



# Advances In Sustainable Materials And Green Construction Technologies: A Review

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## Abstract:

**Background of Study:** Climate change, driven by human-induced greenhouse gas emissions, presents a global crisis. The construction sector is a primary contributor, responsible for 30–40% of global energy use and over 30% of emissions throughout the building life cycle. Despite innovations like low-carbon materials and Building Information Modeling (BIM), current research remains fragmented. A significant gap exists in integrating technical, economic, and environmental aspects into a single analytical framework.

**Aims Paper:** This paper aims to identify trends in sustainable materials and green technologies through a systematic review. It evaluates their performance across technical, environmental, and economic dimensions while formulating future research directions to achieve sustainable development goals.

**Methods:** A Systematic Literature Review (SLR) was conducted using the Scopus database (2016–2025). Five core keywords were used to identify relevant studies, which were then cleaned using OpenRefine and visualized via VOSviewer. Elicit AI assisted in screening and synthesizing the final 12 journal articles.

**Result:** Analysis of 12 articles shows that experimental studies (50%) and Multi-Criteria Decision-Making (25%) are the dominant methodologies. Research primarily focuses on optimizing specific materials like waste-based concrete and geopolymers. While material innovation is a priority, there is limited integration of technical data with long-term Life Cycle Assessment (LCA) or life-cycle cost analysis.

**Cocnclusion:** Current sustainable construction research emphasizes technical material optimization through experimental approaches. While decision-support models are evolving, empirical integration of the circular economy and LCA remains limited. Future research must adopt holistic frameworks, expand data sources, and include diverse geographical case studies to support effective sustainability practices.

**Keywords:** *Circular economy; Green construction technologies; Low-carbon construction; Sustainable materials; Systematic literature review*

## 1. INTRODUCTION

Climate change has become an increasingly urgent global challenge, largely driven by human activities. Reports from the Intergovernmental Panel on Climate Change (IPCC) indicate with very high confidence that current global warming is predominantly caused by greenhouse gas (GHG) emissions resulting from fossil fuel combustion, urbanization, and industrial activities (Manyuchi et al., 2022; Sheng et al., 2023).

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Scientific evidence shows that the five warmest years in modern climate records have occurred since 2015, indicating a continuing global warming trend. Furthermore, faster warming over land compared to oceans has affected atmospheric circulation and global precipitation patterns, thereby increasing climate instability across various regions of the world (Ito et al., 2020).

The impacts of climate change are broad and complex, encompassing disruptions to ecological systems as well as serious threats to human health. Changes in temperature and precipitation patterns have triggered shifts in species distribution and increased the risk of biodiversity loss, making it difficult for many organisms to adapt to continuously changing environmental conditions (Moumouni et al., 2025; Shen et al., 2023). Moreover, the increasing frequency and intensity of extreme weather events, such as floods, droughts, and heatwaves, have significantly affected food security and agricultural productivity (Sheng et al., 2023; Pan et al., 2023). From a health perspective, exposure to extreme heat and declining air quality has been associated with higher risks of heat-related illnesses, respiratory disorders, and infectious

diseases, particularly in developing countries with limited adaptive capacity (Manyuchi et al., 2022; Odonkor & Sallar, 2020).

Energy consumption plays a central role in accelerating climate change due to its close association with carbon dioxide (CO<sub>2</sub>) emissions. The combustion of fossil fuels for electricity generation, transportation, and industrial processes remains the primary source of global GHG emissions (Dissanayake et al., 2023; Jaya et al., 2023). Although energy consumption is often considered an indicator of economic growth, heavy reliance on fossil fuels creates a dilemma between economic development and long-term environmental sustainability (Kombo et al., 2022). Therefore, sustainable development has emerged as a strategic approach that emphasizes balancing economic growth, environmental protection, and social welfare through improved energy efficiency and a transition toward renewable energy sources (Pranatasari et al., 2024; Tambunan, 2023).

In the context of energy consumption and carbon emissions, the construction sector is one of the largest global contributors. Data from the International Energy Agency (IEA) indicate that the building sector accounts for approximately 30–40% of total global energy consumption and more than 30% of greenhouse gas emissions (Manyuchi et al., 2022). CO<sub>2</sub> emissions in this sector originate not only from the operational phase of buildings but also from material production, construction processes, and building maintenance throughout their life cycle (Ito et al., 2020; Ren et al., 2023). Although the construction sector significantly contributes to the global economy, conventional practices that remain dominant often overlook energy efficiency and environmental protection, thereby exacerbating negative impacts on long-term sustainability (Mei et al., 2022).

In response to these challenges, sustainable construction approaches have evolved through the adoption of environmentally friendly materials and green construction technologies aimed at reducing energy consumption and carbon emissions. Innovations such as low-carbon materials, geopolymers, waste-based materials, prefabrication technologies, and the implementation of Building Information Modeling (BIM) demonstrate significant potential to enhance resource efficiency and reduce the environmental impact of the construction sector (Pan et al., 2023; Liu et al., 2025; Qamar et al., 2024). However, existing scientific studies remain fragmented, often focusing separately on materials and technologies, with limited integration of technical, economic, and environmental aspects simultaneously (Khotimah et al., 2022). This condition highlights the need for a systematic and integrated literature review to provide a comprehensive understanding of the role of sustainable materials and green construction technologies in supporting long-term sustainable development.

Although research on sustainable construction continues to expand, the existing literature still demonstrates clear fragmentation between studies on sustainable materials and green construction technologies, where most research addresses these topics separately without integrating them into a comprehensive analytical framework. Furthermore, there remains limited research offering an extensive synthesis that simultaneously links material types, technical performance, and environmental and economic impacts, making holistic evaluation of innovation effectiveness in supporting long-term sustainability challenging. This condition reveals a research gap that underscores the necessity for a systematic and integrated literature review to identify major trends and key types of sustainable materials and green construction technologies, evaluate their performance from technical, environmental, and economic perspectives, and formulate future research directions to promote more effective sustainable construction practices in supporting climate change mitigation and the achievement of sustainable development goals.

## 2. MATERIAL AND METHOD

This study employed the **Systematic Literature Review (SLR)** method to systematically identify, evaluate, and synthesize research developments related to sustainable materials and green construction technologies. The literature search was conducted using the Scopus database due to its reputation as a leading scientific database with extensive coverage of international journals. The publication period was limited to 2016–2025, considering that the topic under investigation represents a relatively recent and rapidly evolving field.

Five main keywords were utilized in this study: *sustainable materials*, *green construction*, *eco-friendly building materials*, *low-carbon construction*, and *circular economy in construction*. These keywords were combined into two search strings to obtain more relevant and focused results. All retrieved articles were downloaded in CSV format, merged, and subsequently cleaned using OpenRefine to remove duplicates and metadata bias. The cleaned dataset was then analyzed using VOSviewer to generate bibliometric visualizations, including network visualization, overlay visualization, and density visualization, which map the relationships among keywords, authors, and documents.

Furthermore, the literature review process was supported by Elicit AI to facilitate the screening of relevant articles, extraction of key information, synthesis of research findings, and identification of research gaps based on an evidence-based approach. The overall stages of the Systematic Literature Review (SLR) process—from keyword determination, literature search, and data cleaning to analysis and synthesis—are summarized in **Figure 1.** dan **Tabel 2.**

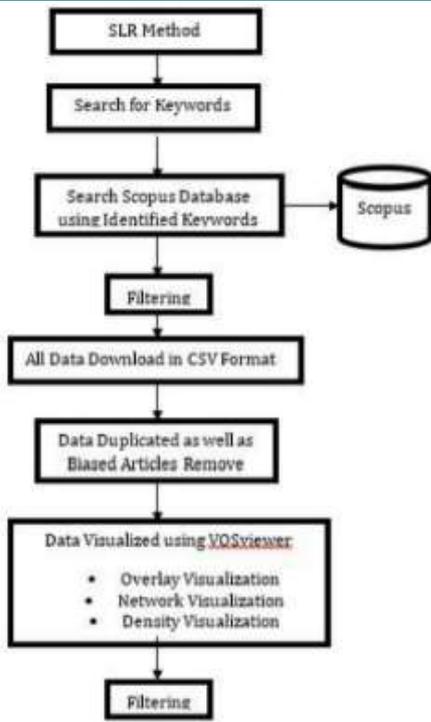


Figure 1. Research Method Flowchart

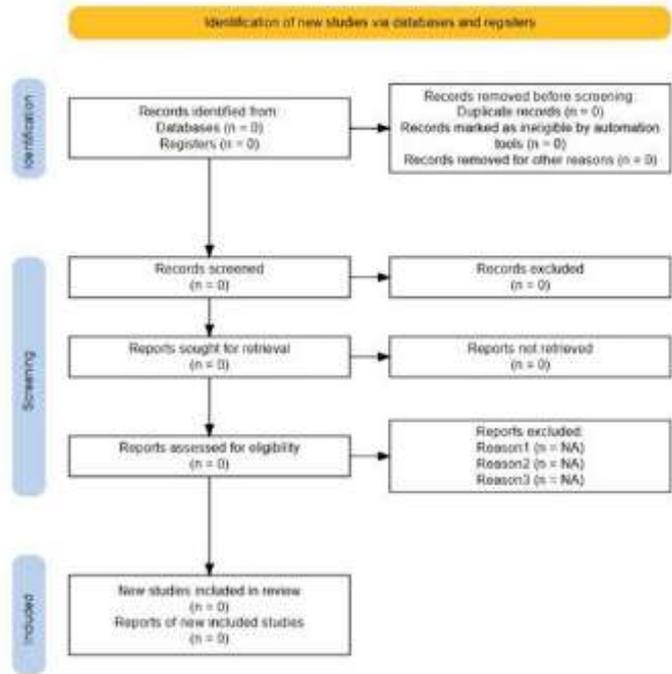


Figure 2. Prism Method Diagram

To provide an overview of the types of publications included in this study, the selected articles were classified based on their publication type. The distribution of publication types is presented in **Table 1**.

Table 1. Distribution of Publication Types

Publication Type	Number of Publications
Journal Articles	12
<b>Total</b>	<b>12</b>

To better understand the methodological approaches adopted in the selected studies, the articles were categorized based on their primary research methodology. The distribution of methodologies is presented in **Table 2**.

Table 2. Distribution of Research Methodologies

Methodological Category	Number of Papers	Percentage
Experimental Studies	5	41,70%
MCDM (Multi-Criteria Decision-Making)	3	25,00%
Statistical Modeling	2	16,70%
Systematic Literature Review (SLR)	1	8,30%
Mixed Methods	1	8,30%

To identify the primary research contributions within the selected studies, the articles were classified based on their main findings. This categorization highlights the dominant research focus areas in sustainable materials and green construction technologies. The summary of key findings is presented in **Table 3**.

Table 3. Classification of Main Research Findings

Category of Main Findings	Number of Articles	Representative Findings
Optimization and Performance of Specific Materials	6	Optimization of waste-based concrete (SCBA, SD), improvement of geopolymer performance, and optimal fiber parameters in low-carbon concrete
Effectiveness of Decision-Making Models/Frameworks	4	Application of AHP, MCDM, and hybrid frameworks (CIT2F-AHP, IVIF-MARCOS) for sustainable material selection
Holistic and Strategic Impacts of Green Construction	2	The role of green construction in sustainable

development and GHG emission mitigation toward net-zero targets

Systematic Reviews

1

8%

a single research framework

Structured synthesis of literature related to sustainable construction

To further examine the research orientation of the selected studies, the articles were categorized based on their primary research focus. This classification provides insight into dominant thematic directions within the field of sustainable materials and green construction. The distribution is presented in **Table 4**.

**Table 4.** Distribution of Research Focus

Research Focus	Number of Articles	Percentage
Development of New/Environmentally Friendly Materials	6	50%
Development of Decision Models/Frameworks	4	33%
Application/Case Study of Green Construction	1	8%
Systematic Literature Review	1	8%
Total	12	100%

To obtain a clearer understanding of the research designs applied in the selected studies, the articles were categorized based on their study design. This classification helps illustrate the dominant methodological structures employed in sustainable construction research. The distribution is presented in **Table 5**.

**Table 5.** Distribution of Study Designs

Study Design	Number of Articles	Percentage	Main Characteristics
Experimental Studies	6	50%	Laboratory testing, measurement of mechanical and environmental properties of materials
Observational Studies	4	33%	Case studies, quantitative descriptive approaches, without direct intervention
Multi-Method Studies	1	8%	Combination of qualitative and quantitative methods within

To identify future research directions proposed in the selected studies, the articles were classified based on their main recommendations. This categorization highlights the priority areas emphasized by previous researchers to advance sustainable materials and green construction practices. The summary is presented in **Table 6**.

**Table 6.** Classification of Research Recommendations

Recommendation Category	Frequency	Level of Urgency	Example Recommendations
Validation & Development of Models/Frameworks	5	High	Integration of Life Cycle Assessment (LCA), development of digital platforms, and life-cycle cost evaluation
Contextual Expansion & Replication	4	Moderate-High	Replication of models across different regions and project types
Advanced Material Optimization & Characterization	3	Moderate	Long-term performance studies and investigation of material interactions

### 3. RESULT AND DISCUSSION

#### Results:

The results of the literature search conducted using the Scopus database with five main keywords yielded a total of 53 initial articles. After merging the datasets and cleaning the metadata using OpenRefine to remove duplicates, the number of articles was reduced to 12 that met all inclusion criteria. All analyzed publications were journal articles, as summarized in Table 1, and the systematic selection process is illustrated through the PRISMA diagram in Figure 2.

The bibliometric analysis indicates that the research themes are predominantly centered on sustainable material

selection and material performance, which show strong linkages with the concepts of sustainable materials, circular economy, and life cycle assessment. The distribution of research methodologies across the 12 selected articles reveals that experimental approaches are the most dominant method, followed by multi-criteria decision-making (MCDM) techniques, as presented in Table 2.

The synthesis of the main findings demonstrates that most studies focus on the optimization and performance of specific materials, followed by research evaluating the effectiveness of decision-making models or frameworks, and a smaller proportion highlighting the strategic impact of green construction on sustainable development. A comprehensive summary of the classification of main findings, study designs, and future research directions is presented in Table 3 through 6.

#### **Discussion:**

The research findings indicate that the primary focus in the field of sustainable construction remains largely dominated by technical and experimental investigations of specific materials, such as waste-based concrete and geopolymer materials. The predominance of this approach suggests that efforts to enhance mechanical performance and reduce environmental impacts through material innovation continue to be the main priority in current research.

In addition, the emergence of multi-criteria decision-making methods, such as the Analytic Hierarchy Process (AHP) and Multi-Criteria Decision-Making (MCDM), reflects the growing need for systematic approaches in selecting sustainable materials capable of balancing technical, environmental, and economic considerations. However, the number of studies integrating technical evaluation with long-term environmental assessments, such as Life Cycle Assessment (LCA) and life-cycle cost analysis, remains relatively limited.

These findings suggest that although the concepts of green construction and the circular economy have been widely discussed at a conceptual level, their integrated implementation within empirical research still requires further development, particularly to support decision-making processes oriented toward long-term sustainability.

#### **Implication:**

The findings of this study have important implications both theoretically and practically. From a theoretical perspective, the results reinforce the understanding that material selection is a key element in the development of sustainable construction and should be viewed as a multidimensional process involving technical, environmental, and economic considerations. From a practical standpoint, the findings may serve as a reference for construction practitioners and policymakers in selecting more sustainable materials and construction technologies. The dominance of experimental approaches highlights the need to bridge laboratory findings with real-world implementation through standards and policies that are more adaptive to environmentally friendly material innovations.

#### **Research Contribution:**

This study makes a scholarly contribution by presenting an integrated synthesis of developments in sustainable materials and green construction technologies through a Systematic Literature Review approach. It not only maps research trends and methodologies employed in the field but also systematically classifies the main findings, study designs, and future research directions. Therefore, this study contributes to addressing the existing literature gap regarding the integration of material innovation, decision-making frameworks, and sustainability objectives within the construction sector.

#### **Limitation:**

This study has several limitations that should be acknowledged. First, the literature search was conducted using only one database, namely Scopus, which means that relevant articles indexed in other databases may not have been included. Second, the publication period was limited to 2016–2025, potentially excluding important studies published prior to this timeframe. Third, the literature synthesis process was partially supported by artificial intelligence-based tools; therefore, the analytical results remain dependent on the quality of the metadata and the researcher's interpretation.

#### **Suggestion:**

Based on the findings and limitations of this study, future research is recommended to expand data sources by incorporating more than one scientific database in order to achieve broader and more comprehensive literature coverage. Additionally, future studies should integrate Life Cycle Assessment (LCA), life-cycle cost analysis, and material durability aspects within a holistic analytical framework. Applied research and case studies across diverse geographical contexts and construction project types are also necessary to enhance the relevance and generalizability of findings related to sustainable construction.

## 4. CONCLUSION

This study presents a Systematic Literature Review (SLR) on the development of sustainable materials and green construction technologies within the construction sector. Based on the analysis of 12 selected journal articles, the findings indicate that recent studies are predominantly characterized by experimental approaches focusing on optimizing the technical performance of materials, particularly waste-based and low-carbon materials. In addition, the application of multi-criteria decision-making models has increasingly evolved as a decision-support tool for selecting sustainable materials by simultaneously considering technical, environmental, and economic aspects. Although concepts such as the circular economy and Life Cycle Assessment (LCA) have been widely discussed, their integration within comprehensive empirical research remains relatively limited. Therefore, this study addresses the research questions by identifying major research trends, evaluating the focus on material and technological

performance, and revealing research gaps that require further investigation to support more holistic and effective sustainable construction practices.

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## 6. AUTHOR CONTRIBUTION STATEMENT

PWR contributed to the formulation of the research concept, the design of the Systematic Literature Review methodology, the literature search and selection process, as well as the bibliometric analysis and data synthesis. AAM contributed to the validation of the methodology, interpretation of the results, and critical review of the scientific substance of the manuscript. All authors were involved in the writing, revision, and final approval of the manuscript.

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