 10′ 0″ E. It covers a total of 7,315 square kilometers, and lies in the middle part of the country, The Abuja FCT area features an interesting terrain, which combines rounded hills and clusters of rock outcrops dissected by river valleys, as well as gentle rolling plains, it falls

within the Abuja hills and dissected zones, The territory is located just north of the confluence of the Niger River and Benue River. It is bordered by t
he states of Niger to the West and North, Kaduna to the northeast, Nasarawa to the east and south and Kogi to the southwest.. Generally viewing the study area, the hilly areas are found towards the eastern part, posing constraint to physical development while the plains occupy the central and western areas.

The study area which is the Federal Capital City (FCC) is located in the Gwagwa Plains, in the north-eastern "panhandle" of the Federal Capital Territory (FCT). The FCC lies within latitude 9 0 15'N and 8 0 56'N of the equator and longitude 7 0 09'E and 7 0 34'E. It occupies about 535sq km that constitute about seven percent (7%) of the total 8,000 km2 land area of the FCT.

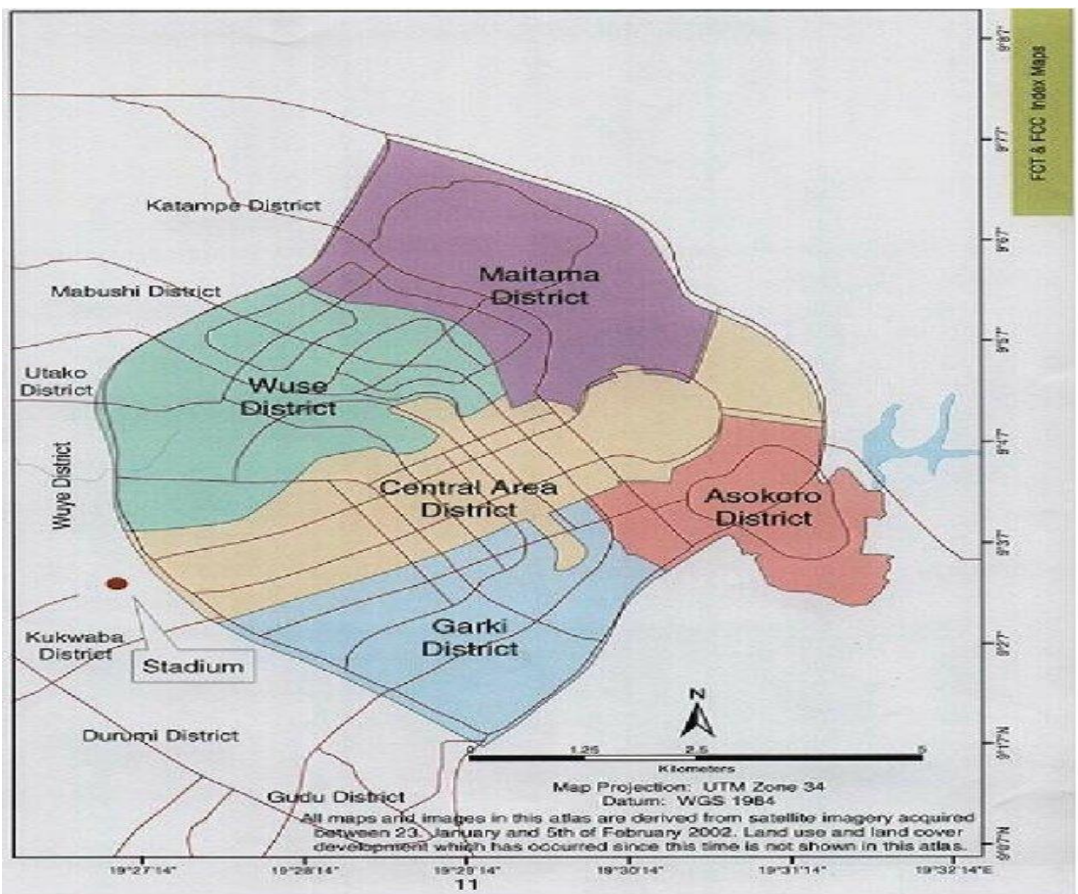

Figure 1: Map of the Federal Capital City **Source: Fanan, 2010.**

The study employed a **Descriptive-Survey Research Design** with a mixed-method approach, incorporating both **quantitative and qualitative** data collection techniques to gain a comprehensive understanding of the socio-economic and environmental impacts of green building techniques in **Abuja, Nigeria**. Data was gathered from both **primary and secondary sources,** including structured surveys, semi-structured interviews, field observations, and literature reviews. The **sampling technique** followed a multi-stage approach, selecting **key stakeholders** such as developers, architects, government officials, and property owners, with the **Krejcie and Morgan sample size determination table** used to ensure statistical validity. **Quantitative data** focused on financial metrics, cost analyses, and stakeholders' perceptions of green buildings, while **qualitative data** provided insights through interviews and direct observations of construction practices. The **data analysis** incorporated **statistical techniques, AMOS (Structural Equation Modeling), comparative analysis, and content analysis** to evaluate key sustainability indicators, economic viability, and policy frameworks. This mixed-method approach allowed for a **holistic assessment** of green building adoption in Abuja, addressing both the **opportunities and challenges** associated with sustainable construction practices.

RESULTS

Classification of Green Building Techniques applicable to the Federal Capital City

Without doubt, green building has contributed to the environmental sustainability, reduced operational cost and create a healthier atmosphere all around the globe and the Federal Capital City. Under this segment, the study categories and classified the green building techniques that are inherent in the FCC.

Energy-Saving and Energy Utilization (ESEU) Green Building Techniques

The increasing energy consumption in buildings is one of the most significant drivers for enhancing building energy efficiency, which in turn promotes the implementation of green building (GB) practices. Recent studies highlight that buildings account for a substantial portion of global energy use, with energy consumption in this sector projected to rise. For instance, a study by Zhang et al. (2023) indicates that energy consumption in commercial buildings is expected to increase by 20% over the next decade due to urbanization and changing climate patterns.

In response to these challenges, the Energy Savings in Existing Units (ESEU) regulation has been introduced to address energy efficiency requirements during the operational phase of buildings. The ESEU framework focuses on improving equipment operating efficiency, reducing energy waste, and integrating renewable and sustainable energy sources. It evaluates these aspects from four key perspectives: building structure and envelope, heating, ventilation, and air conditioning (HVAC) systems, lighting and electronic equipment, and the utilization of renewable energy. Recent research by Li et al. (2024) emphasizes the importance of a holistic approach to building design, which incorporates energy-efficient technologies across all four perspectives to maximize overall energy savings.

Furthermore, Figure 2 illustrates the performance of 19 techniques within the ESEU framework, categorizing them into two segments: the bottom part represents Off-Grid Systems (OSG), while the upper section pertains to Traditional Grid Systems (TTSG). This classification allows for a comparative analysis of energy efficiency strategies. Research conducted by Kumar and Prakash (2023) demonstrates that integrating OSG technologies, such as solar photovoltaic systems and battery storage, can significantly enhance energy independence and efficiency, particularly in residential buildings.

The integration of renewable energy sources into building operations is not only crucial for reducing reliance on fossil fuels but also for meeting regulatory standards and achieving sustainability goals. A comprehensive study by Martin et al. (2022) explores various renewable technologies, including solar, wind, and geothermal systems, and their impact on building energy consumption. This research underscores the necessity for policies like the ESEU to encourage the adoption of such technologies in building designs.

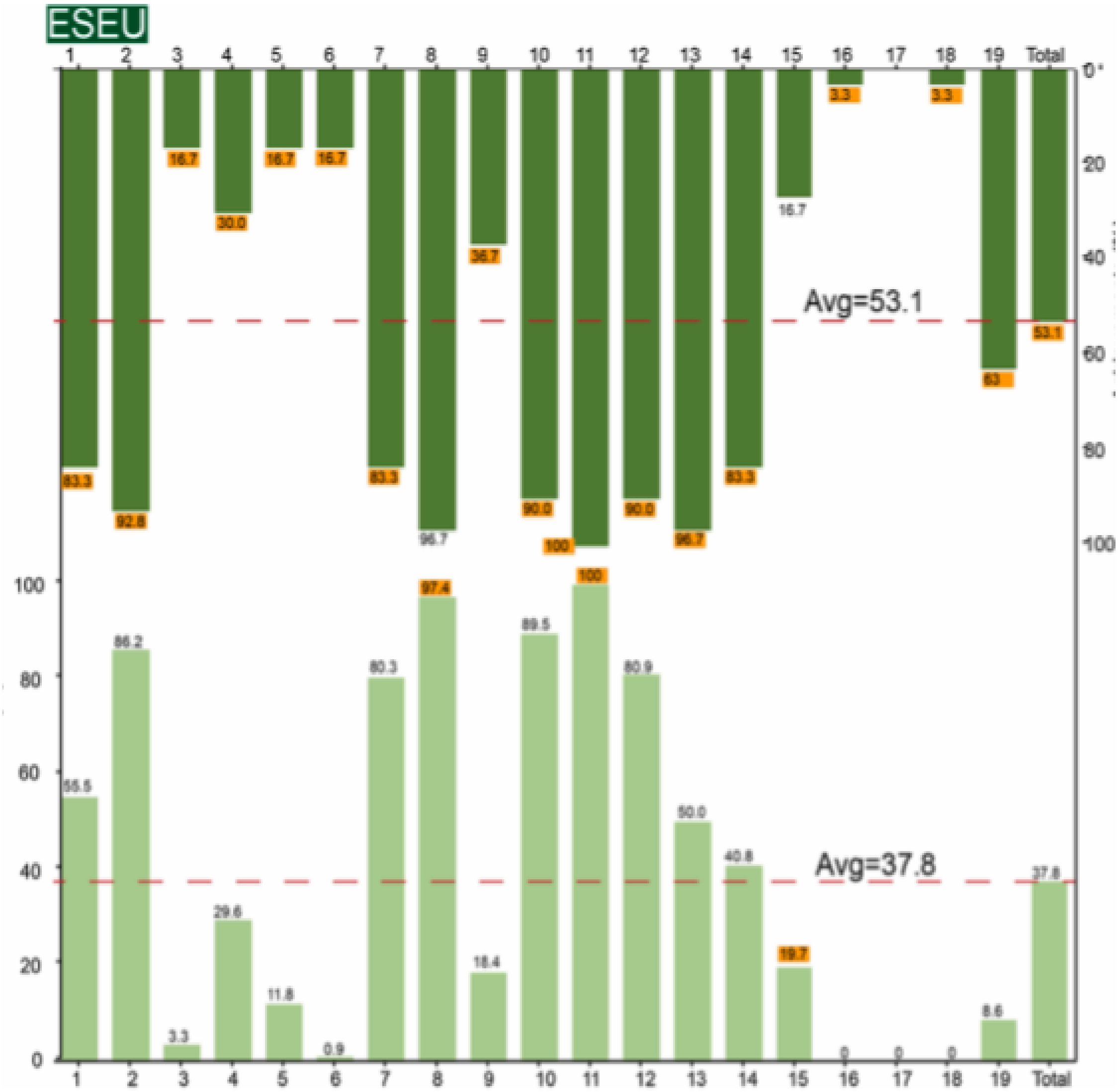

Figure 2: The comparison of the performance of 19 GB techniques in OSG and TTSG under ESEU (energy saving and energy utilisation) category
Source: Field Analysis, 2024

For OSG, it had a low average performance of 37.8%, inferior to nine techniques. However, only two techniques, including ESEU-8 (room orientation and space division) and ESEU-11 (lighting control system), reached very high levels. Following them, ESEU-2 (natural ventilation), ESEU-7 (HVAC use in transitional seasons), ESEU-10 (frequency conversion technology for water and wind systems) and ESEU-12 (lighting power density control) are four techniques standing between the third and sixth position, depending on their performance of 86.2%, 80.3%, 89.5%, and 80.9%. There were ten techniques having low performance, compared with the average value. For others, the performance were below 60% or just slightly higher than the average value. The performance of ESEU-4 (efficiency of heating/cooling units in HVAC system, 29.6%) was slightly lower than the average value, while five techniques were negligible, such as ESEU-3(envelop thermal performance), ESEU-6 (HVAC selection and optimisation), ESEU-16 (energy recovery system), ESEU-17(cool/heat storage system), and ESEU 18 (waste heat reuse). For ESEU-5 (central heating system), ESEU-9 (selection of cooling/heating unit), ESEU-15 (water pump and fan equipment), and ESEU-19 (reasonable use of renewable energy based on local climate), their performance were lower than 20%.

For TTSG, compared with its average value, there were ten techniques having higher performance, among which performance of nice techniques were far higher than the average value and only ESEU-19 achieved as lightly higher value. For ESEU-8, ESEU-10, ESEU-11, ESEU 12, and ESEU-13 (elevator selection), they were highly implemented with>90% performance. The performance of the remainder were still higher than 80%. Nevertheless, nine techniques achieved lower scores, in which ESEU-16, ESEU-17, and ESEU-18 were still negligible. Comparing OSG and TTSG, we found that the performance of ESEU-8 and ESEU-15 under went sight reductions and ESEU-17 got no attention in both groups. Nevertheless, 16 of the 19 techniques witnessed an increase in performance from OSG to TTSG. Moreover, there were three techniques experiencing significant increase, as shown in Table 4.1 The performance of ESEU-13, ESEU-14, and ESEU-19 were elevated by more than 40%, indicating the achievability for the transitions from OSG to TTSG. The improvement of ESEU-13 and ESEU-14 shows the economic driver to some advanced GB adoption, while the variation of ESEU-19 indicates more actions to adopt renewable energy.

Water-Saving and Water Utilization (WSWU) Green Building Techniques

The Assessment Standard for Green Building (ASGB) regulates items to meet the basic requirements, such as water waste reduction and non-traditional water sources utilisation. In specific, the WSWU highlights the water-saving system, equipment and facilities, and the use of non-traditional water source. It indicates that most of these techniques can be achieved through the adoption of various equipment or facilities, rather than the design technique. There are 16 techniques in WSWU, and their performances are given in Fig. 3.

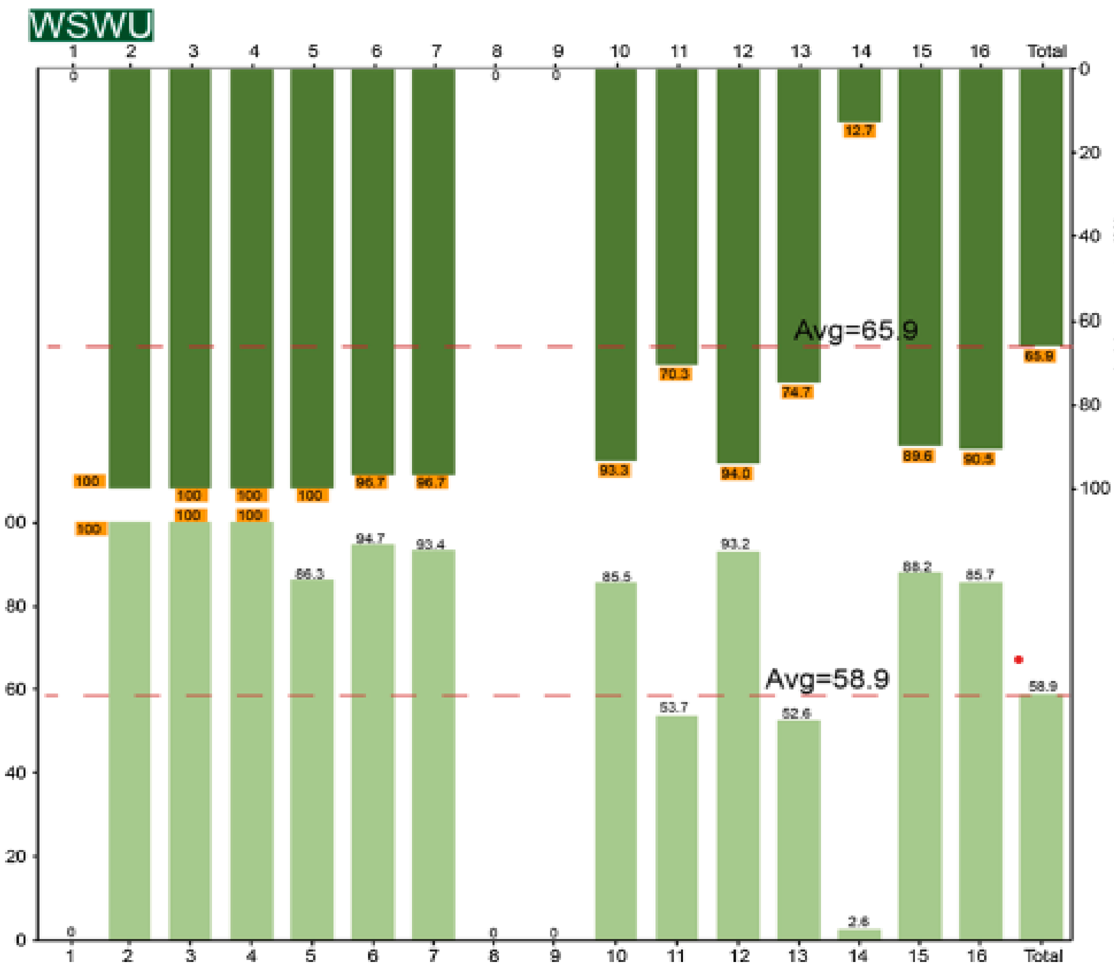

Figure 3: The comparison of the performances of 16 GB techniques in OSG and TTSG under WSWU (water-saving and water utilisation) category

Source: Field Analysis, 2024

Figure 3 reveals two distinctive performance patterns regarding Off-Grid Systems (OSG) and Traditional Grid Systems (TTSG). In the case of OSG, ten techniques outperformed the average performance benchmark of 58.9%, consistently achieving performance levels above 80%. Among these, six techniques—WSWU-2 (pipe tightness), WSWU-3 (pipe leakage avoidance measures), WSWU-4 (water consumption report), WSWU-6 (water metering equipment), WSWU-7 (water payment equipment), and WSWU-12 (water-saving cooling technology in HVAC systems)—demonstrated exceptionally high performance metrics. This indicates a significant focus on effective water management strategies, which is crucial in mitigating energy consumption associated with water usage in buildings (Zhao et al., 2023).

In contrast, several other techniques, including WSWU-5 (reasonable water pressure), WSWU-10 (efficient sanitary ware), WSWU-15 (non-traditional water for cooling), and WSWU-16 (rainwater utilization for landscape design), also exceeded the 80% performance threshold. However, WSWU-11 (water-saving irrigation) and WSWU-13 (additional water-saving techniques) experienced a sharp decline in performance, dropping to around 50%. This variance suggests that while many techniques are effective, others may require further development or implementation strategies to enhance their efficiency (Guo et al., 2023).

Notably, WSWU-1 (basic water requirements) was excluded from all green building (GB) cases, indicating its perceived lack of significance in the current context. Additionally, techniques such as WSWU-8 (thermostatic shower) and WSWU-9 (paid shower function) were deemed irrelevant for residential and public buildings. The integration of non-traditional water resources (WSWU-14) was also infrequently considered, reflecting a potential area for future exploration in sustainable building practices.

When comparing the transition from OSG to TTSG, there was no recorded implementation of WSWU-1, WSWU-8, and WSWU-9, similar to the findings in OSG. However, techniques that were fully adopted in OSG, specifically WSWU-2, WSWU-3, and WSWU-4, achieved a remarkable 100% performance in TTSG. All other techniques also recorded higher performance scores compared to their OSG metrics. While many techniques in the Water-Saving Utilization (WSWU) category maintained high performance levels in OSG, the overall increase in performance for specific techniques was not significantly pronounced.

However, WSWU-11 and WSWU-13 saw improvements in their performance levels, rising from below 50% to over 70%, indicating progress in the implementation of water-saving technologies. Conversely, WSWU-14, although showing a slight increase of 10.1% in performance, remained underperforming in TTSG. This highlights the need for continued innovation and integration of various water-saving techniques within building energy efficiency frameworks (Smith et al., 2024).

Material-Saving and Material Utilization (MSMU) Green Building Techniques

Buildings consume a large amount of natural resource such as cement and steel, which also a cause of land deterioration. The primarily feasible approach to conserving material includes reasonable building design, material strength improvement, material service duration prolongation, and waste material reuse. These techniques are specified via 17 techniques (Fig. 4).

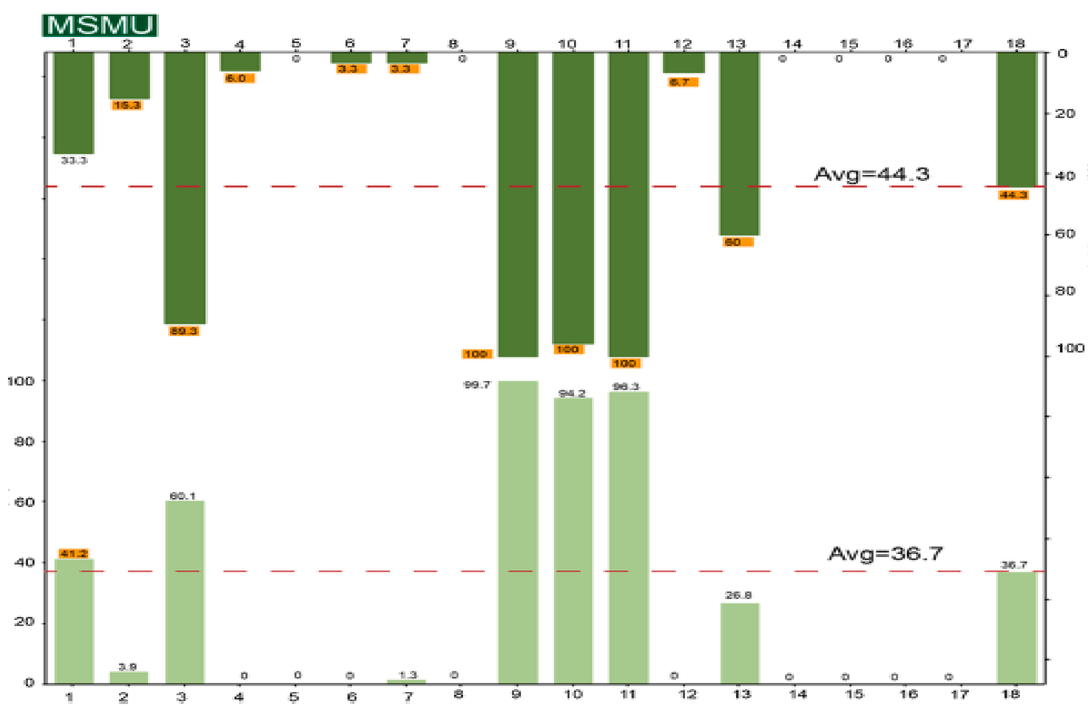

Figure 4: The comparison of the performance of 17 GB techniques in OSG and TTSG under MSMU (material saving and material utilisation) category.

Source: Field Analysis, 2024

In Off-Grid Systems (OSG), there was a notable variation in technique performances, with five techniques exceeding the average performance value of 36.7%. Particularly, MSMU-9 (pre-mixed concrete), MSMU-10 (premixed mortar), and MSMU-11 (high-strength structure) achieved remarkable performances, nearing 100%. This indicates a strong reliance on advanced materials in construction practices. Following these, MSMU-1 (building shape optimization) and MSMU-3 (integration of construction and decoration) performed at 41.2% and 60.2%, respectively. However, MSMU-13 (renewable and recyclable materials) was the only technique that fell below the average performance, reflecting its limited adoption despite its sustainability benefits. Additionally, the remaining eleven techniques were rarely implemented, suggesting a gap in the application of innovative materials and methods in OSG contexts (Chen et al., 2023).

Transitioning to Traditional Grid Systems (TTSG), five techniques surpassed the average performance value of 44.3%. Notably, MSMU-9, MSMU-10, and MSMU-11 were fully implemented, further underscoring their effectiveness in construction applications. MSMU-3 also achieved a commendable performance of about 90%. In contrast, MSMU-13 improved its performance to 60%, indicating a growing recognition of the importance of renewable materials in building projects. Despite this progress, twelve techniques still exhibited low performance levels, with five, including MSMU-5 (prefabricated components), MSMU-14 (reuse of waste materials), MSMU-15 (use of plain concrete), MSMU-16 (use of durable and maintainable façade material), and MSMU-17 (use of durable and maintainable decoration material), not being implemented at all.

Although techniques such as MSMU-4 (convertible building space), MSMU-6 (one-piece kitchen), MSMU-7 (one-piece bathroom), and MSMU-12 (high durability structure) were adopted, their performances were notably low, each falling below 10%. This low performance indicates potential barriers to effectively utilizing these techniques in construction. A significant transition was observed from OSG to TTSG, with ten techniques seeing performance increases; however, MSMU-1 was deprioritized. The most substantial performance enhancement occurred in MSMU-3, which rose from 60% in OSG to 90% in TTSG, demonstrating the importance of integrating construction processes and design to enhance overall building efficiency (Liu et al., 2024). These findings highlight the critical need for further research and investment in sustainable construction practices to optimize performance and resource utilization across both OSG and TTSG frameworks. Enhanced adoption of innovative techniques could significantly contribute to building energy efficiency and sustainability goals in the future.

Indoor Environment Quality (IEQ) Green Building Techniques

IEQ is the only one that is closely related to occupants' comfort sensation and health condition. IEQ determines if the GBs can provide people will comfortable, healthy and safe living spaces. The regulation of IEQ includes four aspects, including indoor sound environment, indoor lighting environment, indoor thermal and humid environment, and indoor air quality. These aspects are reflected by 19 techniques, as shown in Fig. 5.

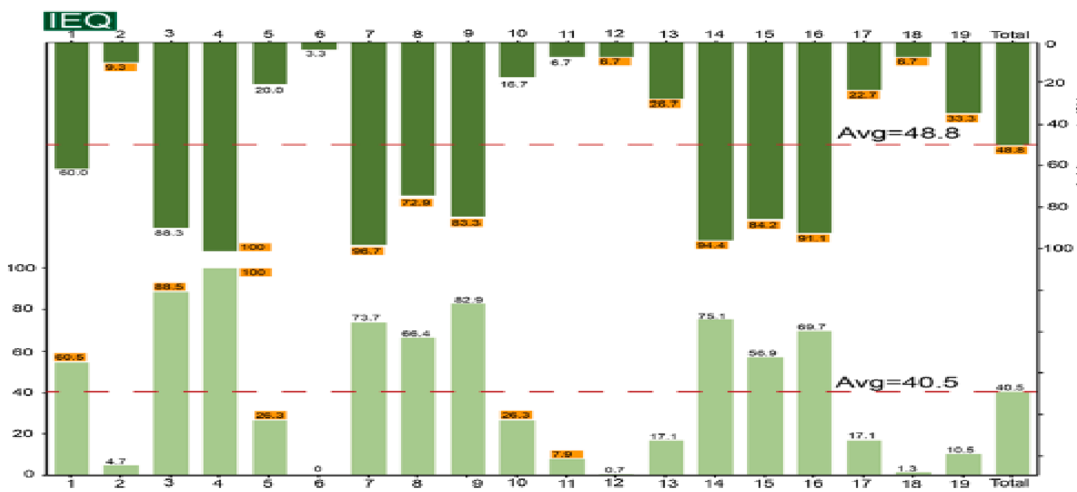

Figure 5: The comparison of the performance of 19 GB techniques in OSG and TTSG in IEQ.

Source: Field Analysis, 2024

Unlike the clearly defined groups of implemented and non-implemented techniques observed in Water-Saving Utilization (WSWU) and Material and Structural Utilization (MSMU), the techniques within Indoor Environmental Quality (IEQ) display a continuous variation in performance, ranging from 0%

to 100%. In Off-Grid Systems (OSG), nine techniques surpassed the average performance score of 40.5%. Notably, only one technique, IEQ-4 (Spatial layout for noise control), was fully implemented, reflecting its critical importance in managing acoustic comfort within buildings. Following this, IEQ-3 (floor noise insulation) achieved a commendable score of 88.5%, while IEQ-9 (dazzle lighting control) performed well at 82.9%. The performance of other techniques ranged from 56.9% to 75.1%, each exceeding the average score by at least 16.4%.

Conversely, four techniques fell significantly below the average performance. These included IEQ-2 (sound insulation between adjacent buildings) with a mere 4%, IEQ-6 (specific acoustic design) at 0%, IEQ-12 (adjustable sunshade measures) scoring 0.7%, and IEQ-18 (integration between pollution alarm and ventilation system) at 1.3%. Additionally, some techniques, such as IEQ-11 (daylighting of underground space) at 7.9%, IEQ-13 (adjustable HVAC system) at 17.1%, IEQ-17 (carbon dioxide control) at 17.1%, and IEQ-19 (integration between ventilation system and carbon monoxide monitoring system in the underground) at 10.5%, were implemented only in a limited number of cases, indicating a significant gap in applying effective IEQ strategies (Mok et al., 2024).

In Traditional Grid Systems (TTSG), nine techniques also exceeded the average performance score of 48.8%. Notably, IEQ-4 was fully implemented in this context. Other techniques, including IEQ-7 (Vision of main functional room), IEQ-14 (Natural ventilation), and IEQ-16 (Air pollutant control), demonstrated impressive performance, each exceeding 90%. Techniques such as IEQ-3, IEQ-9, and IEQ-15 (airflow organization) achieved scores between 80% and 90%. However, nine techniques underperformed, with IEQ-6 reporting an extremely low score of 3.3%. Additionally, four techniques—IEQ-5 (low drainage noise), IEQ-13, IEQ-17, and IEQ-19—saw performance levels above 20%, indicating some degree of effective implementation.

Transitioning from OSG to TTSG, twelve techniques experienced increases in performance. However, five techniques witnessed declines. Notably, the decreases in IEQ-1 (from 60.5% to 60.0%), IEQ-3 (from 88.5% to 88.3%), and IEQ-11 (from 7.9% to 6.7%) were minimal, while IEQ-5 and IEQ-10 (indoor daylighting coefficient) saw more significant decreases of 6.3% and 9.6%, respectively. On the other hand, four techniques showed substantial increases in performance: IEQ-7 with a 23.0% increase, IEQ-14 with a 19.3% increase, IEQ-15 with a 27.3% increase, and IEQ-16 with a 21.4% increase. These improvements underscore the importance of prioritizing IEQ strategies to enhance overall building performance and occupant comfort (Zhou et al., 2023).

Site Planning and Land Surveying (SPLS) Green Building Techniques

Site planning determines the sustainability of urban development, as it is the first step to concern the relationship between building and its environmental impacts. Through land-use optimisation, better site planning and land saving strategies can help address several issues in relation to transportation, outdoor thermal environment, excessive energy and water consumption. Moreover, reasonable utilisation of built environment can maximise land efficiency. Fig. 5 presents the performance of 27 techniques in SPLS, where the bottom part is the GB technique performance for OSG and the upper for TTSG. In OSG, the performance of 12 techniques were above the overall average value of 52.7%, among which three techniques (SPLS-17, SPLS26 and SPLS-5) received extremely high performance. The SPLS-17 (pedestrian accessibility design) and SPLS-26 (planting trees based on local climate) were the only two techniques witnessing full performance. The transmission light emission ratio of the glass curtain wall (SPLS-5) had an performance of 98.7%. Following them, four techniques including SPLS-11 (indoor-outdoor pressure difference), SPLS-19 (car parking availability), SPLS-3 (Greenland for public) and SPLS-15 (public transportation) stood at the fourth to seventh position, with their performance ranging between 80% and 90%.

In comparison, the performance of 14 techniques were below the overall average performance, in which performance of SPLS-4 (underground space), SPLS-8 (wintertime wind) and SPLS-21(site design) were about 52.7%, while the implementation of eight techniques, mainly in responses overheating and rainfall, was extremely low(below 20%). Measures to mitigate urban heat island (UHI) effects (SPLS-12, SPLS-13) and site rainwater infrastructures (SPLS-22, SPLS-23, SPLS24) had been rarely adopted, with their performance lower than 10%. The bicycle parking shelters (SPLS-18, 19.7%) and site rainwater control (SPLS-25, 15.1%) also witnessed low performance.

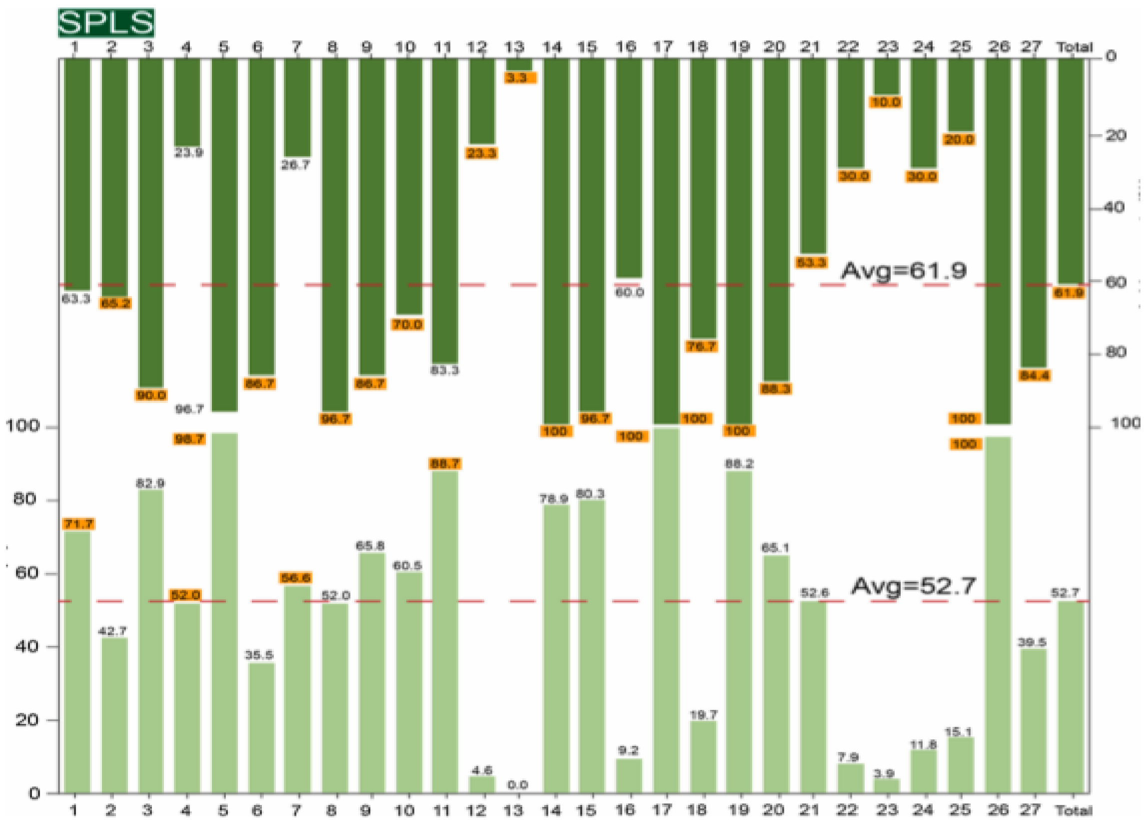

Figure 6: The comparison of the performance of 27 GB techniques in OSG and TTSG in SPLS

Source: Field Analysis, 2024

When it comes to TTSG, Fig. 6 indicates 17 techniques had achieved higher performance than the average performance of 61.9%, in which four techniques including SPLS-14 (site entrance to public transportation), SPLS-17, SPLS-19, and SPLS-26 were implemented in all GB projects. Four techniques including SPLS-3, SPLS-5, SPLS-8, and SPLS15 observed high performance above 90%. Akin to the situation in OSG, techniques for UHI mitigation and site rainwater infrastructures were not prioritised, ranking at the last positions.

For SPLS-4 and SPLS7 (site noise control), their performance were low in TTSG, although they received good performance close to the average value. Comparing technique performance in OSG with that in TTSG, it is found 22 techniques received higher performance in TTSG, consistent with the higher score to obtain two-star or three-star certification. However, five techniques had lower performance in TTSG, including SPLS-1 (floor area ratio), SPLS-4, SPLS-5, SPLS-7, and SPLS-11. The performance SPLS-5 and SPLS-11 in two groups exhibited negligible difference as shown in Table 4.5 while performance of SPLS-1, SPLS-4, and SPLS-7 witnessed obvious reductions of 8.4%, 28.1%, and 29.9%, respectively. Table 4.6 further summarizes the techniques that experienced more than 40% increase in performance from OSG to TTSG. For SPLS-6, SPLS-8, SPLS-16, and SPLS-27, their performance exceeded the average value of TTSG. Although SPLS-16 was still lower than the average performance of TTSG, its performance increased up to 50% compared to its extremely low value in OSG.

Table 1: Details of the techniques experiencing decrease from OSG to TTSG in SPLS

Code	Contents	Performance	
		OSG	TTSG
SPLS-1	Floor area ratio	71.7	63.3
SPLS-4	Reasonable use of underground space	52.0	23.9
SPLS-5	The visible light emission ratio	98.7	96.7
SPLS-7	The noise inside the site	56.6	26.7
SPLS-11	>50% of the open window between indoor-outdoor wind pressure less than 0.5 Pa	88.2	83.3

Source: Field Analysis, 2024

Table 2: Details of the techniques experiencing increase from OSG to TTSG in SPLS

Code	Contents	Performance	
		OSG	TTSG
SPLS-6	Outdoor lighting meets the industry of urban lighting design specification	35.5	86.7

SPLS-8	Typical wind speed in winter	52.0	96.7
SPLS-16	Pedestrian walking distance from the public walking point	9.2	60.0
SPLS-18	Very convenient place for bicycle parking and have the protection from sun and rain	19.7	76.7
SPLS-27	No less than three trees every 100 square meters	29.5	84.4

Source: Field Analysis, 2024

Figure 7 illustrates the overall achievements in green building (GB) practices across six categories: Sustainable Product Life Cycle Strategies (SPLS), Energy Savings in Existing Units (ESEU), Water-Saving Utilization (WSWU), Material and Structural Utilization (MSMU), Indoor Environmental Quality (IEQ), and Innovative Materials and Technologies (IMIN). Notably, the achievement levels of GB techniques in the two-star and three-star group (Traditional Grid Systems, TTSG) generally surpassed those in the one-star group (Off-Grid Systems, OSG). In TTSG, WSWU achieved the highest score of 64.5%, which is 2.9% higher than the second-highest category, SPLS, at 61.6%. The performance of ESEU, IEQ, and MSMU was recorded at 53.1%, 48.8%, and 44.0%, respectively, all falling below the 60% threshold. This indicates increasing challenges in implementing these techniques effectively in practice. Furthermore, IMIN achieved a mere 3.8%, significantly lower than the other categories, reflecting a lack of innovative materials and technologies being utilized in current projects (Zhang et al., 2024).

In contrast, the absence of innovative GB techniques in OSG may suggest that either the realization of these techniques is particularly challenging, or that designers or engineers have not prioritized their implementation. In OSG, the overall GB achievements across the six categories were organized in the following pattern: WSWU (58.9%) > SPLS (52.7%) > IEQ (40.4%) > ESEU (37.8%) > MSMU (37.0%) > IMIN (0.0%). This ranking roughly aligns with the order seen in TTSG: WSWU > SPLS > ESEU > IEQ > MSMU > IMIN.

The difference in the ranking between ESEU and IEQ can be attributed to a more substantial increase in ESEU performance (approximately 15.3% from OSG to TTSG) compared to the relatively smaller increase in IEQ (about 8.4%

from OSG to TTSG). This pattern highlights a significant upward trend in the implementation of energy savings measures. Additionally, the variations in GB technique adoption were recorded as 8.9%, 5.6%, 7.0%, and 3.8% for SPLS, WSWU, MSMU, and IMIN, respectively. These variations indicate the fluctuating focus and effectiveness of different techniques across the two systems, underscoring the need for continued innovation and adaptation in GB practices (Liu et al., 2023).

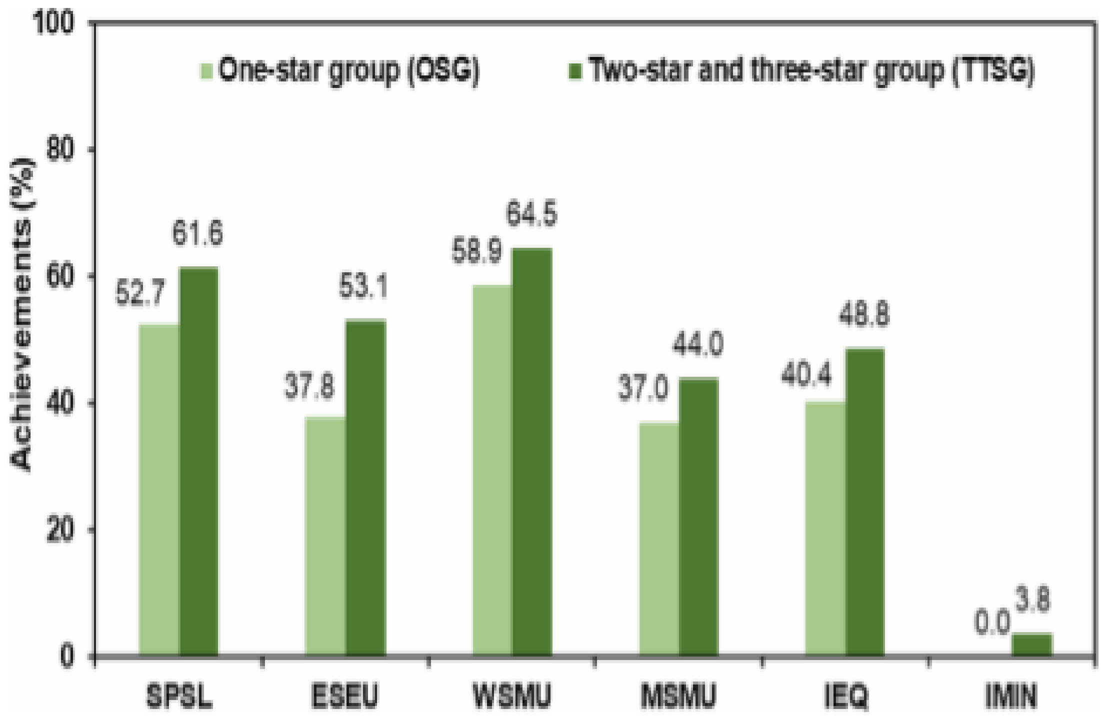

Figure 7: The overall Green Building performance statistics of six categories of SPLS, ESEU, WSWU, MSMU, IEQ and IMIN in OSG and TTSG.

CONCLUSION

The adoption of green building techniques in the Federal Capital City (FCC), Abuja, presents a significant opportunity for achieving both environmental sustainability and socio-economic benefits. The research highlights the potential of green buildings to reduce energy consumption, enhance water conservation, and improve the overall environmental quality of the city. Green building techniques also contribute to economic benefits such as reduced operational costs, job creation, and the promotion of sustainable development. However, the study also identifies several challenges, including the high initial costs of green technologies, limited technical expertise, and insufficient policy enforcement, which have hindered the widespread adoption of these practices in Abuja.

RECOMMENDATIONS

To overcome these challenges, it is crucial for the government to develop and enforce strong policies that promote sustainable construction practices. This could include the implementation of mandatory green building codes and providing financial incentives such as tax rebates, grants, or low-interest loans for developers who adopt green building techniques. Additionally, there is a need for capacity-building initiatives aimed at training professionals in the construction industry, such as architects, engineers, and contractors, on the benefits and implementation of sustainable building practices. Public awareness campaigns should also be prioritized to educate both developers and the public on the long-term benefits of green buildings.

Another important recommendation is to encourage public-private partnerships (PPPs) to facilitate the financing and implementation of large-scale green building projects. These partnerships could provide a collaborative platform for government agencies, developers, and financial institutions to address the financial barriers associated with green building adoption. Further, research and development into locally sourced eco-friendly materials should be supported to reduce construction costs while maintaining high sustainability standards.

The integration of smart technologies, such as solar energy, energy-efficient appliances, and intelligent building management systems, should be promoted in green buildings in Abuja. These technologies not only enhance energy efficiency but also improve the long-term viability of buildings by reducing operational costs. Moreover, community engagement in sustainable urban planning should be encouraged, ensuring that residents and local stakeholders are involved in the development and maintenance of green buildings. This would increase community ownership and ensure the continued success of green building practices in the city.

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