

Green Facade Systems as a Sustainable Solution for Urban Heat Island Mitigation in Lagos State

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DOI: <https://doi.org/10.62154/ajesre.2025.019.01013>

Abstract

Urban Heat Island (UHI) effects intensify heat stress, energy use, and poor air quality in rapidly urbanizing cities like Lagos. This study investigates the potential of green facades as a sustainable UHI mitigation strategy through a qualitative approach involving literature review, secondary climatic data, and comparative case studies. The analysis reveals that green facades can reduce surface temperatures by 2°C–5°C through shading and evapotranspiration, lower indoor cooling demand, and improve thermal comfort and urban air quality. Additional benefits include biodiversity enhancement and energy efficiency. However, challenges such as high installation costs, plant maintenance, and limited technical expertise may hinder adoption. Opportunities lie in Lagos' evolving sustainability agenda, policy frameworks, and private-sector involvement. The study recommends integrating green facades into building codes, providing economic incentives, and promoting multi-stakeholder collaboration for maintenance. This research positions green facades as a feasible climate-adaptive solution for UHI mitigation and sustainable urban development in tropical environments like Lagos.

Keywords: Climate Resilience, Green Facades, Lagos, Sustainable Cooling, Urban Biodiversity, Urban Heat Island.

Introduction

The Urban Heat Island (UHI) phenomenon, where urban areas record higher temperatures than nearby rural environments due to dense construction, reduced vegetation, and human activities, is an increasingly critical challenge in expanding cities (Kim & Brown, 2021). Lagos, Nigeria's most populous city and one of Africa's fastest-growing megacities, is particularly vulnerable due to its rapid urbanization, concrete-dominated landscape, high-rise buildings, and minimal green cover (Obiefuna et al., 2021). These conditions intensify energy demand for cooling, worsen air quality, and elevate health risks.

In response to these issues, nature-based cooling interventions such as green facades, which involve incorporating vegetation on the external surfaces of buildings, are gaining traction in cities worldwide. These systems provide environmental and thermal benefits by reducing surface temperatures, improving air quality, and enhancing visual appeal (Sayad et al., 2024). Despite their proven success in temperate and high-income cities, Lagos has yet to adopt green facades widely. Financial constraints, maintenance concerns, and limited public awareness contribute to their limited application (Bassett et al., 2020).

There is a lack of localized research evaluating the effectiveness and feasibility of green facades in tropical urban contexts such as Lagos. This study addresses this gap by investigating how green facade systems can contribute to UHI mitigation, improve urban microclimates, and promote sustainable urban development in Lagos. The findings aim to inform climate-responsive design strategies, influence policy, and guide the implementation of green infrastructure in similar tropical cities.

Problem statement

Despite the intensifying Urban Heat Island (UHI) effect in Lagos due to rapid urbanization, dense construction, and limited green infrastructure, there is limited empirical research exploring localized strategies for mitigation. While green facade systems have shown success in temperate cities, their application in tropical urban environments like Lagos remains underexplored. The absence of data-driven insights, contextual design adaptations, and policy support continues to hinder their integration into the built environment. This gap highlights the urgent need to investigate the viability, benefits, and challenges of implementing green facade systems as a sustainable UHI mitigation strategy in Lagos.

Aim

The aim of this study is to evaluate the potential of green facade systems in mitigating the Urban Heat Island effect in Lagos and to propose effective strategies for their implementation.

Objectives

The objectives of this research are to;

- i. Analyse climatic data and assess the intensity of UHI in Lagos.
- ii. Explore green facade design principles and their impact on temperature reduction.
- iii. Examine case studies of successful green facade applications in UHI mitigation.
- iv. Evaluate the feasibility and challenges of implementing green facades in Lagos.

This research offers insights that can guide planners, developers, and policymakers in adopting green infrastructure to improve environmental resilience, lower energy consumption, and enhance urban comfort in Lagos and similar tropical cities.

Literature Review

Understanding the Urban Heat Island (UHI) Effect

The Urban Heat Island (UHI) effect refers to a phenomenon where urban areas experience significantly higher temperatures than their rural surroundings. This effect results from the replacement of natural vegetation with impervious surfaces such as asphalt, concrete, and glass, which absorb and retain heat (Hajer Khaled Jabbar et al., 2023). Factors such as reduced vegetative cover, anthropogenic heat emissions, and restricted airflow due to

high-density developments intensify the UHI effect (Wonorahardjo et al., 2022). UHI has far-reaching implications, including increased energy consumption for cooling, greenhouse gas emissions, health complications, and exacerbated air pollution, particularly from ground-level ozone formation (Yadav & Singh, 2024; Arunab & Mathew, 2024).

The UHI Effect in Lagos

Lagos, Nigeria, one of Africa's most populous cities, is experiencing a pronounced Urban Heat Island (UHI) effect driven by rapid urbanization, industrial activity, and deforestation. With a population exceeding 20 million (Oyewo, 2023), the city's expansion has replaced natural landscapes with concrete infrastructure, heat-retentive surfaces, and high-density developments, all of which contribute to elevated land surface temperatures (LST) and microclimatic alterations (Faremi et al., 2021; Umunna, 2024).

Multiple studies confirm the growing intensity of UHI in Lagos. Early field-based research documented temperature differences of up to 5°C between urban cores and surrounding rural zones, largely attributed to impervious surfaces like asphalt and concrete (Ayanlade et al., 2021). More recent remote sensing studies using thermal imaging suggest even greater disparities, with urban LSTs reaching 4–7°C higher than nearby vegetated areas (Obe et al., 2024). This trend reflects a broader pattern of heat entrapment and low evapotranspiration in densely developed districts.

Satellite-based climatic models from NASA's MODIS and Landsat 8 platforms have identified specific UHI hotspots across Lagos. Key areas include:

1. Central Business District (CBD) and Marina: characterized by dense high-rise buildings, limited vegetation, and intense vehicular activity.
2. Oshodi, Mushin, and Apapa: industrial corridors with high emissions, sparse green cover, and significant energy use.
3. Ajah and Lekki Phase 1: fast-developing zones where construction-driven deforestation has worsened thermal stress.

These spatial patterns are corroborated by thermal datasets from platforms such as Climate CHIP and the YCEO UHI Map, which consistently show Lagos' urban core exhibiting significantly higher surface temperatures than its peri-urban counterparts. Collectively, the evidence underscores the urgent need for urban heat mitigation strategies tailored to Lagos' climatic and socio-spatial context.

Impacts of UHI in Lagos

The environmental, social, and economic consequences of UHI in Lagos are acute. High urban temperatures increase electricity consumption for cooling and burden the already strained power infrastructure (Gonzalez-Trevizo et al., 2021). Vulnerable populations face heightened risks of heat-related illnesses, including dehydration, heatstroke, and respiratory diseases (Yadav et al., 2023). Additionally, intensified air pollution from ozone

and trapped particulate matter further worsens public health. Urban flooding is also aggravated by UHI, as impermeable heated surfaces hinder water infiltration and increase stormwater runoff, putting additional pressure on drainage systems (Liang et al., 2021). These interconnected issues highlight the urgency for sustainable, climate-sensitive urban design interventions.

Green Facades as a Strategy for UHI Mitigation

Green facades, also known as vertical greenery systems, have emerged as viable, nature-based solutions for UHI mitigation. They function by covering building exteriors with vegetation through climbing plants or modular panels (Moreira-Zambrano & Moreno-Rangel, 2020). The vegetative layer reduces solar absorption, enhances evapotranspiration, and creates shading, all of which contribute to microclimate improvement. Studies demonstrate green facades can reduce exterior wall temperatures by 10–20°C and lower internal heat gains, improving energy efficiency (Blanco et al., 2020; Aung et al., 2023). Beyond thermal regulation, green facades filter pollutants, sequester carbon, and offer acoustic and visual benefits. However, most empirical studies on their performance have focused on temperate climates. Research specific to Lagos or other West African urban environments is sparse. There is limited data on plant species suitability, structural integration, and long-term maintenance in tropical, humid conditions. This gap in locally grounded research suggests a critical need to examine green facade applications tailored to Lagos' climate, socio-economic realities, and architectural practices.

Case Studies of Green Facades in UHI Mitigation

The effectiveness of green facades in mitigating the Urban Heat Island (UHI) issue has been proven through numerous studies in urban areas worldwide. Examining case studies proves useful in providing insights into the application, benefits, and challenges involved in utilizing green facade systems in urban environments. A case in point is Milan, Italy's Vertical Forest (Bosco Verticale), consisting of two residential skyscrapers with about 20,000 trees, shrubs, and a variety of flora species. The high density of flora can cause a drop in surface temperatures, improvement in air quality, and an improvement in urban biodiversity in a high-density city environment. According to studies, temperatures in external walls can drop by 30%, lessening the demand for cooling in warmer months (Isunju et al., 2022). The practice is a perfect demonstration of utilizing vertical foliage in high-rise buildings to promote thermal comfort in addition to ecologic benefits.



Figure 1: Bosco Verticale in Milan

Source: Ivica, E. (2024).

A similar case in point is One Central Park in Sydney, Australia, featuring an exemplary green facade designed to maximize sunlight and thermal impact. The vegetated panels, in collaboration with a sophisticated heliostat system, effectively deflect sunlight and maintain thermal comfort indoors. Studies have proven that such a system lowered indoor cooling costs by 25%, proving high potential for energy savings in vertical urban buildings (Fleck et al., 2022).

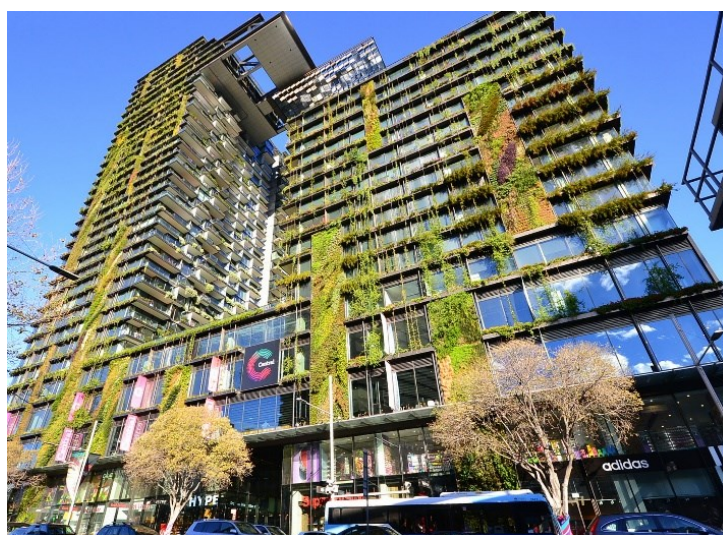


Figure 2: Image of One Central Park in Sydney

Source: Wikimedia.org. (2025).

In a tropical context, the Oasia Hotel Downtown in Singapore presents a relevant case study for Lagos. Designed with a lush green envelope that covers over 50% of the building's

surface, the project significantly reduces urban heat accumulation while promoting natural ventilation (Singh et al., 2024). Singapore's experience highlights the feasibility of green facades in warm, humid climates and serves as a model for implementing similar strategies in Lagos, where high temperatures and limited green spaces contribute to severe UHI effects.



Figure 3: Image of the Oasis Hotel Downtown, Singapore
Source: Austin, S. (2022).

These case studies demonstrate that green facades are not just theoretical solutions but proven strategies for mitigating urban heat. While implementation in Lagos may require considerations such as plant selection, irrigation methods, and maintenance strategies, these successful examples provide a foundation for adapting green facade technologies to local climatic and urban conditions. By leveraging lessons from these projects, Lagos can incorporate green facades into its urban fabric to enhance sustainability, reduce heat stress, and improve overall liveability.

Research Gaps and Comparative Literature

Urban Heat Island (UHI) mitigation studies across global cities have demonstrated the value of green infrastructure in enhancing thermal comfort, yet a notable research gap exists in localized studies focusing on Lagos. For instance, Irfeey et al. (2023) emphasize the importance of green walls and sustainable building materials in managing UHI in dense cities like Colombo and Melbourne, noting that widespread adoption is limited by policy and economic barriers. Although their study offers detailed insight into green wall structures and materials, it lacks contextual alignment with sub-Saharan climates and socio-economic realities like those found in Lagos.

Similarly, Teo et al. (2022) explored the effectiveness of Green Mark buildings and skyrise greenery in reducing urban heat in Singapore. Their findings confirmed a strong correlation between urban greening density and reduced surface temperatures, particularly in non-commercial zones. However, the study's recommendations, including high-density urban gardens and government-backed certification systems, reflect Singapore's unique policy and urban planning environment which are conditions not yet present in Lagos State, Nigeria.

In contrast, Oni & Ibeabuchi (2023) conducted a spatial mapping of UHI zones in Ibadan, Nigeria, using remote sensing data. Their research, while geographically closer to Lagos, still centres on UHI diagnosis rather than green infrastructure solutions. Although they recommend increased vegetation and reflective materials, no specific assessment of green facades was included. This highlights the scarcity of empirical and application-based studies on vertical greenery in Nigerian cities.

This study, however, fills this critical research gap by examining green facades specifically in the Lagos context by evaluating not only their theoretical benefits but also practical feasibility, implementation challenges, and contextual relevance. Unlike prior works focused on cities with established green policy frameworks or different climate zones, this research addresses the lack of local data and policy support in tropical West Africa, making a novel contribution to sustainable urban cooling strategies for Lagos state, Nigeria.

Opportunities for Green Facades in Lagos

Green facades present a viable, space-efficient solution for enhancing urban thermal comfort and sustainability in Lagos. Given the city's compact high-rise landscape and widespread use of heat-retaining construction materials, especially in commercial and high-income residential areas such as Ikoyi, Victoria Island, and Lekki, vertical greenery offers a feasible alternative for UHI mitigation (Bassett et al., 2020). By reducing solar heat gain and surface temperatures, green facades can lower indoor cooling demand, improve air quality through particulate filtration, and enhance the aesthetic character of high-traffic urban corridors like Ojuelegba, Ikeja, and Apapa. These co-benefits also contribute to improved mental well-being and liveability in densely populated environments (Pacini et al., 2022).

There is growing potential for integrating green facades into Lagos' urban planning frameworks. Policy instruments such as tax incentives, green building certification programs, and revised zoning codes could support adoption. Agencies like the Lagos State Physical Planning Permit Authority (LASPPA) and the Lagos State Environmental Protection Agency (LASEPA) could play key roles in promoting and enforcing such policies. In addition to environmental benefits, green facades can stimulate job creation in sectors such as landscaping, maintenance services, irrigation infrastructure, and plant nursery

operations. If supported by public-private partnerships and sustained investment, green facades could become an integral component of Lagos' broader climate resilience strategy.

Challenges of Green Facades in Lagos

While green facades hold significant promise for UHI mitigation in Lagos, several challenges hinder their widespread adoption. The high initial costs of installation and ongoing maintenance, including irrigation infrastructure and resilient plant species, remain a major barrier, particularly in the absence of financial incentives (Anthony Adenaike et al., 2020). Lagos' tropical climate, with alternating dry and rainy seasons, complicates plant survival and system durability, especially where proper maintenance is lacking. Technical limitations are another concern. Many existing buildings are not structurally suited for retrofitting green facades, and there is limited local expertise in vertical greenery design and long-term management. Additionally, the selection of climate-appropriate, low-maintenance plant species is constrained by insufficient research, leading to suboptimal performance or pest vulnerability. Weak policy frameworks and limited awareness among architects and developers further reduce uptake (Pacini et al., 2022). Addressing these challenges will require targeted actions such as training programs, supportive policies, species trials, and public-private partnerships. Strategic planning and regulatory support can help scale up green facades as a feasible solution for improving urban resilience in Lagos.

Methodology

This study adopted a qualitative, exploratory research design using secondary data to investigate the potential of green facades as a strategy for mitigating the Urban Heat Island (UHI) effect in Lagos. Primary data collection was not undertaken due to time constraints and limited access to field-based resources. Instead, data were gathered from credible and validated sources, including climatic platforms such as Climate CHIP and the YCEO UHI Map, which provided spatial visualisations and long-term temperature trends for Lagos. Peer-reviewed journal articles, institutional reports, and documented case studies from cities such as Singapore, Sydney, and Milan were also reviewed to extract insights on green facade implementation, design strategies, and performance outcomes in urban environments. The selection of these sources was guided by their relevance to the study's objectives and their methodological reliability. A thematic content analysis approach was used to synthesise key findings across the literature and organise them around recurring themes such as UHI causes, green facade benefits, and implementation challenges in tropical contexts. Although no original statistical analysis was conducted, the study referenced regression-based findings from previous empirical studies to illustrate the relationship between green facade coverage and temperature reduction, typically ranging between 2°C and 5°C. While the absence of primary data is acknowledged as a limitation, the triangulation of diverse and credible secondary sources ensured analytical rigour. This

methodology provided a robust foundation for evaluating the applicability of green facades in Lagos and offers direction for future empirical research and policy development.

Results and Discussion

Key Findings from Data Analysis

Climatic data from Climate CHIP and UHIMAP, in conjunction with literature and international case studies, provided strong evidence for the potential of green facades to mitigate Urban Heat Island (UHI) effects in Lagos. Lagos exhibits high UHI intensity, particularly in dense urban zones such as the Central Business District, Ikeja, Apapa, and Lekki Phase 1. These areas consistently record higher surface temperatures compared to surrounding vegetated or peri-urban areas, as confirmed by thermal imagery and urban climate models.

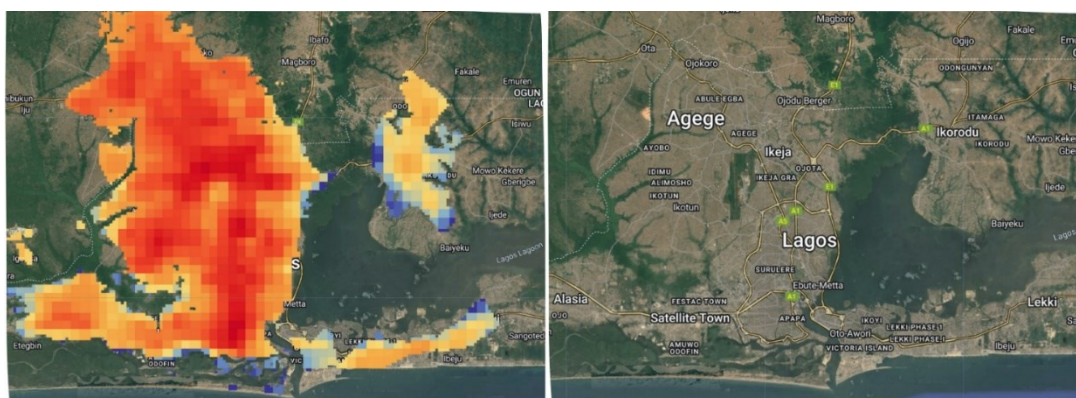


Figure 4: Images showing the SUHI (Surface Urban Heat Island) Hotspots in Lagos state

Source: (Global Surface UHI Explorer, 2025)

In UHI-prone cities like Singapore, Sydney, and Milan, green facades have been shown to lower surface and ambient temperatures by 2°C to 5°C, depending on the density and structure of vegetation used (Sayigh Ali & Trombadore, 2022; Perini et al., 2021). These reductions are achieved primarily through shading, evapotranspiration, and reduction in solar heat gain. For instance, Singapore's Oasia Hotel and Milan's Bosco Verticale both demonstrated improved microclimates and energy savings through vertical greening systems (Blanco et al., 2023). Although Lagos lacks large-scale green facades, similar interventions in its UHI hotspots could yield comparable benefits. Satellite-based thermal data suggest that commercial and high-density residential zones in Lagos would particularly benefit from the thermal regulation properties of vertical greenery.

The impact of green facades on temperature reduction in Lagos would likely be most significant in areas with poor ventilation and low vegetation cover. Climatic observations suggest that introducing vertical greenery in these zones could reduce wall and surface temperatures by up to 5°C (Okwandu & Nwokediegwu, 2024), similar to global benchmarks,

which would ease indoor cooling loads and enhance thermal comfort. While this estimate is based on findings from comparable environments, its accuracy for Lagos depends on plant selection, system maintenance, and structural design.

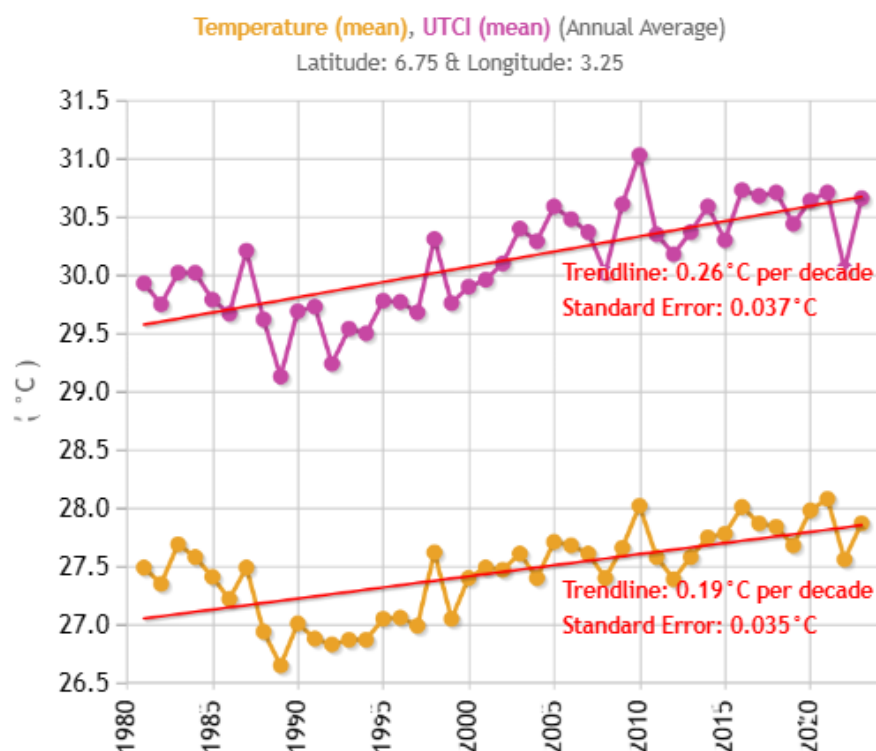


Figure 5: Chart illustrating the temperature and UTCI mean values for Lagos State until 2023. Source: Climate Chip. (2024).

Although no green facade systems are currently implemented at scale in Lagos, literature suggests that evergreen species like *Ficus pumila* and *Hedera helix*, known for their thermal regulation properties, could perform well under Lagos' tropical conditions (Hian et al., 2021). Considerably, Lagos would benefit from adapting international strategies to its own climate and urban morphology. Unlike Singapore and Milan, which operate within well-established green building frameworks and offer financial incentives, Lagos lacks clear policy structures and technical expertise supporting green infrastructure.

Green facades offer Lagos a viable UHI mitigation strategy. While empirical, site-specific testing is still needed, both climatic data and comparative case studies affirm their potential to lower urban temperatures, improve air quality, and reduce energy consumption. Integrating green facades into urban planning could enhance the city's resilience to rising temperatures, provided that design adaptations, local plant trials, and supportive policies are pursued.

Conclusion

This study examined the potential of green facades as a sustainable solution to mitigate Urban Heat Island (UHI) effects in Lagos. The analysis drew on climatic data, case studies, and literature to evaluate how green facades could reduce surface temperatures, improve air quality, and enhance urban resilience. Findings revealed that Lagos experiences high UHI intensity, particularly in densely built areas with limited vegetation, and that green facades could lower surface temperatures by 2°C to 5°C in similar climates, based on evidence from cities like Singapore and Milan.

In addressing the first objective, climatic data from Climate CHIP and UHIMAP confirmed that key hotspots in Lagos include commercial and high-density residential zones. The second objective was met by synthesizing literature that highlighted the role of green facades in thermal regulation through shading, evapotranspiration, and insulation. Regarding the third objective, case studies demonstrated that green facades improve thermal comfort, reduce energy consumption, and enhance biodiversity in urban areas. Lastly, the feasibility and challenges of implementing green facades in Lagos were discussed, revealing obstacles such as high installation and maintenance costs, limited technical expertise, and weak policy frameworks. While the use of secondary data allowed for broad insight, the absence of primary fieldwork limited the specificity of findings. To add, the variability in climate, design practices, and urban governance between Lagos and case study cities may affect the direct transferability of results.

Despite these limitations, this study affirms that green facades represent a promising, though underutilized, strategy for cooling Lagos. Their integration into urban planning could contribute significantly to improving environmental quality and reducing urban heat stress.

Recommendations

To support the implementation of green facades in Lagos, the following stakeholder-specific actions are recommended:

- i. Urban policymakers and regulatory bodies (e.g., LASPPPA, LASEPA) should integrate green facades into building codes and zoning policies, prioritizing UHI-prone areas.
- ii. The Lagos State Government should establish financial incentives, such as tax rebates or green building grants, to encourage private sector adoption.
- iii. Research institutions and universities should initiate pilot studies to identify climate-appropriate plant species and assess long-term performance of green facade systems in Lagos.
- iv. Professional bodies and training institutes should develop capacity-building programs for architects, engineers, and contractors in green facade design and maintenance.

- v. Private developers and construction firms are encouraged to adopt green facades in new and retrofitted projects to align with sustainability goals.
- vi. Community-based organizations and NGOs can support public awareness campaigns and facilitate local engagement in the maintenance and monitoring of facade systems.
- vii. Future researchers should conduct empirical field studies to quantify thermal benefits, user perceptions, and long-term maintenance needs specific to Lagos.

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