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A SYSTEMATIC LITERATURE REVIEW OF GREEN BUILDING IMPLEMENTATION FOR IMPROVING ENERGY EFFICIENCY AND ENVIRONMENTAL SUSTAINABILITY

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ABSTRACT

The Background: The application of green building concepts has become increasingly important in addressing environmental challenges, particularly in reducing carbon emissions and improving the health and comfort of building occupants through environmentally responsible design. However, despite its potential benefits, the implementation of green building practices still faces several challenges, including high initial investment costs and limited regulatory support, especially in developing countries. **Objective:** This study aims to evaluate the effectiveness of green building concepts in improving energy efficiency, conserving natural resources, and reducing negative environmental impacts in building structures. **Method:** This research employed a qualitative approach using a systematic literature review method. Scientific publications related to green building implementation were collected from various secondary sources, including academic journals, books, and institutional reports. The selection of literature was conducted purposively based on relevance and publication recency. The collected data were then analyzed using thematic synthesis and interpretative analysis to identify implementation patterns, challenges, and sustainability strategies. **Results:** The results indicate that the implementation of green building principles can improve building energy efficiency by approximately 20–30%, optimize the use of environmentally friendly materials, and promote healthier and more comfortable indoor environments. In addition, green building practices contribute to better resource management and reduced environmental impact. **Contribution:** This study provides a comprehensive overview of the role of green building concepts in enhancing energy efficiency and environmental sustainability, particularly as a reference for researchers, practitioners, and policymakers in promoting sustainable building development.

Keywords: Environment, energy efficiency, friendly materials, green buildings.

1. INTRODUCTION

The global construction sector plays a pivotal role in energy consumption and greenhouse gas emissions, accounting for approximately 40% of global energy use and nearly one-third of total carbon emissions, according to the International Energy Agency (IEA) (González-Torres et al., 2022). These figures highlight the urgent need to improve energy efficiency and environmental sustainability within the built environment. As the impacts of climate change intensify and urbanization continues to grow rapidly, the development of sustainable construction practices has become a critical global priority. One of the most widely recognized approaches to addressing these challenges is the adoption of the green building concept, which

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emphasizes environmentally responsible design and efficient resource utilization throughout the building life cycle.

Green buildings are designed to optimize the use of natural resources such as energy, water, and construction materials while minimizing environmental impacts during construction, operation, and maintenance phases (Xiang et al., 2022). In addition to environmental benefits, green buildings also contribute to improved occupant well-being through better indoor air quality, enhanced natural lighting, and reduced waste generation (Xiang et al., 2022). In Indonesia, the adoption of green building principles has gradually been promoted in line with the national commitment to achieving the Sustainable Development Goals (SDGs) by 2030 (Lu et al., 2022). Despite increasing awareness, the implementation of green building practices in Indonesia remains limited due to several challenges, including high initial investment costs, limited public and industry awareness, and the lack of comprehensive regulatory frameworks (Lu et al., 2022).

Although numerous studies have examined green building initiatives worldwide, most of them focus on case-specific analyses or contexts in developed countries. Research that comprehensively reviews the overall performance, implementation barriers, and sustainability impacts of green buildings in developing countries, particularly Indonesia, remains relatively limited (Priyanto et al., 2024). This condition indicates the need for a systematic synthesis of existing studies in order to provide a broader understanding of green building implementation and its contribution to improving energy efficiency and environmental sustainability. Therefore, this study aims to systematically review previous research related to green building implementation, performance evaluation, and policy development with a particular focus on energy efficiency and sustainability outcomes (Wahyudi et al., 2023).

The scope of this review includes both global perspectives and Indonesian experiences to identify key factors influencing successful implementation as well as the main challenges faced in adopting green building practices (Shen & Pan, 2023). The contribution of this study lies in providing a comprehensive synthesis of literature on green building performance and sustainability strategies by integrating environmental, economic, and social dimensions within a unified framework. The findings of this research are expected to provide valuable insights for policymakers, developers, and researchers in promoting sustainable construction practices and supporting the development of energy-efficient, resilient, and environmentally responsible building structures (Rinchen et al., 2024).

2. LITERATURE REVIEW

Green Building Performance Optimization and Energy Efficiency

Green building performance optimization has become a central focus in sustainable construction research due to the significant contribution of buildings to global energy consumption and carbon emissions (Firoozi et al., 2025). Existing literature emphasizes that improving building performance requires an integrated approach combining architectural design, building systems, operational strategies, and advanced optimization techniques. Researchers increasingly highlight the transition from conventional energy saving measures toward performance-driven optimization models that address multiple objectives simultaneously, such as

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energy efficiency, occupant comfort, cost effectiveness, and environmental impact. However, many previous studies primarily focus on technical optimization methods or specific building case studies, while comprehensive syntheses that examine how these optimization approaches contribute to broader sustainability outcomes remain limited. This gap indicates the need for a more systematic understanding of how green building performance optimization can effectively support energy efficiency and sustainable building development. Therefore, this study seeks to address this gap by systematically reviewing existing research to identify key strategies, challenges, and implementation patterns related to green building performance optimization.

Optimization Methods in Green Building Design

A foundational review by Nguyen et al., (2014) systematically examines optimization methods applied in building energy performance analysis. The study categorizes optimization techniques into gradient-based methods, metaheuristic algorithms, and simulation-based optimization. The authors argue that metaheuristic approaches such as genetic algorithms and particle swarm optimization are particularly effective for solving complex, nonlinear, and multi-objective building performance problems. Their findings indicate that early-stage design optimization—especially envelope design, orientation, and material selection—can significantly reduce energy demand while improving thermal comfort. This study provides a methodological baseline for understanding how optimization tools contribute to sustainable building design.

Multi-Objective Optimization for Sustainable Performance

Evins, (2013) Extends the discussion by focusing on multi-objective optimization in sustainable building design. The study highlights the inherent trade-offs between energy efficiency, environmental impact, and economic feasibility. Using simulation-based optimization frameworks, the research demonstrates that no single optimal solution exists; instead, Pareto-optimal solutions allow designers to balance competing performance criteria. This work is critical in establishing that green building optimization should not prioritize energy efficiency alone but must integrate sustainability indicators such as lifecycle carbon emissions and long-term operational costs.

Integration of Simulation Tools and Building Systems

A comprehensive review by Machairas et al., (2014)analyzes the role of simulation-based optimization in building energy performance. The authors emphasize the importance of coupling building performance simulation tools with optimization algorithms to evaluate thousands of design alternatives efficiently. Their findings show that integrated optimization frameworks are particularly effective in optimizing HVAC systems, passive design strategies, and renewable energy integration. However, the study also identifies limitations related to computational cost and the lack of interoperability between simulation platforms, which remain critical challenges in practical applications.

Systematic Perspectives on Energy Efficiency and Sustainability

More recent systematic evidence is provided by Hafez et al., (2023), who review energy efficiency strategies in sustainable buildings with a focus on implementation barriers and policy relevance. The study concludes that while technological solutions for energy optimization are widely available, their

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effectiveness is often constrained by regulatory frameworks, economic incentives, and user behavior. This perspective reinforces the argument that green building performance optimization must be supported by governance structures and post-occupancy evaluation to achieve long-term sustainability outcomes.

3. RESEARCH METHODOLOGY

This study employs a Systematic Literature Review (SLR) approach to identify, evaluate, and synthesize previous research related to the implementation of green building concepts in improving energy efficiency and sustainability. The SLR method is appropriate for obtaining a comprehensive understanding of existing knowledge and identifying research gaps in a structured and transparent manner. A systematic review provides a rigorous framework for collecting and interpreting existing studies to answer specific research questions within a defined scope. This study also follows the principles of the Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA) to ensure methodological transparency and reproducibility.

Table 1. Summary of Research Methodology

Research Component	Description
Research Method	Systematic Literature Review (SLR) used to identify, evaluate, and synthesize previous studies related to green building implementation, energy efficiency, and sustainability.
Review Framework	The study follows the **PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses)** framework to ensure transparency and reproducibility in the literature selection process.
Research Approach	Qualitative descriptive approach focusing on identifying themes, patterns, and critical insights from previous studies regarding green building practices.
Data Sources	Academic databases including **Scopus, ScienceDirect, JSTOR, and Google Scholar**, supported by books, technical reports, and institutional publications.
Search Keywords	“Green building”, “sustainable building”, “energy efficiency”, “environmental sustainability”, and “implementation challenges”.
Publication Period	Literature published between **2013–2024** to capture recent developments in green building research.
Inclusion Criteria	Peer-reviewed journal articles, conference papers, and academic books discussing green building design, operational performance, or policy implementation; written in **English or Indonesian**; providing empirical findings or conceptual contributions.
Exclusion Criteria	Non-academic publications, articles without full-text access, and studies not directly related to green building or energy sustainability.

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Literature Selection Process	PRISMA stages: **Identification → Screening → Eligibility → Inclusion**. Duplicates were removed before title/abstract screening and full-text review.
Data Analysis Technique	**Qualitative content analysis** following Snyder (2019) to synthesize findings, identify patterns, compare global and Indonesian studies, and generate strategic insights for improving green building implementation.

Research Approach

The review was conducted using a qualitative descriptive approach, focusing on identifying recurring themes, patterns, and critical findings from the selected literature. This approach allows for a deeper understanding of how green building practices contribute to energy efficiency, environmental performance, and sustainability in both global and national contexts.

Data Sources

Data were obtained from major and credible academic databases, including Scopus, ScienceDirect, JSTOR, and Google Scholar. These databases were selected for their extensive coverage of peer-reviewed scientific journals and their relevance to the topic of sustainable construction and green building performance. Additional supporting sources, such as books, technical reports, and official publications, were also included to strengthen the analysis.

Search Strategy

The literature search was performed using carefully selected keywords and Boolean operators such as: “green building”, “sustainable building”, “energy efficiency”, “environmental sustainability”, and “implementation challenges”. The search covered publications from 2013 to 2024 to capture recent advancements in green building research. Furthermore, the reference lists of selected studies were reviewed to identify additional relevant publications.

Inclusion and Exclusion Criteria

To ensure the quality and relevance of the reviewed literature, the following inclusion and exclusion criteria were applied. To ensure that the materials reviewed in this study were relevant and of high academic quality, a set of inclusion and exclusion parameters was established before the selection process began. Only literature that met specific standards of credibility and relevance was considered suitable for analysis. The review primarily included peer reviewed journal articles, academic books, and conference papers that discuss issues related to green building design, operational performance, or policy implementation. Both empirical and theoretical studies were taken into account, as long as they provided measurable findings or clear conceptual contributions to the understanding of green building practices. Publications written in English or Indonesian were accepted to accommodate both international and national perspectives on the topic.

On the other hand, several types of literature were deliberately excluded to maintain the focus and validity of the review. Works that were not accessible in full text were omitted, as incomplete materials could hinder a comprehensive evaluation of content and methodology. Studies that did not directly address the themes of green building or energy sustainability were also excluded from consideration. In addition, non-academic publications such as news reports, opinion essays, or

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popular media articles were not incorporated into the analysis because they lack the methodological rigor and peer-review standards required in scholarly research.

Literature Selection Process

The selection process consisted of several stages identification, screening, eligibility, and inclusion, following the PRISMA flow structure [13]. The initial search yielded numerous articles; duplicates were removed before screening titles and abstracts for relevance. Subsequently, the remaining papers were reviewed in full text to ensure their suitability for the research objectives. Only those studies meeting all inclusion criteria were retained for analysis.

Data Analysis Technique

A qualitative content analysis was carried out to organize and interpret the findings obtained from the reviewed studies. Each publication was carefully examined to identify recurring ideas and patterns related to energy efficiency, sustainable resource use, regulatory frameworks, and the practical challenges encountered in the implementation of green building practices.

The analysis procedure followed the guidelines proposed by (Snyder, 2019), emphasizing the integration of multiple research findings to generate a comprehensive understanding of a phenomenon. Cross-comparison between global and Indonesian studies was performed to reveal contextual differences, recurring patterns, and strategic insights for improving green building practices. Through this structured synthesis, the review provides an overview of current evidence, identifies research gaps, and formulates practical and policy-oriented recommendations to strengthen the implementation of green building principles.

4. RESULT DAN DISCUSSION

Based on the analysis of various literature sources collected, there are several key findings that lead to an increase in understanding related to the application of green buildings in buildings. The following are the findings obtained from the literature study.

Green Building Implementation and Energy Efficiency

A The discussion of this study addresses the research question regarding the impact of implementing green building principles on energy performance. A number of previous studies consistently emphasize that the application of green building strategies contributes significantly to improving energy efficiency in buildings. Research conducted in Indonesia by Lendra et al. (2025) reported that the adoption of passive cooling techniques and daylighting systems reduced building energy consumption by approximately 20–30%. Similar findings have also been observed in other regional contexts. Studies conducted in Malaysia reported energy savings of around 15%, while research in Singapore indicated reductions exceeding 35%, primarily due to the implementation of enhanced thermal insulation and automated lighting control systems. These findings demonstrate a consistent pattern indicating that green building principles positively influence energy performance across different building environments.

However, the magnitude of energy savings varies among studies. These variations may be explained by several contextual factors, including climatic conditions, building typologies, levels of technological adoption, and the effectiveness of local regulatory frameworks. Therefore, while the concept of green

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buildings provides clear benefits for energy efficiency, its effectiveness depends on the specific environmental and regulatory context in which it is implemented. Overall, these comparisons support the conclusion that integrating green building principles can significantly enhance energy performance, although the degree of improvement is influenced by local design strategies and policy implementation.

Sustainable Resource Management and Eco-Friendly Materials

Previous works reveal that the use of sustainable materials and efficient resource management strategies play an essential role in reducing environmental footprints. A study conducted on healthcare facilities in Indonesia (Marshal et al., 2021) demonstrated that the implementation of low carbon and environmentally friendly building materials can significantly reduce carbon emissions throughout the building lifecycle. Comparable findings were observed in China (You et al., 2025) where the implementation of low carbon building materials in residential construction has been shown to reduce environmental impacts and overall lifecycle energy demand.These findings indicate that material selection is a key determinant of environmental sustainability. Despite the growing recognition of sustainable construction practices, the widespread implementation of green building strategies continues to face major obstacles, including limited availability of certified eco friendly materials and higher upfront investment costs. These challenges vary across regions, as shown in the following summary of material utilization strategies and their corresponding environmental impact reductions:

Tabel 1.1 Summary of Environmental Impact Reduction through Sustainable Material Application

Country / Region	Type of Material / Strategy	Environmental Impact Reduction (%)
Indonesia (Riau)	Recycled steel, energy efficient glass	20–25%
China	Locally sourced, low carbon concrete	18%
Australia	Timber-based composite materials	30%

Regulatory Barriers and Implementation Challenges in Indonesia

Several studies have also explored the regulatory and economic barriers that limit the broader implementation of green buildings in Indonesia. Higher initial investment costs, weak policy enforcement, and limited awareness among stakeholders are the dominant obstacles (Ohene et al., 2023). In comparison, developed countries benefit from strong incentive schemes, tax reductions, and certification frameworks that encourage compliance (Rumasukun & Noch, 2023). This gap underscores the need for government intervention through clearer standards and economic incentives to encourage developers to adopt sustainable building practices.

Environmental and Social Benefits of Green Building Application

Multiple studies conclude that green buildings not only contribute to environmental protection but also enhance occupant health and comfort (Khan et al., 2023), natural ventilation and daylighting systems have been associated with improved indoor air quality and psychological well being. Comparable results are found in Japan and the United States (Feijão et al., 2024) where green certified buildings report higher occupant satisfaction levels. These findings reinforce the holistic value of sustainable design, which benefits both the environment and

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human well being (Mohammad et al., n.d.).

Comparative Review and Research Gap

A comprehensive synthesis of more than thirty previous studies demonstrates that the adoption of green building principles consistently contributes to measurable improvements in energy performance, environmental sustainability, and overall occupant well being (Pavate et al., 2024). These studies collectively reveal that implementing energy efficient technologies, sustainable materials, and passive architectural strategies can substantially reduce energy use and operational costs over time. Nevertheless, the extent of improvement reported across the literature varies considerably (Montgomery, 2023). Differences in building typology, climatic conditions, user behavior, and the level of technology adoption often explain the wide range of reported efficiency gains. In several comparative analyses, for instance, energy savings were found to range between 10% and 40%, depending on factors such as geographic region, building function, and the regulatory framework supporting implementation (ALI-TAGBA et al., 2024). These variations can be better understood through the following summary, which highlights differences in building types, strategies, and corresponding levels of energy efficiency improvement achieved across various regions.

Tabel 1.2 Range of reported energy efficiency improvements from green building implementation.

Geographic Region	Building Type	Key Strategies Implemented	Reported Energy Savings (%)
China	Commercial	Passive ventilation, high-efficiency HVAC	35–40%
Indonesia	Educational	Natural lighting, energy-efficient materials	20–25%
United Kingdom	Residential	Renewable integration, insulation improvement	15–22%
China	Mixed-use	Smart monitoring, local material sourcing	25–30%
Japan	Office	Energy-efficient building envelope	10–18%

A synthesis of more than thirty previous studies reveals that the implementation of green building principles consistently enhances energy efficiency, environmental performance, and indoor comfort. The reviewed literature indicates that the integration of energy saving technologies, passive design strategies, and sustainable materials can significantly reduce overall energy consumption and operational costs throughout a building's life cycle. However, the degree of improvement reported across studies varies notably, depending on climate conditions, building functions, technological adoption, and user behavior. Several comparative studies have shown that the rate of energy savings can range from 10% to 40%, reflecting differences in regional contexts and implementation strategies. Despite this generally positive trend, substantial research gaps remain (Jain, 2025). Many existing works tend to focus primarily on technical and design components such as insulation systems, natural lighting optimization, and ventilation efficiency while providing limited discussion on broader factors like economic feasibility, public awareness, and policy integration. Future research should therefore place greater emphasis on examining how socioeconomic settings, institutional support,

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and user behavior over time affect the real world performance of green buildings. This is particularly relevant in developing countries such as Indonesia, where diverse environmental conditions and limited policy enforcement pose additional challenges to achieving long-term sustainability outcomes.

5.CONCLUSION

Referring This study systematically reviewed previous research on the implementation of green building concepts and their contribution to energy efficiency and environmental sustainability. The findings indicate that green building practices significantly improve building performance by reducing energy consumption, optimizing the use of environmentally friendly materials, and enhancing indoor environmental quality. The reviewed literature also highlights that green building strategies such as efficient HVAC systems, natural lighting, and sustainable material selection play a key role in lowering carbon emissions and supporting sustainable construction practices.

Despite these benefits, the study identifies several challenges that limit the broader adoption of green buildings, particularly in developing countries such as Indonesia. These challenges include high initial investment costs, limited regulatory support, and relatively low awareness among industry stakeholders and the public. Overall, this review confirms that green buildings represent an important strategy for improving energy efficiency and promoting sustainable development in the built environment. The findings provide useful insights for policymakers, developers, and researchers to strengthen policies, encourage sustainable construction practices, and support the wider implementation of green building principles.

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