E-Journal of Humanities, Arts and Social Sciences (EHASS)
ISSN – Online 2720-7722 | Print 2821-8949
Volume 6 Issue 14 2025 pp 3616 - 3642
Available online at: https://noyam.org/journals/ehass/
DOI: https://doi.org/10.38159/ehass.20256148

Greening Brick and Mortar in South Africa: A Critical Review of Green Architecture and Green Technologies

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ABSTRACT

This paper presents a critical review of green architecture and green technologies, focusing on their evolution and implementation within the South African context. As climate change, resource scarcity, and urbanisation accelerate, the construction industry in South Africa is also arguably increasingly embracing sustainable building practices. This study, in turn, employed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology to systematically review existing literature on green architecture and technologies relevant to South Africa from 2015 to 2024. Using a clear and reproducible process of screening and selection of peer-reviewed studies, the study synthesized and identified trends, challenges, and opportunities in the greening of brick-and-mortar construction. The findings reveal an increasing recognition and implementation of sustainable practices, especially in the utilisation of alternative materials, energy-efficient design, and water-conserving technologies. The review also recognizes considerable obstacles, such as elevated costs, insufficient regulatory enforcement, and a deficiency in technical proficiency. For the more successful integration of green design into mainstream construction, there is a demand for policy alignment, stakeholder education, and incentives for innovation. This assessment, borne out by the literature review, enhances the comprehension of sustainable development in the Global South and provides a basis for future research and practice in green architecture and green technology.

Keywords: Green architecture, Green technologies, Green bricks, Green mortar, South Africa, PRISMA, Sustainable construction

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Publication History
Received: 4th June, 2025
Accepted: 16th October, 2025
Published online:
29th December, 2025

To Cite this Article:
Makandwa, Tackson, and Maheshvari Naidu. "Greening Brick and Mortar in South Africa: A Critical Review of Green Architecture and Green Technologies." *E-Journal of Humanities, Arts and Social Sciences* 6, no. 14 (2025): 3616 - 3642, https://doi.org/10.38159/ehass.20256148.

INTRODUCTION

This paper presents a critical overview of green architecture and green technologies, focusing on their evolution and implementation within the South African context. Despite ongoing efforts to promote sustainable construction, its implementation remains limited in Africa.[1] Research points that the global construction environment is a major contributor to pollution, causing greater environmental degradation

[1] Frank Victor Mushi, Huba Nguluma, and Jacob Kihila, "Factors Influencing Adoption of Green Buildings in Tanzania: A Qualitative Case Study," *International Journal of Building Pathology and Adaptation* 43, no. 5 (2025): 1255–78; Oluwaseun Dosumu and Clinton Aigbavboa, "Drivers and Effects of Sustainable Construction in the South African Construction Industry," *Acta Structilia* 28, no. 2 (2021): 78–107; Bankole O Awuzie et al., "Evaluation of Factors Influencing Environmental Sustainability Performance of Construction Projects in South Africa," *Sustainability and Climate Change* 14, no. 2 (2021): 122–32; Clinton Aigbavboa, Ifije Ohiomah, and Thulisile Zwane, "Sustainable Construction Practices:'A Lazy View' of Construction Professionals in the South Africa Construction Industry," *Energy Procedia* 105 (2017): 3003–10.

than most other industries, adversely affecting the natural environment and air quality.[2] Consequently, the modern built environment must emphasise sustainable enhancements that alleviate the ecological impacts of construction practices. Sustainable development is increasingly acknowledged as the optimal approach for tackling the intricate, interrelated challenges of contemporary society, meant to benefit both current and future generations, while ensuring the enduring conservation of the planet and its natural resources.[3] In turn, the built environment is crucial in influencing urban sustainability and livability, as buildings and infrastructure substantially contribute to environmental degradation, energy consumption, and greenhouse gas emissions.[4] In Africa and in South Africa, concerns regarding climate change, urbanisation, and human wellbeing have heightened the necessity for more sustainable and habitable cities. The nation's swift urbanisation has strained infrastructure, services, and resources, prompting concerns regarding the standard of living and welfare of urban inhabitants.[5]

Green design and technologies offer an effective answer to these difficulties by minimising the environmental impact of buildings and promoting sustainable development.[6] Green buildings seek to reduce their environmental impact by utilising sustainable resources, energy-efficient technologies and innovative design approaches. Renewable energy systems and green roofs can be incorporated into buildings to diminish their environmental impact.[7] Green architecture and technologies are becoming increasingly significant in South Africa, propelled by governmental efforts, industrial innovation, and community engagement. The South African Green Building Council (SAGBC) has established a green building rating system that functions as a framework for the design and construction of sustainable buildings.[8] This rating system assesses buildings according to their environmental performance, energy efficiency, and social accountability.

This systematic review seeks to present a critical review of green architecture and green technologies, focusing on their evolution and implementation within the South African context. The investigation will examine the current state of green building techniques, encompassing green building rating systems, energy-efficient design concepts, and the utilisation of sustainable materials. The review will examine the benefits and drawbacks of sustainable design and technologies across all construction industry in South Africa, including possible energy savings, water conservation, and decreases in greenhouse gas emissions. Also, the review will delineate options for enhancing sustainability in constructed environments, encompassing governmental incentives, education, training, and technical advancements. This review aims to assess the present condition of green architecture and technology to promote the advancement of more sustainable and habitable cities, as well as to foster the broader implementation of green building practices and technologies within the built environment. Efforts to make the housing sector more environmentally friendly are sometimes perceived as expensive and labour-intensive,[9] yet South Africa's approach to present construction difficulties will profoundly influence its capacity to develop resilient communities and foster sustainable living for its citizens.

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[2] Sukanya Mehra et al., "Impact of Construction Material on Environment," in *Ecological and Health Effects of Building Materials* (Springer, 2021), 427–42; Daniel Cheriyan and Jae-ho Choi, "A Review of Research on Particulate Matter Pollution in the Construction Industry," *Journal of Cleaner Production* 254 (2020): 120077.

[3] N. P. Hariram et al., "Sustainalism: An Integrated Socio-Economic-Environmental Model to Address Sustainable Development and Sustainability," *Sustainability* 15, no. 13 (2023): 10682; Deepak Kumar Garg, "Environmental Challenges and Sustainable Development," *Journal of Global Values* 14 (2023): 203–10; Justice Mensah, "Sustainable Development: Meaning, History, Principles, Pillars, and Implications for Human Action: Literature Review," *Cogent Social Sciences* 5, no. 1 (2019): 1653531.

[4] David Emanuel Andersson and Åke E Andersson, "Sustainability and the Built Environment: The Role of Durability," *Sustainability* 11, no. 18 (2019): 4926; Mohammad Shahidehpour, Zhiyi Li, and Mehdi Ganji, "Smart Cities for a Sustainable Urbanization: Illuminating the Need for Establishing Smart Urban Infrastructures," *IEEE Electrification Magazine* 6, no. 2 (2018): 16–33.

[5] Robert Mutemi Kajiita and Simon Murote Kang'ethe, "Socio-Economic Dynamics Inhibiting Inclusive Urban Economic Development: Implications for Sustainable Urban Development in South African Cities," *Sustainability* 16, no. 7 (2024): 2803.

[6] Constantin C Bungau et al., "Green Buildings as a Necessity for Sustainable Environment Development: Dilemmas and Challenges," *Sustainability* 14, no. 20 (2022): 13121.

[7] Bungau et al., "Green Buildings as a Necessity for Sustainable Environment Development: Dilemmas and Challenges"; Mara Lombardi et al., "Green Tunnel Solutions: An Overview of Sustainability Trends in the Last Decade (2013–2022)," *Buildings* 13, no. 2 (2023): 392.

[8] GBCSA, "Net Zero Movement," in *Conference Proceedings.* (Cape Town.: https://gbcsaconvention.org.z, 2018).

[9] E. S. E. Varghese, " Designing Guidelines for Sustainable Housing: What We Learn from the Development of the Green Building Sector in South Africa.," 2022.

Green Building (GB) - Definition and Overview

Several scholars have shed light on the concept of green building. According to Howe and Cole, a green building is defined as one that is engineered, built, refurbished, or managed in an environmentally sustainable and resource-efficient manner throughout its lifecycle, emphasising energy efficiency, water conservation, waste reduction, pollution mitigation, and the utilisation of resource-efficient materials.[10] Gunnell et al. assert that green buildings emphasise energy and water efficiency while employing biodegradable materials that do not harm the environment, hence fostering healthier and more sustainable living or working conditions.[11] Nhamo and Mjimba underscore that the green building process acknowledges the significance of interconnectivity; these buildings are not standalone entities but integral components of a larger urban framework that encompasses transportation networks and services.[12] This interconnectedness highlights the comprehensive essence of green construction, which advocates for "green infrastructure" concepts and tackles global challenges encompassing climate change, energy efficiency, and renewable energy.[13]

Moreover, green buildings incorporate design, construction, and operational methods that seek to substantially mitigate or eradicate adverse environmental effects while enhancing resource efficiency and encouraging healthier living and working environments.[14] The World Green Building Council argues that to achieve these objectives, internationally acknowledged rating systems such as LEED (USA), BREEAM (UK), and Green Star (Australia) have been instituted to certify buildings that comply with rigorous sustainability criteria.[15] The Green Star South Africa Rating System, derived from the Australian model, offers a framework for the construction of sustainable buildings in South Africa, assessing them on environmental performance, energy efficiency, and social responsibility. The utilization of rating systems is expanding in South Africa, as developers and architects increasingly implement these standards to guarantee adherence to both local and international sustainability benchmarks.[16]

A fundamental aspect of green building initiatives is the thorough and integrated design process, which considers the distinctive architectural features frequently lacking in conventional buildings. The increasing interest in eco-friendly design and technologies in recent years has been propelled by pervasive concerns over environmental sustainability and human well-being.[17] Green buildings seek to mitigate environmental impact by employing sustainable materials and energy-efficient technologies, and creative design methodologies.[18] Thus, this systematic literature review seeks to deliver a thorough overview of the present status of green architecture and technologies, analyzing their advantages, problems, and future potential in sustainable development.

In Africa, the benefits of green buildings are extensively recorded and encompass reduced energy usage, water preservation, and decreased operational expenses.[19] Moreover, green buildings have demonstrated the capacity to enhance indoor air quality, promote occupant health and productivity, and elevate property values.[20] Research in South Africa has consistently demonstrated that green design and technologies promote sustainable development while simultaneously alleviating environmental degradation.[21]

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[10] J Cullen Howe, "Overview of Green Buildings," *Envtl. L. Rep. News & Analysis* 41 (2011): 10043; Laura B Cole, "Green Building Literacy: A Framework for Advancing Green Building Education," *International Journal of STEM Education* 6, no. 1 (2019): 18.

[11] Kelly Gunnell, Chrisna Du Plessis, and Jeremy Gibberd, "Green Building in South Africa: Emerging Trends," *Department of Environmental Affairs and Tourism (DEAT)*, 2009.

[12] Godwell Nhamo and Vuyo Mjimba, *The Green Building Evolution* (African Books Collective, 2019).

[13] Nhamo and Mjimba, *The Green Building Evolution*.

[14] Godwell Nhamo and Vuyo Mjimba, *Sustainable Development Goals and Institutions of Higher Education* (Springer, 2019).

[15] World Green Building Council., *World Green Building Council.* , 2025.

[16] GBCSA, "Net Zero Movement."

[17] Bungau et al., "Green Buildings as a Necessity for Sustainable Environment Development: Dilemmas and Challenges."

[18] GBCSA, "Net Zero Movement."

[19] Faith Owoha et al., "Categorising Green Building Features in Developing Countries: The Case of South Africa," *Journal of Engineering, Design and Technology* 20, no. 6 (2022): 1627–47; Bungau et al., "Green Buildings as a Necessity for Sustainable Environment Development: Dilemmas and Challenges"; Mushi, Nguluma, and Kihila, "Factors Influencing Adoption of Green Buildings in Tanzania: A Qualitative Case Study."

[20] Mushi, Nguluma, and Kihila, "Factors Influencing Adoption of Green Buildings in Tanzania: A Qualitative Case Study"; Bungau et al., "Green Buildings as a Necessity for Sustainable Environment Development: Dilemmas and Challenges."

[21] Nhamo and Mjimba, *The Green Building Evolution*; Owoha et al., "Categorising Green Building Features in Developing Countries: The Case of South Africa"; Dosumu and Aigbavboa, "Drivers and Effects of Sustainable Construction in the South African Construction

Cities within the Framework of Climate Change

Cities are widely acknowledged as crucial contributors to the global response to climate change, with sustainable building techniques serving a fundamental role in both mitigation and adaptation strategies.[22] The United Nations indicates that cities account for almost 70% of worldwide greenhouse gas emissions, underscoring their vital role in any climate change mitigation approach.[23] Green building practices, encompassing energy-efficient design, incorporation of renewable energy systems, and the utilization of sustainable materials, present a viable approach to reducing the carbon footprint of urban structures and infrastructure, thereby making a substantial contribution to climate change mitigation.[24]

In addition to mitigation, green buildings provide crucial advantages for climate change adaptation. As urban areas encounter increasing temperatures, more frequent extreme weather conditions, and various climate-related issues, sustainable building methods can mitigate the susceptibility of urban infrastructure. Features like green roofs and walls offer insulation, mitigating the urban heat island effect, while simultaneously fostering biodiversity by establishing habitats for urban wildlife.[25] These initiatives enhance urban resilience to the effects of climate change and simultaneously elevate the standard of living for city dwellers.

Housing and Green Sustainability in Africa

Green buildings are gaining popularity globally owing to the energy crisis, global warming, and other environmental challenges of the 21st century. Green buildings are designed to mitigate ecological effects and decrease carbon emissions, increasingly vital for environmentally conscious professionals.[26] This increased awareness has amplified individuals' willingness to invest additional funds in properties that prioritise ecological sustainability. Green buildings are essential for mitigating global warming, energy inefficiency, and the depletion of natural resources. Housing constitutes a significant challenge in South Africa, exacerbated by an extraordinary demand and limited supply capacity. Practitioners in the housing sector, both public and private, often address this difficulty by focusing on urgent demands instead of strategising for long-term advantages. Construction techniques are increasingly unsustainable, necessitating a transition from traditional approaches to those that foster sustainability.[27] Vijayan et. al., argue that, to adhere to sustainable criteria, the Architecture, Engineering, and Construction (AEC) sector must function within the earth's capacity to assimilate the waste and pollutants produced by its operations, while perpetually advancing more stringent standards for the extraction and transformation of raw materials.[28] Sustainable construction and green initiatives are being embraced in Africa to mitigate environmental effects and foster eco-friendly growth.[29]

Moreover, Maller et. al., note that engaging in home renovation is intricate and distressing; however continues to be a prevalent occurrence.[30] Home renovators aiming to reduce their environmental impact face increased complexities. Increasingly, chances to enhance a building's performance manifest during the course of home renovations, leading to the emergence of "green renovations". In South Africa, the adoption of green construction materials and energy-efficient technologies is becoming more

Industry"; Aigbavboa, Ohiomah, and Zwane, "Sustainable Construction Practices:'A Lazy View' of Construction Professionals in the South Africa Construction Industry."

[22] Bongani Chavalala, Vuyo Mjimba, and Godwell Nhamo, "Green Building in the Context of Climate Change," *The Green Building Evolution*, 2019, 22; Cole, "Green Building Literacy: A Framework for Advancing Green Building Education."

[23] Sara Thabit et al., "United Nations Human Settlements Programme (UN-Habitat)," 2020.

[24] Sou-Sen Leu and Jun-Yang Shi, "Effective Green Building Design Assessment Support Using Sequential Multidisciplinary Design Optimization," *Journal of Building Engineering* 96 (2024): 110543.

[25] Flavie Mayrand and Philippe Clergeau, "Green Roofs and Green Walls for Biodiversity Conservation: A Contribution to Urban Connectivity?," *Sustainability* 10, no. 4 (2018): 985.

[26] Jitender Kumar et al., "Exploring Sustainable Pathways in the Green Housing Market: An Investigation of Green Housing Purchase Behavior by Using PLS-SEM," *Property Management* 43, no. 2 (2025): 288–304.

[27] Varghese, " Designing Guidelines for Sustainable Housing: What We Learn from the Development of the Green Building Sector in South Africa."

[28] Dhanasingh Sivalinga Vijayan et al., "A State of Review on Instigating Resources and Technological Sustainable Approaches in Green Construction," *Sustainability* 15, no. 8 (2023): 6751.

[29] Mushi, Nguluma, and Kihila, "Factors Influencing Adoption of Green Buildings in Tanzania: A Qualitative Case Study"; Bungau et al., "Green Buildings as a Necessity for Sustainable Environment Development: Dilemmas and Challenges."

[30] Cecily Maller, Ralph Horne, and Tony Dalton, "Green Renovations: Intersections of Daily Routines, Housing Aspirations and Narratives of Environmental Sustainability," *Housing, Theory and Society* 29, no. 3 (2012): 255–75.

prevalent, partly due to government laws and incentives. A primary obstacle to the execution of sustainable construction practices in Africa and South Africa in particular is the insufficient understanding and education regarding the benefits and techniques of green building.[31]

The knowledge gap can make it difficult for builders, policymakers, and other stakeholders to make informed decisions regarding sustainable construction practices. Research indicates that educational and training programs can effectively tackle this obstacle and facilitate the implementation of sustainable construction techniques.[32] Government rules and policies are essential in advancing sustainable construction practices in Southern Africa. A significant milestone has been realised in the current G20 resolution, guided by the spirit of Ubuntu (Bantu African-origin value systems that emphasise the interconnectedness of individuals with their surrounding societal and physical worlds). South Africa's G20 Presidency has a strong greening agenda, evident in its theme "Solidarity, Equality, and Sustainable Development".[33] This theme is reflected in various focus areas, including energy transitions, sustainable development, and climate change mitigation. The G20 also aims to address environmental challenges like biodiversity loss, land degradation, and ocean pollution.[34]

The South African government has instituted several programs to advance green building and sustainable development, such as the Green Building Council of South Africa and the National Building Regulations.[35] These initiatives have facilitated growth in the green construction sector and advanced sustainable development techniques. Notwithstanding advancements in sustainable construction, numerous issues remain to be resolved. Masia et al. identify the significant difficulty of elevated initial costs associated with eco-friendly construction materials and technologies in sustainable development in South Africa.[36] Through this review, we aim to further explore the role of green building practices in advancing sustainability and addressing pressing environmental challenges.

METHODOLOGY

A systematic review was conducted following the guidelines outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement,[37] ensuring a structured, transparent, and reproducible approach. Key components of the PRISMA framework include the formulation of a clear research question, the systematic identification of relevant literature, and the application of rigorous inclusion and exclusion criteria. The framework also emphasizes the importance of visualizing the review process through a PRISMA flow diagram (see figure 1), which outlines the number of studies identified, screened, and included at each stage of the review. This methodological rigour allows the research to achieve a thick analysis that is critical for publication in scholarly outlets. By adhering to the PRISMA framework, the research will not only achieve a high standard of methodological quality but also enhance the credibility and impact of its findings, ensuring that they are well-positioned to inform both academic and practical applications.

The systematic approach further allows for the identification of emerging themes, trends, and gaps in the literature, providing a valuable roadmap for advancing knowledge in the field. This review aimed to evaluate the current body of literature on green architecture and green technologies in Africa, with a specific focus on South Africa. The review followed a systematic process that included a comprehensive search strategy, selection of relevant studies according to established inclusion and exclusion criteria, data

[31] Abimbola Olukemi Windapo and Jack Steven Goulding, "Understanding the Gap between Green Building Practice and Legislation Requirements in South Africa," *Smart and Sustainable Built Environment* 4, no. 1 (2015): 67–96; O A Oguntona et al., "Benefits and Drivers of Implementing Green Building Projects in South Africa," in *Journal of Physics: Conference Series*, vol. 1378 (IOP Publishing, 2019), 032038.

[32] Amos Darko and Albert Ping Chuen Chan, "Strategies to Promote Green Building Technologies Adoption in Developing Countries: The Case of Ghana," *Building and Environment* 130 (2018): 74–84; Albert P C Chan et al., "Barriers Affecting the Adoption of Green Building Technologies," *Journal of Management in Engineering* 33, no. 3 (2017): 04016057.

[33] G20 South Africa., *G20 South Africa.*, 2025.

[34] G20 South Africa., *G20 South Africa.*

[35] Gunnell, Du Plessis, and Gibberd, "Green Building in South Africa: Emerging Trends."

[36] Thendo Masia, Kahilu Kajimo-Shakantu, and Akintayo Opawole, "A Case Study on the Implementation of Green Building Construction in Gauteng Province, South Africa," *Management of Environmental Quality: An International Journal* 31, no. 3 (2020): 602–23.

[37] David Moher et al., "Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement," *Bmj* 339 (2009); Ayşe Adin Selçuk, "A Guide for Systematic Reviews: PRISMA," *Turkish Archives of Otorhinolaryngology* 57, no. 1 (2019): 57; Rafael Sarkis-Onofre et al., "How to Properly Use the PRISMA Statement," *Systematic Reviews* 10, no. 1 (2021): 117.

extraction and quality evaluation. A comprehensive and systematic literature search was conducted across several academic databases and search engines to guarantee the retrieval of relevant studies.

The Search Strategy

The databases and search engines used included Google Scholar, PubMed/MEDLINE, ProQuest and Scopus. The search relied on the following search terms: "green architecture", "green technologies", “green bricks”, “green mortar”, “green sustainability”, "sustainable buildings" and "South Africa". These terms were chosen to capture a wide range of studies related to green architecture and technologies, particularly those applicable to the South African context. The search was conducted using various combinations of these keywords to ensure the retrieval of a broad spectrum of relevant articles.

Inclusion and Exclusion Criteria

The systematic review employed a methodical approach to identify, select, and exclude studies according to established inclusion and exclusion criteria. The inclusion and exclusion criteria were established to refine the search results and guarantee the relevance and quality of the studies incorporated in the review. The inclusion criteria specified that only studies published in peer-reviewed journals and reports from 2015 to 2024 were considered (see Figure 1 below for the step-by-step inclusion and exclusion process). This permitted a focus on the current dynamics in the field of green construction and technologies. More importantly, technological advancements are rapid and require a clear time window to guide the study. The database and manual search of article bibliographies provided 572 articles and reports. Of the 572 articles and reports screened, 82 articles were excluded due to duplicate investigations. This means 490 articles were available for retrieval. Further, 340 articles were excluded for various reasons, including not being related to the topic of green architecture or green technologies, or they did not focus on South Africa, and some were not peer-reviewed journal articles.

These included conference papers, editorials and opinion pieces. 150 articles underwent full-text review, of which 110 articles were excluded at this stage for various reasons. Eventually, 40 studies were incorporated into the systematic review. Figure 1 being the PRISMA flow chart, captures the salient features of the process. The studies that met the inclusion criteria were synthesised to identify key themes and trends related to green architecture and technologies in South Africa. The data was analyzed using a thematic approach, which involved grouping studies based on common themes. This synthesis allowed for the identification of both the benefits and challenges associated with green building practices in South Africa, as well as the opportunities for improving sustainability in the construction industry.

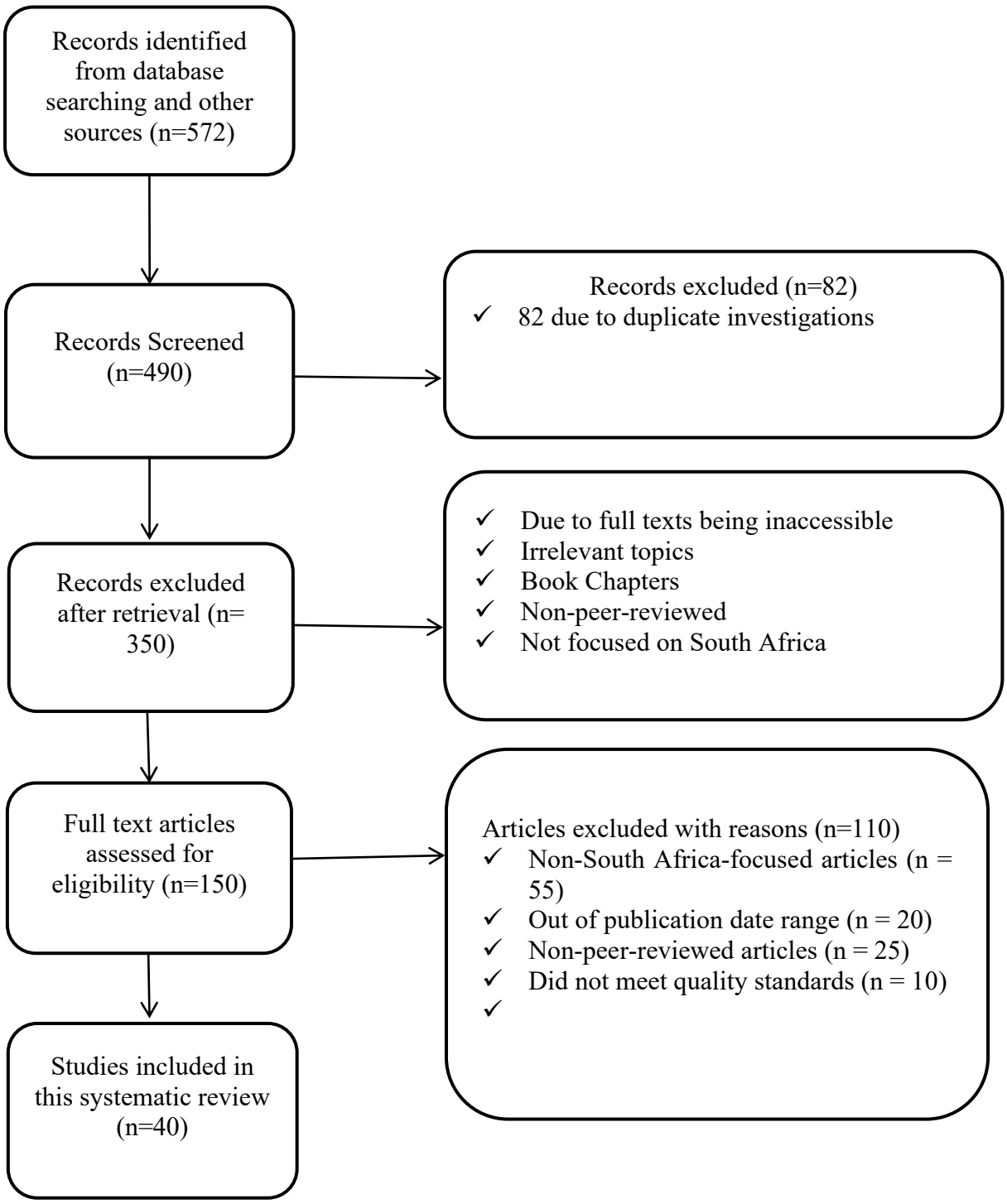
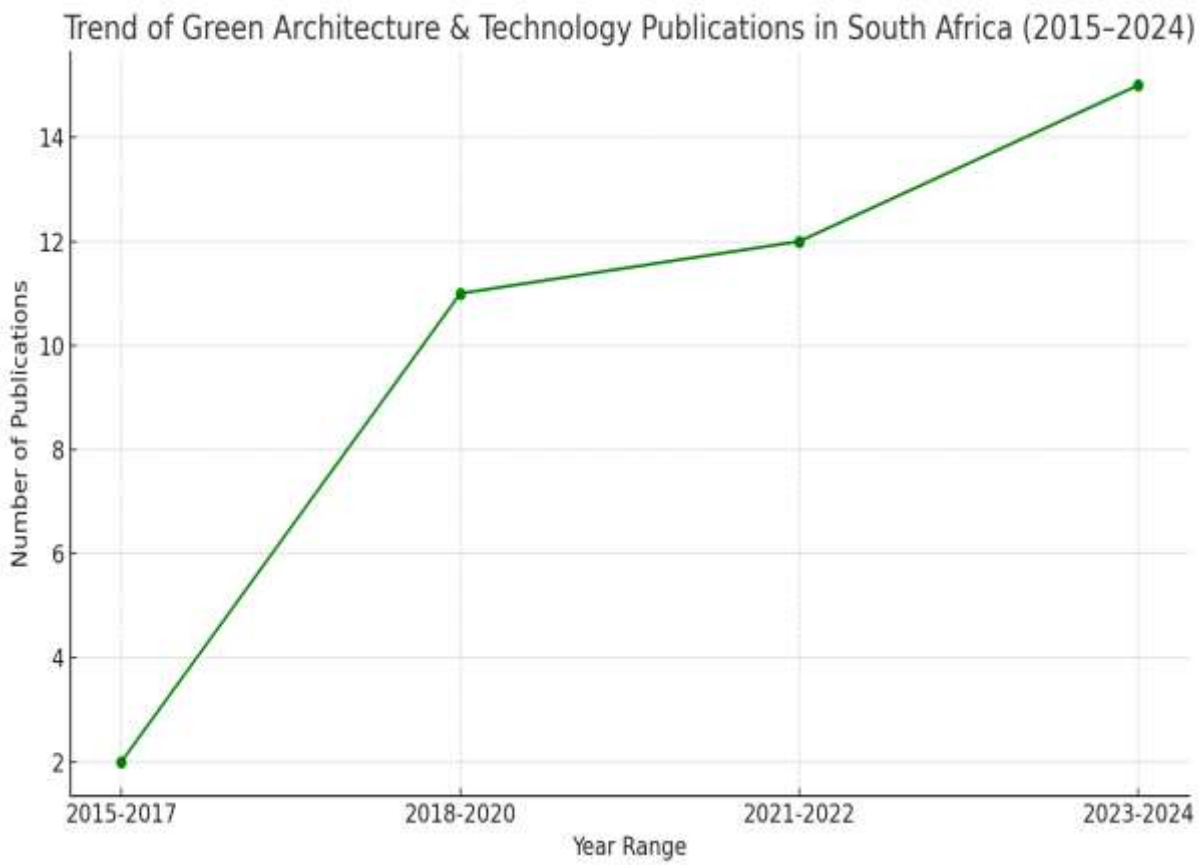


Figure 1: Source selection process from literature databases

PRESENTATION OF RESULTS AND DISCUSSION

Perhaps somewhat predictably, between 2015 and 2024, the number of publications on green buildings and green technologies in South Africa increased significantly. The pattern in the trend analysis can be observed in Figure 2 below.

Figure 2: Trend Analysis showing the 10-year developments in green architecture and green technology in South Africa



From 2015 to 2024, the number of academic and professional publications on green architecture and green technology in South Africa has shown a distinct rising trend. The data reveals that the interval from 2015 to 2017 saw minimal scholarly activity, with merely two articles documented. This indicates that sustainability issues were still developing in the national dialogue or that obstacles such as insufficient funds, expertise, or institutional emphasis may have hindered research efforts during this period. A significant rise is shown from 2018 to 2020, with the number of publications escalating to 11. The growing trend persists, though at a diminished rate, from 2021 to 2022, with 12 publications. The growth, however, is less pronounced than the prior surge, indicating ongoing academic and professional commitment to green solutions. This plateau indicates a maturing of the discourse, characterized by the emergence of more sophisticated and technical research rather than merely an increase in interest based on volume. The latest term, spanning 2023 to 2024, indicates an additional increase to 15 publications. This indicates a revitalized and potentially more varied involvement with green architecture and technology, likely driven by policy measures like the 2024 Climate Change Act, augmented international funding, and a wider societal movement towards equitable energy transitions and climate adaptation. It signifies the integration of environmental issues as fundamental priorities within South Africa's research and innovation frameworks. The prevailing trend indicates an increasing and intensifying interest in sustainable construction and technologies, along with global and local demands for environmental stewardship and

economic resilience. Table 1 details the number of studies, the key developments, adoption rates and key measurements of the period under review.

Time Period	Number of studies	Key Developments	Adoption Rates	Impact Measures
2015–2017	2	Early adoption of Green Star/EDGE, focus on the commercial sector	Low-moderate, mainly commercial/high-end	Initial energy/water savings, case studies
2018–2020	9	Expansion to residential, low-income pilots, and more reviews	Gradual increase, some low-income pilots	Life Cycle Assessment/Life Cycle Costing studies, operational savings, and social acceptance issues
2021–2022	10	Broader research, digital technology, policy focus	Moderate, more diverse sectors	Quantified energy/carbon savings, cost-benefit analyses, regulatory reviews
2023–2024	9	Focus on advanced/alternative technology (blue-green roofs, sandbags, timber), market value studies.	Growing awareness, slow for innovative technology	Mixed evidence on market value, persistent barriers, and policy gaps

Table 1: detailing the major trends and developments during the period of study (2015 – 2024)

Characteristics of included studies

Architects and designers in the country are leading the way in creating top green buildings and implementing green technologies that prioritize natural ventilation, incorporate energy-efficient technologies, and utilizing sustainable building materials. A critical review of the existing body of knowledge revealed significant insights into the evolution, benefits, and barriers of sustainable building practices. This critical literature review study outlines the characteristics of the research and their significant conclusions on green architecture and green technology in South Africa as follows - see Table 2 below.

Table 2: detailing the characteristics of included studies

Study	Study Focus	Type	Geographic Region	Key Findings
Masia et al.,[38]	Green building principles, benefits, barriers in commercial buildings	Qualitative case study (2 Green Star South Africa-certified buildings)	Gauteng Province, South Africa	Energy and water efficiency implemented; 35% energy savings; cost savings drive adoption; lack of incentives and benchmarking data are barriers.
Moghayedi et al.,[39]	Impact of innovative	Mixed-methods, multi-case study	South Africa (national)	Innovative technology yields up to 23% energy savings;

[38] Masia, Kajimo-Shakantu, and Opawole, "A Case Study on the Implementation of Green Building Construction in Gauteng Province, South Africa."

[39] Alireza Moghayedi et al., "Appraising the Nexus between Influencers and Sustainability-oriented Innovation Adoption in Affordable Housing Projects," *Sustainable Development* 30, no. 5 (2022): 1117–34.

	technologies on energy in commercial properties			carbon dioxide footprint reduced; improved productivity; slow adoption due to regulation.
Isimbi and Park,[40]	EDGE accreditation for residential complexes to enhance design efficiency	Quantitative analysis of 17 complexes	South Africa (major cities)	Average 29.7% energy, 31% water, 54% embodied energy savings; no correlation with floor area; positive for affordability
Windapo et al., [41]	Sustainable vs. conventional technology in low-income housing	Mixed-methods case study & survey	All 9 provinces, South Africa	Sustainable technology has lower carbon dioxide emissions, a higher cost, but shorter construction time, and recommends targeted measures for low-income housing.
Simpeh et al.,[42]	Challenges to green building implementation	Quantitative survey (sample size = 106)	Four provinces, South Africa	High upfront costs, lack of skilled professionals, regulatory barriers, and need for early challenge identification.
Hoffman et al.,[43]	Trends in Green Star South Africa credits in office buildings	Quantitative analysis (sample size = 95 buildings)	South Africa (national)	High achievement in water or energy credits; low in innovation; trends may affect sustainability outcomes
Saini and Ledwani,[44]	Life Cycle Assessment/Life Cycle Costing (LCA/LCC) of sandbag housing	Quantitative LCA/LCC	Western Cape, South Africa	Sandbag technology: 189–174 kg carbon dioxide equivalent per square meter upfront; 262–247 kg carbon dioxide equivalent per square meter whole life; affordable, low-carbon, but limited to single-storey
Emere et al.,[45]	Sustainable building construction features for project delivery in South Africa	Quantitative survey (sample size = 281)	Gauteng Province, South Africa	Key features: resource use, waste minimization, sustainable design; Building Information Modeling (BIM), smart appliances, renewables highlighted
Sundayi et al.,[46]	The costs and benefits of	Mixed-methods (interviews, case study)	KwaZulu-Natal, South Africa	4.74% cost premium; payback 3.5–4.4 years; internal rate of

[40] Delphine Isimbi and Jihyun Park, "The Analysis of the EDGE Certification System on Residential Complexes to Improve Sustainability and Affordability," *Buildings* 12, no. 10 (2022): 1729.
[41] Abimbola Oluwakemi Windapo and Alireza Moghayedi, "Adoption of Smart Technologies and Circular Economy Performance of Buildings," *Built Environment Project and Asset Management* 10, no. 4 (2020): 585–601.
[42] Eric Kwame Simpeh and John Julian Smallwood, "An Integrated Model for Predicting the Probability of Adoption of Green Building in South Africa," *Journal of Engineering, Design and Technology* 18, no. 6 (2020): 1927–50.
[43] Danie Hoffman et al., "Trends in Application of Green Star SA Credits in South African Green Building," *Acta Structilia* 27, no. 2 (2020): 1–29.
[44] Himanshi Saini and Lalita Ledwani, "A Review on Application of Green Materials in Different Construction Systems, Their Processing, Surface Modification, Testing and Certification," *MRS Energy & Sustainability* 11, no. 2 (2024): 267–303.
[45] Chijioke Emmanuel Emere et al., "A Principal Component Analysis of Sustainable Building Construction Features for Project Delivery in South Africa," *Journal of Engineering, Design and Technology*, 2024.
[46] Shallyne Sundayi, Vittorio Tramontin, and Claudia Loggia, "An Investigation into the Costs and Benefits of Green Building in South Africa," *IEEE Technology and Society Magazine*, 2015, 77–82.

	green building in South Africa			return 28.55%; operational savings significant
Aghimien et al., [47]	Blue-green roofs: knowledge, barriers, motivations	Quantitative exploratory survey (sample size = 85)	South Africa (national)	Growing awareness, slow adoption; barriers: technical, economic, regulatory; stormwater management as key driver
du Toit and Wagner,[48]	Uptake of stormwater controls in a residential estate	Quantitative case study (sample size = 73)	Pretoria, Gauteng, South Africa	Permeable paving (44%), rainwater harvesting (28%), retention ponds (30%), green roofs (2%); attitudes and peer pressure key
Crafford et al.,[49]	Wood-based construction: resource and impact	Quantitative modelling	South Africa (Eastern Cape, KwaZulu-Natal, Western Cape)	20% wood-based market: 4.9% embodied energy/global warming potential reduction; all-wood: 30% reduction; local resources sufficient
Owoha et al.,[50]	Categorizing green building features	Quantitative survey (sample size = 107)	Western Cape, South Africa	Top features: water-efficient fittings, photovoltaic, water metering; grouped into 7 feature categories.
Simpeh and Smallwood,[51]	Perceived benefits of green buildings	Quantitative survey (sample size = 106)	Four provinces, South Africa	20–40% energy, 30–40% water savings; benefits: cost, health, community; no market value premium.
Adetooto and Windapo,[52]	Social acceptance of sandbag technology	Mixed-methods (literature review, survey sample size = 228)	South Africa (national)	Barriers: lack of knowledge, training, skills; sandbag technology is sustainable, low-cost, but has low adoption.
Bisola et al.,[53]	Green features and rental value	Mixed-methods (text mining, machine learning)	Cape Town, Western Cape	Eco-friendly attributes exert minimal influence on rental value; floor area, bathrooms, and furniture are more important.
Boshoff and Mey.[54]	The Building Emission Reduction	Qualitative review	South Africa (national)	16% energy intensity reduction possible by 2030; offset by

[47] Douglas Omoregie Aghimien, John Aliu, and Clinton Aigbavboa, "Exploring Blue-Green Roof for a Sustainable Built Environment in South Africa," *Smart and Sustainable Built Environment* (Emerald Publishing Limited, 2024).

[48] Jacques du Toit and Claire Wagner, "Property Owners' Uptake of Stormwater Source Controls: A Case Study of a Low-Density Upmarket Residential Estate in Pretoria, South Africa," *Urban Water Journal* 19, no. 5 (2022): 538–45.

[49] Philip L Crafford and C Brand Wessels, "South African Log Resource Availability and Potential Environmental Impact of Timber Construction," *South African Journal of Science* 116, no. 7–8 (2020): 1–8.

[50] Owoha et al., "Categorising Green Building Features in Developing Countries: The Case of South Africa."

[51] Eric Kwame Simpeh and John Julian Smallwood, "Incentive Mechanism for Promoting the Uptake of Green Building in South Africa," *Open House International* 49, no. 2 (2024): 340–57.

[52] Johnson, Adetooto and Abimbola Windapo, "Concomitant Impediments to the Social Acceptance of Sandbag Technology for Sustainable and Affordable Housing Delivery: The Case of South Africa," *Buildings* 12, no. 6 (2022): 859.

[53] Tawakalitu Bisola Odubiyi et al., "Impact of Green Features on Rental Value of Residential Properties: Evidence from South Africa," *Real Estate* 1, no. 1 (2024): 65–79.

[54] Brian Boshoff and Cornelia Mey, "The Building Emission Reduction Potential of South African Residential Building Efficiency Tools–A Review," *Acta Structilia* 27, no. 2 (2020): 151–85.

	Potential Of South African Residential Building Efficiency Tools – A Review			floor area growth; more ambitious targets needed.
Adetooto et al.,[55]	Drivers/barriers to alternative building technology	Qualitative focus groups (sample size = 13)	Cape Town, Western Cape	Sandbag technology: sustainable, affordable, job creation; barriers: awareness, training, prototypes.
Marsh et al.,[56]	Barriers/drivers to sustainable construction	Integrative review	South Africa (national)	Barriers: socio-cultural, economic, stakeholder, political, technological; environmental benefits recognized.
Agbajor and Mewomo,[57]	Green building research synthesis	Scoping review	South Africa (national)	Growth in research; drivers: finance, digital technology, curricula; need for post-occupancy studies.
Adegun,[58]	Residents' Relationship with Green Infrastructure in Low-Income Housing.	Qualitative interviews/focus group	Cosmo City, Gauteng	Benefits: air quality, biodiversity, social capital; need for context-sensitive design.
Adegun,[59]	Just sustainability in informal settlement upgrading	Qualitative case study	Ruimsig informal settlement, Gauteng	Solar home systems, green spaces, reduced flood risk; social/institutional structures key.
Uche and Ngepah,[60]	Green technology, energy transition, resource rents	Quantitative econometric analysis	South Africa (national)	Clean energy transition; improves low-carbon footprint; green technology effect limited; resource rents mixed.
Gwedla et al.,[61]	Tree planting in low-cost housing	Mixed-methods survey (sample size = 800)	Eastern Cape	52% households have trees; willingness to participate is

[55] Johnson Adetooto, Abimbola Windapo, and Francesco Pomponi, "The Use of Alternative Building Technologies as a Sustainable Affordable Housing Solution: Perspectives from South Africa," *Journal of Engineering, Design and Technology* 22, no. 5 (2024): 1447–63.

[56] R J Marsh, A C Brent, and I H De Kock, "Understanding the Barriers and Drivers of Sustainable Construction Adoption and Implementation in South Africa: A Quantitative Study Using the Theoretical Domains Framework and COM-B Model," *Journal of the South African Institution of Civil Engineering= Joernaal van Die Suid-Afrikaanse Instituut van Siviele Ingenieurswese* 63, no. 4 (2021): 11–23.

[57] Favour D Agbajor and Modupe Cecilia Mewomo, "Green Building Research in South Africa: A Scoping Review and Future Roadmaps," *Energy and Built Environment* 5, no. 2 (2024): 316–35.

[58] Olumuyiwa Bayode Adegun, "Exploring Just Sustainability in Re-Blocking Intervention in a Johannesburg Informal Settlement," *Journal of Asian and African Studies* 53, no. 5 (2018): 782–96.

[59] Adegun, "Exploring Just Sustainability in Re-Blocking Intervention in a Johannesburg Informal Settlement."

[60] Emmanuel Uche and Nicholas Ngepah, "How Green-Technology, Energy-Transition and Resource Rents Influence Load Capacity Factor in South Africa," *International Journal of Sustainable Energy* 43, no. 1 (2024): 2281038.

[61] Nanamhla Gwedla, Charlie M Shackleton, and Lausanne Olvitt, "Trees Stocks in Domestic Gardens and Willingness to Participate in Tree Planting Initiatives in Low-Cost Housing Areas of the Eastern Cape, South Africa," *Urban Forestry & Urban Greening* 68 (2022): 127484.

				high; green space disparities persist
United Nations Environment Programme (UNEP)[62]	Green Economy Policy Review Of South Africa's Industrial Policy Framework	Report	South Africa (National)	South Africa seeks to shift towards an inclusive green economy, integrating economic advancement, social equity, and environmental sustainability. Nonetheless, both the economy and society are markedly unsustainable. The transition to an inclusive green economy represents a significant and transformative change. Industrial policy is fundamental to this process, particularly to facilitate a "just transition" and navigate a balancing act that maximizes the advantages of the change while minimizing the risks of inaction.
Pillay and Saha,[63]	Passive, Low-Energy Design and Green Star Strategy for Green Star-Certified Buildings in South Africa	Quantitative	South Africa (National)	The development of eco-friendly structures results in enhanced conditions for occupants and promotes sustainable architecture.
Loggia et al.,[64]	Sustainable housing in developing nations: Achieving social and environmental objectives through the "greening" of low-income communities in South Africa	Mixed methods, both qualitative and quantitative	eThekwini Municipality, Durban, South Africa.	The advancement of green retrofits presents significant prospects for enhancing buildings' energy efficiency, decreasing GHG emissions, engaging local communities, and increasing individuals' quality of life.
Adetooto and Windapo,[65]	Concurrent Barriers to the Societal Acceptance of	mixed method research approach that employs a	South Africa (National)	Insufficient comprehension of the advantages of sandbags, an absence of sandbag courses and training, and a deficiency in

[62] United Nations Environment Programme (UNEP), "Green Economy Policy Review of South Africa's Industrial Policy Framework," 2020.

[63] Theogan Logan Pillay and Akshay Kumar Saha, "Passive, Low-Energy Design and Green Star Strategy for Green Star-Rated Buildings in South Africa," *Energies* 15, no. 23 (2022): 9128.

[64] Claudia Loggia, Vittorio Tramontin, and Cristina Trois, "Sustainable Housing in Developing Countries: Meeting Social and Environmental Targets by 'Greening' Low-Income Settlements in South Africa," *International Journal Sustainable Policy Practice* 9, no. 4 (2015): 1–12.

[65] Adetooto, Windapo, and Pomponi, "The Use of Alternative Building Technologies as a Sustainable Affordable Housing Solution: Perspectives from South Africa."

	Sandbag Technology for Sustainable and Economical Housing Provision: The South African Context	comprehensive literature review in identifying 18 social barriers to using SBTs and a questionnaire survey of 228 building experts based in South Africa to obtain empirical data		professional expertise and skills. Significant constraints provide government agencies and construction partners with a framework to make informed and pragmatic decisions regarding the delivery of more sustainable and affordable housing.
Odubiyi et al.,[66]	Influence of Eco-Friendly Attributes on Rental Valuation of Residential Properties: Evidence from South Africa	Mixed methods approach of both qualitative and quantitative approaches		Data pertaining to 389 residential properties were gathered and compiled from a webpage. Text mining and machine learning algorithms were employed to assess the influence of eco-friendly attributes on the rental value of residential units. The findings revealed that floor area, quantity of bathrooms, and presence of furnishings are the three primary factors influencing the rental value of residential homes. Eco-friendly attributes are infrequently referenced in rental advertisements for residential buildings. The findings indicate that eco-friendly attributes contribute minimal value to residential homes in South Africa.

In analysing the characteristics of the green architecture and green technology in South Africa, Figure 3 below represents an overview of the key findings. These findings are structured around five central themes aligned with the scope of the study. These include energy efficiency, sustainable materials, the role of green technologies, adoption challenges, and policy frameworks. However, several challenges and barriers to adoption remain, including high upfront costs, lack of awareness and education, and regulatory hurdles.[67]

[66] Odubiyi et al., "Impact of Green Features on Rental Value of Residential Properties: Evidence from South Africa."
[67] Windapo and Moghayedi, "Adoption of Smart Technologies and Circular Economy Performance of Buildings."

Figure 3: Overview of word frequency visual analysis of thematic areas

Energy Efficiency in the South African Built Environment

The literature shows that energy efficiency has emerged as a central component in transforming the South African built environment toward sustainability. Driven by a confluence of global climate imperatives and local energy challenges, including load shedding, rising electricity tariffs, and dependence on carbon-intensive energy sources, stakeholders increasingly prioritise efficient design and operational practices.[68] The integration of passive architectural strategies, high-efficiency lighting, and advanced heating, ventilation, and air conditioning (HVAC) systems has become a hallmark of green building in South Africa.[69] These interventions collectively contribute to reduced energy consumption and improved occupant comfort, particularly in commercial and institutional facilities. As Vijayan et al., point out, when creating green buildings, it is necessary to remember that we are generating a new ecosystem, the basis of which is plants.[70] Green roofs are a typical anthropogenic ecosystem where human civilisation determines the composition of the soil profile (substrate) and vegetation, as well as the water regime. These factors interact and are confronted with the surrounding ecosystems.

Literature reveals empirical data from Green Star SA-certified buildings that provide strong evidence of the efficacy of sustainable design. According to the GBCSA, buildings rated under the Green Star system demonstrate energy savings of up to 50% compared to conventional structures.[71] These findings are consistent with international studies suggesting that high-performance green buildings consume significantly less energy due to the adoption of integrated design principles and energy management technologies.[72] The widespread adoption of Building Management Systems (BMS) has also played a critical role in optimising energy use through real-time monitoring and data-driven decision-making. Pillay and Saha note that in commercial contexts, particularly office buildings and shopping centers, BMS technologies have been found to reduce energy consumption by enabling predictive maintenance and adaptive climate control.[73]

[68] Abimbola Windapo et al., "Causality between Challenges, Availability, and Extent of Use of Local Building Materials," *South African Journal of Science* 118, no. 7–8 (2022): 1–11; Masia, Kajimo-Shakantu, and Opawole, "A Case Study on the Implementation of Green Building Construction in Gauteng Province, South Africa"; Tumai Murombo, "Regulatory Imperatives for Renewable Energy: South African Perspectives," *Journal of African Law* 66, no. 1 (2022): 97–122.

[69] GBCSA., "Net Zero Movement. ."

[70] Vijayan et al., "A State of Review on Instigating Resources and Technological Sustainable Approaches in Green Construction."

[71] Windapo et al., "Causality between Challenges, Availability, and Extent of Use of Local Building Materials"; Masia, Kajimo-Shakantu, and Opawole, "A Case Study on the Implementation of Green Building Construction in Gauteng Province, South Africa"; Isimbi and Park, "The Analysis of the EDGE Certification System on Residential Complexes to Improve Sustainability and Affordability."

[72] Darko and Chan, "Strategies to Promote Green Building Technologies Adoption in Developing Countries: The Case of Ghana."

[73] Pillay and Saha, "Passive, Low-Energy Design and Green Star Strategy for Green Star-Rated Buildings in South Africa."

However, the findings highlight that energy efficiency outcomes are not uniform across the country. According to Olawumi and Chan, regional variation in architectural responses to climate and geography influences the most effective efficiency strategies.[74] For instance, Matandirotya et. al. pointed out that in the highland provinces such as Gauteng, buildings often incorporate enhanced insulation and passive solar heating due to colder winters.[75] Conversely, structures in coastal provinces like KwaZulu-Natal emphasise cross-ventilation and solar shading to mitigate high humidity and heat loads.[76] These contextual differences underscore the importance of climate-responsive design that aligns with the distinct environmental characteristics of each region. Without such adaptation, energy-saving interventions may be rendered suboptimal or even counterproductive. In the same mood, Owoha et. al., remarked that a high-performance building façade and skylight form an important aspect of the building envelope in terms of contributing to energy saving by reducing the use of artificial lighting.[77] Findings from Owoha et al indicate that skylights are often located on the upper horizontal plane of buildings, filtering and bringing natural lighting into the building from the roof or any horizontal plane of buildings with good exposure to daylight.[78] In effect, high-performance building energy design increases building value by providing an adequate level of daylighting and a substantial reduction in the cost of energy annually.[79] This feature also adds value to buildings by minimising the heat island effect and provides improved indoor air quality and comfort level.

Most of the green buildings and sustainable construction papers from the 10-year period under study covered energy efficiency in great depth. The findings underline energy efficiency as a required criterion and a basic component of green and sustainable architecture. Other scholars have pointed out, many different built environment professionals, including architects and engineers, have proposed and used energy-efficient design optimisation as both a design philosophy and a pragmatic tool.[80] On the other hand, Owoha et.al., have said that solar technologies enable the extraction of a renewable energy source by using power from the sun, which is quite crucial in this age of ongoing electrical shortages and load shedding.[81] According to Ginidza, South Africa advocates for new energy transition strategies at the G20 2025 meeting point that Africa has the greatest solar potential and the fastest growing demand for energy services, which require partnership in the sector.[82] Emere et. al., argue that typical low-energy active renewable technologies are solar thermal collectors and biomass burners. The results imply that zero-energy buildings might be produced by transitioning to renewable energy sources.[83] To reduce the yearly energy needs for heat and power, buildings must employ renewable technology, including solar thermal, photovoltaic and wind turbines, which are environmentally friendly, efficient and healthy to society.[84] This emphasises the need to use renewable energy sources and materials in reaching sustainability objectives within the built environment sector. From minimizing energy consumption, advancing green building practices in South Africa rely on sustainable building materials, as detailed below.

Sustainable Materials and Construction Methods

Advancing green building practices in South Africa now depends on the combination of sustainable materials and building methods. A study by Vijayan et al. draws attention to the environmental depletion caused by raw material extraction for building and its growing contribution to pollution.[85] There has been a noticeable shift toward materials and techniques that lower embodied carbon, save ecological resources,

[74] Timothy O Olawumi and Daniel W M Chan, "A Scientometric Review of Global Research on Sustainability and Sustainable Development," *Journal of Cleaner Production* 183 (2018): 231–50.
[75] Newton R Matandirotya et al., "The Potential for Domestic Thermal Insulation Retrofits on the South African Highveld," *Clean Air Journal* 29, no. 1 (2019): 21–28.
[76] Matandirotya et al., "The Potential for Domestic Thermal Insulation Retrofits on the South African Highveld."
[77] Owoha et al., "Categorising Green Building Features in Developing Countries: The Case of South Africa."
[78] Owoha et al., "Categorising Green Building Features in Developing Countries: The Case of South Africa."
[79] Owoha et al., "Categorising Green Building Features in Developing Countries: The Case of South Africa."
[80] Pillay and Saha, "Passive, Low-Energy Design and Green Star Strategy for Green Star-Rated Buildings in South Africa"; Odubiyi et al., "Impact of Green Features on Rental Value of Residential Properties: Evidence from South Africa"; Adegun, "Exploring Just Sustainability in Re-Blocking Intervention in a Johannesburg Informal Settlement."
[81] Owoha et al., "Categorising Green Building Features in Developing Countries: The Case of South Africa."
[82] B. Ginidza, "South Africa Advocates for New Energy Transition Strategies at G20 Meeting ," 2025.
[83] Emere et al., "A Principal Component Analysis of Sustainable Building Construction Features for Project Delivery in South Africa."
[84] Emere et al., "A Principal Component Analysis of Sustainable Building Construction Features for Project Delivery in South Africa."
[85] Vijayan et al., "A State of Review on Instigating Resources and Technological Sustainable Approaches in Green Construction."

and improve the lifetime and resilience of built structures as the construction sector tries to minimise its major environmental impact. Recent studies, for instance, Saini and Ledwani, highlight the use of renewable, locally derived, and bio-based materials as a successful way to reduce environmental damage while fitting South Africa's climatic and economic limits.[86] The results show that the South African construction industry (SACI) is usually tardy in embracing sustainable and green building ideas.[87] According to the Green Economy Policy Review of South Africa, South Africa is moving toward an inclusive green economy. However, the path is still long and difficult. This is especially true for green industrial growth. Still present and expanding in South Africa are many "green shoots" encouraging the move to green industrial growth. For example, Masia et al. observed that property developers and clients' adoption is still in the early stage in comparison to industrialised nations.[88] Other scholars argue that reluctance to transition from conventional construction methods and insufficient demand for sustainable structures and products have characterised many people's attitudes.[89] Furthermore, Moghayedi et al. and Emere et al. show that traditional building techniques can compromise the sustainability objectives of the nation by causing environmental damage, high energy use, and waste generation.[90]

Moreover, Emere et al. claim that adopting sustainable structural materials is affordable, reduces resource use, minimises environmental effects, and has no or low human health concerns.[91] They further noted that among other sustainable structural materials are timber and alternative lumber, composite bricks, composite blocks, cementitious materials, reinforced concrete or masonry substitutes. They advise using wood as a harmless and reuse item in low-rise structures.[92] Maake et al. also verified that, particularly for outdoor decks, alternative lumber created from recycled materials, such as composite or plastic lumber (a recyclable material derived from virgin or waste plastic), is getting more use.[93] Apart from that, alternative lumber could be less expensive over time as it needs minimal upkeep during its lifetime.[94] Emere et a.l also found cellular lightweight concrete blocks to be a substitute for traditional bricks or blocks.[95]

According to Marsh et al., and Emere et al., sustainable construction materials can also contain sugarcane bagasse, lime, stone dust and water, which can be used to create lightweight bio-bricks for non-load-bearing walls with great heat and sound insulation.[96] Bhanye et al., on the other hand, noted that, especially across urban and rural locations and between formal and informal housing sectors, the application of such sophisticated and sustainable materials and methods is inconsistent.[97] While many rural and peri-urban communities continue to depend on traditional construction materials like burnt clay bricks and ordinary Portland cement, Masia et al., found that major metropolitan cities like Cape Town, Johannesburg, and Durban are slowly including green building materials into public infrastructure

[86] Saini and Ledwani, "A Review on Application of Green Materials in Different Construction Systems, Their Processing, Surface Modification, Testing and Certification."
[87] Simpeh and Smallwood, "An Integrated Model for Predicting the Probability of Adoption of Green Building in South Africa"; Simpeh and Smallwood, "Incentive Mechanism for Promoting the Uptake of Green Building in South Africa."
[88] Nurul Nadia Abd Aziz et al., "The Mediating Effects of Student Satisfaction on Technostress and Performance Expectancy," in *Accelerating Transformation towards Sustainable and Resilient Business: Lessons Learned from the COVID-19 Crisis* (European Proceedings of Finance and Economics, 2023), 834–48, https://doi.org/10.15405/epfe.23081.76.
[89] Aigbavboa, Ohiomah, and Zwane, "Sustainable Construction Practices:'A Lazy View' of Construction Professionals in the South Africa Construction Industry"; Emere et al., "A Principal Component Analysis of Sustainable Building Construction Features for Project Delivery in South Africa"; Eric Kwame Simpeh et al., "Analytical Taxonomy of Challenges to the Implementation of Green Building Projects in South Africa," *International Journal of Construction Management* 23, no. 2 (2023): 286–96.
[90] Alireza Moghayedi, Dylan Hübner, and Kathy Michell, "Achieving Sustainability in South African Commercial Properties: The Impact of Innovative Technologies on Energy Consumption," *Facilities* 41, no. 5/6 (2023): 321–36; Emere et al., "A Principal Component Analysis of Sustainable Building Construction Features for Project Delivery in South Africa."
[91] Emere et al., "A Principal Component Analysis of Sustainable Building Construction Features for Project Delivery in South Africa."
[92] Emere et al., "A Principal Component Analysis of Sustainable Building Construction Features for Project Delivery in South Africa."
[93] Tebogo Maake et al., "Fire-Retardant Wood Polymer Composite to Be Used as Building Materials for South African Formal and Informal Dwellings—A Review," *Fire* 8, no. 2 (2025): 81.
[94] Crafford and Brand Wessels, "South African Log Resource Availability and Potential Environmental Impact of Timber Construction."
[95] Emere et al., "A Principal Component Analysis of Sustainable Building Construction Features for Project Delivery in South Africa."
[96] Marsh, Brent, and De Kock, "Understanding the Barriers and Drivers of Sustainable Construction Adoption and Implementation in South Africa: A Quantitative Study Using the Theoretical Domains Framework and COM-B Model"; Emere et al., "A Principal Component Analysis of Sustainable Building Construction Features for Project Delivery in South Africa."
[97] Johannes Bhanye et al., "Strategies for Sustainable Innovative Affordable Housing (SIAH) for Low Income Families in Africa: A Rapid Review Study," *Discover Sustainability* 5, no. 1 (2024): 157.

projects.[98] Though their environmental impact and carbon intensity are significant, these materials are ingrained in local building traditions because of their low cost, availability, and proven performance.

Furthermore, South Africa's sustainable building conversation has been more and more affected by the ideas of circular construction. Emere et al.'s study emphasises the need for circular construction in fostering waste minimisation, employing strategies including the reuse of materials from deconstructed buildings and the inclusion of industrial by-products, including fly ash and ground granulated blast furnace slag (GGBFS), into new concrete mixes.[99] This not only lessens the need for virgin resources but also tackles the problem of construction and demolition (C&D) waste, which makes a significant share of the national waste stream. While improving durability and thermal mass, empirical investigations have demonstrated that fly ash-modified concrete can save carbon emissions by as much as 30% when compared to conventional Portland cement concrete.[100] This leads to the next theme detailing the benefits of adopting green technology in the South African context.

The Role of Green Technologies in South African Sustainable Architecture

Emerging as a vital response to systematic problems, including energy insecurity, water scarcity, and the environmental pressure connected with fast urbanisation, Nhamo et al., and Kajiita and Kang'ethe underline that green technologies have become more and more essential to the sustainability agenda within South Africa's urban built environment.[101] They suggest that by improving resource efficiency, reducing environmental effects, and promoting occupant health and well-being, these technologies seek to enhance building performance.[102] Findings from a South African study by Ogra and Onatu on metropolitan housing development in urban fringe areas using a case of three metropolitan cities of Johannesburg, Ekurhuleni, and Tshwane show that the integration of green technologies into architectural and engineering practices has gained momentum, especially in metropolitan areas where environmental pressures and infrastructure demands are most acute.[103]

In a study on the assessment of solar PV potential and performance of a household system in Durban North, South Africa, Ebhota and Tabakov discovered that solar photovoltaic (PV) energy is one of the most notable green technologies in metropolitan South Africa.[104] According to the Green Building Council South Africa [GBCSA], the need for energy independence, despite ongoing electricity supply interruptions caused by ageing infrastructure and load-shedding, has mostly pushed the growing use of rooftop solar PV systems.[105] Solar installations are now seen as ecologically responsible and economically sensible in high-income residential projects and the commercial sector because of long-term operating savings and enhanced energy resilience.[106] According to Moghayedi et al. and Masia et al, the decline in energy use lowered the main electrical consumption as well as the carbon equivalent emissions.[107] Given that the nation is in an energy crisis, this is quite important, given that 90% of South Africa's main

[98] Masia, Kajimo-Shakantu, and Opawole, "A Case Study on the Implementation of Green Building Construction in Gauteng Province, South Africa."

[99] Emere et al., "A Principal Component Analysis of Sustainable Building Construction Features for Project Delivery in South Africa."

[100] Bishnu Kant Shukla et al., "Constructing a Greener Future: A Comprehensive Review on the Sustainable Use of Fly Ash in the Construction Industry and Beyond," *Materials Today: Proceedings* 93 (2023): 257–64.

[101] Luxon Nhamo et al., "Urban Nexus and Transformative Pathways towards a Resilient Gauteng City-Region, South Africa," *Cities* 116 (2021): 103266; Kajiita and Kang'ethe, "Socio-Economic Dynamics Inhibiting Inclusive Urban Economic Development: Implications for Sustainable Urban Development in South African Cities."

[102] Isimbi and Park, "The Analysis of the EDGE Certification System on Residential Complexes to Improve Sustainability and Affordability"; Nhamo et al., "Urban Nexus and Transformative Pathways towards a Resilient Gauteng City-Region, South Africa"; Kajiita and Kang'ethe, "Socio-Economic Dynamics Inhibiting Inclusive Urban Economic Development: Implications for Sustainable Urban Development in South African Cities."

[103] Aurobindo Ogra and George Onatu, "Metropolitan Housing Development in Urban Fringe Areas-a Case Study of Three Metropolitan Cities of South Africa: Johannesburg, Ekurhuleni and Tshwane," *Journal of Civil Engineering and Architecture* 18 (2024): 244–53.

[104] Williams S Ebhota and Pavel Y Tabakov, "Assessment of Solar PV Potential and Performance of a Household System in Durban North, Durban, South Africa," *Clean Technologies and Environmental Policy* 24, no. 4 (2022): 1241–59.

[105] GBCSA., "Net Zero Movement. ."

[106] Moghayedi, Hübner, and Michell, "Achieving Sustainability in South African Commercial Properties: The Impact of Innovative Technologies on Energy Consumption"; Isimbi and Park, "The Analysis of the EDGE Certification System on Residential Complexes to Improve Sustainability and Affordability"; Ebhota and Tabakov, "Assessment of Solar PV Potential and Performance of a Household System in Durban North, Durban, South Africa."

[107] Moghayedi, Hübner, and Michell, "Achieving Sustainability in South African Commercial Properties: The Impact of Innovative Technologies on Energy Consumption"; Masia, Kajimo-Shakantu, and Opawole, "A Case Study on the Implementation of Green Building Construction in Gauteng Province, South Africa."

electricity source is fossil fuel-based.[108] By lowering dependency on coal-generated power, solar PV systems directly support national decarbonisation initiatives, hence complementing South Africa's obligations under the Paris Agreement,[109] Department of Forestry, Fisheries and the Environment [DFFE].[110]

Furthermore, Carden et al., indicate that in water-scarce areas like the Western Cape and eThekwini municipality, other technologies such as rainwater collecting, greywater recycling, and green roofs are gaining popularity in addition to solar energy.[111] These systems reflect a move toward decentralised water management techniques, lowering demand on municipal supply and improving drought resistance.[112] Carden et al and du Toit and Wagner remarked that stormwater harvesting offers a means of reducing municipal potable water demand, decreasing total runoff volumes, offering amenity benefits and, if actively managed, also a means of attenuating peak flows.[113] In certain areas, it offers a means of financially and economically providing water that is less expensive than the currently supplied potable water. Likewise, greywater recycling systems help to utilise household wastewater, hence relieving strain on water infrastructure even further. Du Toit and Wagner argue that by insulating, maintaining urban biodiversity, absorbing toxins, and controlling stormwater runoff, green roofs serve to reduce the urban heat island effect by providing multifunctional advantages.[114] Therefore, the findings by Du Toit and Wagner suggest that green roofing and rainwater collecting seem to be predicted by roof coverage.[115]

According to Windapo and Moghayedi, key factors of energy efficiency and indoor environmental quality have also been developed in building the 'envelope' technology.[116] In commercial buildings and high-end residential projects, innovations such as double-skin façades, vented hollow walls, and low-emissivity (low-e) windows have grown more common. These 'envelope' technologies greatly lower heat transmission, hence improving thermal comfort and reducing energy use linked to heating and air conditioning.[117] Particularly, double-skin façades serve as thermal buffers that control inside temperatures, therefore appropriate for South Africa's different climatic areas. Green Star-certified projects show particularly strong use of such characteristics since certification results depend on performance criteria. However, multiple barriers impede the widespread adoption of sustainable materials and methods. Key among these are the high initial capital costs associated with sustainable technologies, insufficient distribution networks for alternative materials, and a general lack of technical expertise among small-scale builders and contractors. This forms part of the other thematic area for analysis.

Challenges and Barriers to the Adoption of Green Building Practices in South Africa

Although the environmental and operational advantages of green building are widely acknowledged, the widespread adoption of sustainable architecture in South Africa is hindered by a complex interplay of economic, institutional, technical, and socio-cultural barriers,[118] as represented in Figure 4 below and also see Table 1 for the findings under the detailed characteristics of included studies. Simpeh et al., indicate

[108] Moghayedi et al., "Appraising the Nexus between Influencers and Sustainability-oriented Innovation Adoption in Affordable Housing Projects."
[109] S Mutereko et al., "The Role of the Local Government Sector in Promoting Renewable Energy and the Implications on Skills Development," 2023.
[110] DFFE., "Department of Forestry, Fisheries and the Environment Annual Report 2021/22," 2020.
[111] Kirsty Carden et al., "Challenges and Opportunities for Implementing Water Sensitive Design in South Africa," *WRC Project Report K* 5 (2018): 1–120.
[112] Carden et al., "Challenges and Opportunities for Implementing Water Sensitive Design in South Africa."
[113] Carden et al., "Challenges and Opportunities for Implementing Water Sensitive Design in South Africa"; du Toit and Wagner, "Property Owners' Uptake of Stormwater Source Controls: A Case Study of a Low-Density Upmarket Residential Estate in Pretoria, South Africa."
[114] du Toit and Wagner, "Property Owners' Uptake of Stormwater Source Controls: A Case Study of a Low-Density Upmarket Residential Estate in Pretoria, South Africa."
[115] du Toit and Wagner, "Property Owners' Uptake of Stormwater Source Controls: A Case Study of a Low-Density Upmarket Residential Estate in Pretoria, South Africa."
[116] Windapo and Moghayedi, "Adoption of Smart Technologies and Circular Economy Performance of Buildings."
[117] Hoffman et al., "Trends in Application of Green Star SA Credits in South African Green Building."
[118] Mushi, Nguluma, and Kihila, "Factors Influencing Adoption of Green Buildings in Tanzania: A Qualitative Case Study."

that these systemic challenges continue to impede the transition from traditional, resource-intensive construction practices to ecologically responsible and performance-oriented building methodologies.[119]

Figure 4: Word frequency visual analysis of the challenges and barriers of adopting green building practice in South Africa.

Various scholars have pointed out that one of the foremost barriers is the high upfront cost associated with green technologies, sustainable materials, and certification processes.[120] While Emere et.al, note that despite evidence showing that green buildings yield significant long-term operational savings, particularly in energy and water usage, many stakeholders, especially small-scale developers and public institutions, struggle to justify the initial capital outlay.[121] The additional costs incurred through obtaining certifications such as those under the Green Star SA rating system further contribute to this financial burden, making sustainable construction a less accessible option for budget-constrained sectors of the market.[122] Consequently, green building remains largely concentrated in the high-end commercial and residential segments, perpetuating socio-economic inequalities in access to sustainable infrastructure.

Equally critical is the limited awareness and understanding of green building principles among various stakeholders, including property developers, architects, construction managers, and even end-users.[123] Other scholars point out that this knowledge gap results in weak market demand for sustainable features and a fragmented application of green design principles.[124] Many construction professionals remain unconvinced about the practicality or cost-efficiency of green strategies in the South African

[119] Simpeh et al., "Analytical Taxonomy of Challenges to the Implementation of Green Building Projects in South Africa."
[120] Oguntona et al., "Benefits and Drivers of Implementing Green Building Projects in South Africa"; Masia, Kajimo-Shakantu, and Opawole, "A Case Study on the Implementation of Green Building Construction in Gauteng Province, South Africa"; Simpeh et al., "Analytical Taxonomy of Challenges to the Implementation of Green Building Projects in South Africa"; Christopher Amoah and Jeanne Smith, "Barriers to the Green Retrofitting of Existing Residential Buildings," *Journal of Facilities Management* 22, no. 2 (2024): 194–209.
[121] Emere et al., "A Principal Component Analysis of Sustainable Building Construction Features for Project Delivery in South Africa."
[122] GBCSA., "Net Zero Movement."
[123] Marsh, Brent, and De Kock, "Understanding the Barriers and Drivers of Sustainable Construction Adoption and Implementation in South Africa: A Quantitative Study Using the Theoretical Domains Framework and COM-B Model"; Chijioke Emmanuel Emere et al., "A Principal Component Analysis of Corporate Dispositions for Sustainable Building Construction in South Africa," *Frontiers in Built Environment* 10 (2024): 1447621.
[124] Windapo and Goulding, "Understanding the Gap between Green Building Practice and Legislation Requirements in South Africa"; Owoha et al., "Categorising Green Building Features in Developing Countries: The Case of South Africa."

context, particularly in the absence of robust case studies or demonstration projects targeting middle and low-income developments.[125]

Green architecture and green technologies in the South African context encounter social acceptance issues from both construction experts as well as the end users, particularly with reference to sandbag housing, as Adetooto et al., point out that bricks and mortar are the preferred building materials for most South Africans.[126]

> *"Social acceptance is a significant difficulty. People associate living in a sandbag house with poverty and prefer to reside in a masonry building."*[127]

Cementing the same position, they noted that the experts stated that the informal settlement residents burnt down most houses constructed using alternative construction technologies because the community does not accept or approve of them. This further speaks to policy and government supporting frameworks below.

Policy and Regulatory Frameworks Supporting Green Building Initiatives in South Africa

The South African government is essential in establishing and advancing green construction techniques via a blend of legislative, regulatory, and policy measures. These frameworks are essential for integrating sustainability into the built environment and guaranteeing the nation's enduring environmental and economic resilience. In acknowledgment of the environmental repercussions of the construction industry, South Africa has implemented many initiatives to promote and facilitate sustainable building, focusing specifically on energy efficiency, resource conservation, and diminished carbon emissions. The United Nations Environment Programme indicates that in South Africa:

> *"A number of broad policy documents, such as the National Development Plan (NDP), the Innovation Plan, and the National Strategy for Sustainable Development and Action Plan (NSSD), have called for the transition to a more sustainable development path in South Africa. Such documents mention and support (at least in principle) a green industrial transition, but they do not constitute a strategic, coherent, green industrial development vision……..".*[128]

The current G20 resolution has achieved significant milestones and initiatives, inspired by the ethos of Ubuntu. South Africa's G20 Presidency features a robust environmental agenda, as reflected in its theme "Solidarity, Equality, and Sustainable Development." This theme was evident in multiple focal areas, such as energy transitions, sustainable development, and climate change mitigation. The G20 seeks to tackle environmental issues such as biodiversity decline, land degradation, and marine pollution. Nonetheless, the UNEP emphasizes the necessity for multisectoral and multistakeholder involvement in policy formulation and its implementation within the green architecture and green technology sectors in South Africa, as it asserts:

> *"To foster action, the findings of this review should be actively disseminated for government officials, politicians, private sector representatives, labour unions, civil society and citizens at large to engage with its evidence and recommendations. This work should be particularly channeled through government structures. The current development of the Master Plans offers a unique opportunity to initiate the transition to green industrial development in the country. Considering the transition to a green economy should be a requirement for each and every Master Plan. Such work will also provide an impetus to further bridge existing knowledge gaps and trigger implementation……"*[129]

[125] Owoha et al., "Categorising Green Building Features in Developing Countries: The Case of South Africa."
[126] Adetooto, Windapo, and Pomponi, "The Use of Alternative Building Technologies as a Sustainable Affordable Housing Solution: Perspectives from South Africa."
[127] Adetooto, Windapo, and Pomponi, "The Use of Alternative Building Technologies as a Sustainable Affordable Housing Solution: Perspectives from South Africa."
[128] United Nations Environment Programme (UNEP), *Climate Change and Africa: Addressing the Challenges* (Nairobi: UNEP, 2020).
[129] United Nations Environment Programme (UNEP), *Climate Change and Africa: Addressing the Challenges*.

The literature corroborates this, for instance. Boshoff and Mey indicate that in September 2011, the South African National Building Regulations (NBRs) were revised to incorporate a section on energy efficiency, titled 'Part XA energy utilization in buildings'.[130] This provision mandates that all new constructions or significant renovations be designed and constructed to guarantee that their passive design, encompassing orientation, shading, services, and building envelope, facilitates effective energy utilization, with a minimum of 50% of hot water generation by volume.

In South Africa, government regulations and guidelines significantly influence the adoption of green building and sustainable construction processes.[131] An updated evaluation of this legislation revealed its extent at both national and provincial levels. The principal aims of these standards for advancing green building (GB) within the nation are generally delineated, indicating that the majority of standards conform to GB criteria, including waste management, material recycling, utilization of sustainable materials, pollution mitigation, and reduced resource consumption (energy, water, materials, etc.). Boshoff and Mey assert that,

> *"Since sustainable construction seeks to cater for the entire lifespan of buildings, some of these legislations endorse guidelines regarding the design, construction, operational and maintenance phases of construction projects and their finished products. A typical case is the City of Cape Town Green Building Guidelines emphasises on design and construction stages based on principles such as local appropriateness, natural environment conservation, among others.*[132]

Thus, the successful adoption of green building features in South Africa is influenced by enabling factors, including policy support, awareness, and technical capacity. The literature suggests that government incentives and regulations play a role in promoting sustainable practices in the South African context. There is more debate on what policy direction South Africa's green architecture and green technology should adopt. Uche and Ngepah, in their study, pointed out that the republic must be more committed to realising a full-scale transition to clean energy.[133] For example, switching to electric vehicles (EVs) like other emerging countries, such as China, there is a need to review, readjust and realign the prevailing energy and environmental taxes.[134]

CONCLUSION

This critical literature review of academic contributions regarding green architecture and green technology in South Africa from 2015 to 2024 indicates a progressively increasing focus on green architecture and green technology in South Africa, highlighting both advancements and ongoing obstacles. The increase in publications indicates a significant movement towards environmental awareness, driven by global climate demands, national policy efforts, and an enhanced understanding of the socio-economic benefits of sustainable construction. At the beginning of the decade, the discourse was minimal and investigative, hindered by restricted institutional emphasis, finance, and technical capability. By 2018, a more intentional and varied research program began to emerge, aligning with significant national events and the global impetus following the Paris Agreement.

Subsequent years witnessed an expansion of research into low-income homes, new materials such as sandbags and lumber, as well as technology such as blue-green roofs and passive energy systems. These investigations demonstrated the technical feasibility of green solutions and underscored their socio-economic advantages, including cost savings, carbon reduction, and enhanced living circumstances. Nevertheless, adoption persists in an inconsistent manner. Regulatory obstacles, substantial initial expenses, insufficient skilled personnel, and inadequate public awareness persist in hindering extensive implementation, especially in the affordable housing sector.

The most current period (2023–2024) indicates a developing yet prudent optimism, characterized by intricate research examining market dynamics, policy deficiencies, and performance indicators.

[130] Boshoff and Mey, "The Building Emission Reduction Potential of South African Residential Building Efficiency Tools–A Review."
[131] Hoffman et al., "Trends in Application of Green Star SA Credits in South African Green Building"; Windapo and Goulding, "Understanding the Gap between Green Building Practice and Legislation Requirements in South Africa."
[132] Boshoff and Mey, "The Building Emission Reduction Potential of South African Residential Building Efficiency Tools–A Review."
[133] Uche and Ngepah, "How Green-Technology, Energy-Transition and Resource Rents Influence Load Capacity Factor in South Africa."
[134] Uche and Ngepah, "How Green-Technology, Energy-Transition and Resource Rents Influence Load Capacity Factor in South Africa."

Promisingly, policy frameworks such as the 2024 Climate Change Act and developing green economy initiatives have started to integrate green architecture and technology or sustainability as a national priority in South Africa. However, as demonstrated by inconsistent outcomes in market value analyses and persistent opposition to unconventional technology, substantial efforts are still required to harmonize design innovation with economic motivations and societal approval.

In summary, although still in its infancy, South Africa has achieved notable progress in developing a research framework for sustainable green architecture and green technology. Advancing adoption necessitates cohesive policy measures, investment in talent enhancement, and ongoing research to reconcile environmental aspirations with practical execution. The groundwork has been established; the current task is to enhance impact, integrate sustainable practices, and guarantee an equitable, inclusive transformation across all societal sectors.

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