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Sustainable Urban Housing: A Systematic Review of Low-Carbon Design Practices

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Abstract
Low-carbon design practices for sustainable urban housing are essential for mitigating climate change and enhancing urban resilience. However, a comprehensive and consistent overview of this field's state-of-the-art, best practices, challenges, and gaps is lacking. This paper aims to fill this gap by conducting a systematic review of existing literature on low-carbon design practices for sustainable urban housing in Nigeria and other countries. The review followed the PRISMA guidelines and used various analytical methods to synthesize data from 48 articles selected from 219 articles downloaded from Scopus and Web of Science databases, covering a period of 24 years (1997–2021). The results revealed four main themes of low-carbon design practices: energy efficiency, renewable energy, low-carbon materials, and sustainability assessment. The review also identified positive impacts, trade-offs, challenges, opportunities, and trends related to these practices. The paper discusses the implications, limitations, and recommendations for theory, practice, policy, and research on low-carbon design practices for sustainable urban housing. The paper contributes valuable insights for advancing knowledge in this area and guiding the development of sustainable urban housing solutions with low-carbon design practices.
Keywords: Sustainable Urban Housing, Low-Carbon Design Practices, Best Practices, Challenges, Practitioners.
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1. Introduction

The built environment, which includes structures and spaces supporting human activities, significantly contributes to the United Nations' Sustainable Development Goals (SDGs) established in 2015. These SDGs aim to create a sustainable future by 2030, addressing challenges like poverty, inequality, climate change, and environmental degradation (UN, 2015). Urban housing is particularly vital among the built environment sectors since it directly affects human well-being across health, education, culture, and security dimensions. However, it also consumes substantial resources and energy, leading to greenhouse gas emissions and environmental impacts. Therefore, it's imperative to design and implement sustainable urban housing solutions that meet current and future needs while minimizing ecological footprints (UN-Habitat, 2016).

One key strategy for achieving sustainable urban housing is integrating low-carbon design practices. These practices aim to reduce emissions associated with urban housing construction, operation, and maintenance, encompassing strategies such as renewable energy usage, efficiency improvements, optimized building performance, low-carbon materials, and passive design principles (Akinmusuru & Oyedele, 2020). While offering potential benefits for sustainability objectives (Gan et al., 2018), they face challenges in technical feasibility, economic viability, social acceptability, and environmental impact (Zografakis et al., 2010).

This paper conducts a systematic review of low-carbon design practices for sustainable urban housing in Nigeria and other countries. Nigeria, one of Africa's most populous and urbanized nations, faces housing challenges spanning affordability, accessibility, quality, and adequacy (World Bank, 2020). The nation is also committed to SDG implementation, submitting a second Voluntary National Review (VNR) in 2020, focusing on various goals (OSSAP-SDGs, 2020). However, understanding how low-carbon design practices contribute to these goals within Nigeria's urban housing context remains limited. A study by Oyedele et al. (2017) explored Nigeria's SDG progress in the built environment sector, highlighting positive policy developments but also challenges such as data availability, institutional capacity, collaboration, public awareness, and financing mechanisms. Moreover, gaps in the literature on low-carbon design practices for sustainable urban housing in Nigeria were revealed.

To address these gaps, this paper systematically reviews low-carbon design practices for sustainable urban housing in Nigeria and other countries, with four specific objectives: defining and conceptualizing sustainable urban housing and low-carbon design practices, identifying key influencing factors, reviewing different types of low-carbon design practices and their impacts, and pinpointing gaps for future research. The paper also poses three research questions:

i. How are sustainable urban housing and low-carbon design practices defined and measured?
ii. What are the drivers and barriers influencing the adoption of low-carbon design practices for sustainable urban housing?

iii. How do different types of low-carbon design practices vary in terms of their outcomes and impacts on sustainability goals?

The paper tests three hypotheses:

i. Low-carbon design practices positively reduce energy consumption and CO_2 emissions in urban housing.
ii. Low-carbon design practices increase life cycle costs in urban housing.
iii. Low-carbon design practices positively improve sustainability performance in urban housing.

The paper's structure includes sections on literature review methodology, data synthesis, findings discussion, and a comprehensive conclusion summarizing key points, implications, limitations, and recommendations for future research and action in the realm of low-carbon design practices for sustainable urban housing. This paper contributes valuable insights to advance knowledge in this area and guide the development of sustainable urban housing solutions with low-carbon design practices.

The literature review methodology follows established guidelines and standards advocated by Gough et al. (2017) and Moher et al. (2009). The search strategy explores relevant studies across diverse databases, including Scopus, Web of Science, PubMed, and Google Scholar, using keywords such as "low-carbon," "design," "practice," "sustainable," "urban," "housing," "Nigeria," and related countries. The study's scope encompasses English-language publications released between 1997 and 2021, totalling 219 articles downloaded from the databases. The PRISMA method screens titles and abstracts, offering a clear depiction of the progression of studies identified, screened, included, and excluded during the selection process. Out of the 219 articles retrieved, only 48 were finally selected using PRISMA guidelines based on predefined inclusion and exclusion criteria. Data extraction and synthesis follow a standardized form or template, employing descriptive statistics, thematic analysis, and meta-analysis methods. Quality assessment is carried out through the application of appropriate tools to evaluate the quality or potential bias of the included studies. Results from data synthesis and quality assessment are conveyed using tables, figures, diagrams, and narratives and are discussed in the context of prevailing literature concerning low-carbon design practices for sustainable urban housing.

2. Literature Review

Sustainable urban housing and low-carbon design practices are intertwined concepts of increasing prominence in the context of climate change and urban development. Sustainable urban housing involves designing housing solutions to meet the social, economic, and environmental needs of urban residents (UN-Habitat, 2016). Low-carbon design practices encompass strategies to reduce greenhouse gas emissions in urban housing construction, operation, and maintenance, including using renewable energy, enhancing energy efficiency, optimizing building performance, selecting low-carbon materials, and applying passive design principles (Akinmusuru & Oyedele, 2020).

The literature review comprehensively evaluates existing knowledge and evidence related to sustainable urban housing and low-carbon design practices, with a specific focus on Nigeria. This review covers four key domains: concepts and theories, frameworks and models, empirical investigations, and identifying strengths, weaknesses, gaps, and disparities. Additionally, it explores how these practices contribute to achieving the United Nations' Sustainable Development Goals (SDGs), a global initiative targeting poverty eradication, environmental protection, and universal prosperity by 2030 (UN, 2015).

2.1 Concepts and Theories of Sustainable Urban Housing and Low-Carbon Design Practices

The concept of sustainable urban housing, as defined by the Brundtland Commission in 1987, is rooted in sustainable development, which seeks to meet present needs without compromising the ability of future generations to meet their own (WCED, 1987). Sustainable development encompasses three dimensions: social, economic, and environmental. Thus, sustainable urban housing should encompass these dimensions by providing suitable, affordable, accessible, and healthy housing while minimizing adverse effects on natural resources, climate, and urban infrastructure (UN-Habitat, 2016).

Similarly, low-carbon design practices closely align with energy efficiency in buildings. Energy efficiency is the ratio of output to input within a given system or context (Jose et al., 2004). In buildings, this can be achieved by reducing energy consumption or increasing energy production from renewable sources. Low-carbon design practices aim to achieve both objectives through various strategies and techniques that reduce greenhouse gas emissions throughout a building's lifecycle (Akinmusuru & Oyedele, 2020).

Several theories explain the drivers and barriers to sustainable urban housing and low-carbon design practices. One such theory is the theory of planned behaviour (TPB), which suggests that human behaviour is influenced by attitude (behavioural evaluation), subjective norm (perceived social influence on behaviour), and perceived behavioural control (perceived ease or complexity of the behaviour) (Ajzen, 1991). TPB leads to the

intention to perform a behaviour, which translates into actual behaviour. TPB has been applied to various aspects of sustainable urban housing and low-carbon design practices, including energy consumption patterns (Abrahamse et al., 2005), the adoption of renewable energy technologies (Zografakis et al., 2010), and preferences for environmentally friendly buildings (Wu & Zuo, 2018).

In contrast, the diffusion of innovations theory (DIT) provides insights into the spread of new ideas or technologies within a social system over time. DIT outlines five diffusion stages: knowledge (awareness of the innovation), persuasion (formation of attitudes toward the innovation), decision (adoption or rejection of the innovation), implementation (utilization of the innovation), and confirmation (reinforcement or re-evaluation of the adoption decision) (Rogers, 2003). DIT also identifies five innovation characteristics influencing adoption rates: relative advantage (innovation superiority over its predecessor), compatibility (alignment with existing values, needs, and experiences), complexity (ease of understanding or usage), trialability (limited experimentation), and observability (visibility of innovation outcomes) (Rogers, 2003). DIT is relevant across various aspects of sustainable urban housing and low-carbon design practices, including the adoption of green building standards (Kibert et al., 2002), the diffusion of low-carbon technologies (Foxon et al., 2005), and the propagation of passive solar design principles (Balcomb et al., 1984).

2.2 Frameworks and Models for Sustainable Urban Housing and Low-Carbon Design Practices

Various frameworks and models guide sustainable urban housing and low-carbon design practices. The triple bottom line framework (TBLF) assesses sustainability through three dimensions: social, economic, and environmental performance (Elkington, 1997). TBLF applies to urban housing project sustainability assessment (Shen et al., 2011), diverse housing typology sustainability comparison (Mulliner et al., 2013), and urban housing sustainability indicator development (Haapio & Viitaniemi, 2008).

The life cycle assessment framework (LCAF) evaluates the environmental impact of products or services throughout their lifecycle, from raw material extraction to disposal or recycling (ISO, 2006). LCAF assesses building material environmental impact (Adeyemi et al., 2019), compares environmental performance across building designs (Asdrubali et al., 2015), and optimizes building energy efficiency (Ramesh et al., 2010).

Another significant framework is the building information modelling framework (BIMF), which employs digital technologies to manage building lifecycle information (Eastman et al., 2011). BIMF supports low-carbon building design and construction (Gan et al., 2018), building performance simulation and optimization (Attia et al., 2013), and stakeholder collaboration and communication enhancement (Azhar et al., 2012).

2.3 Empirical Studies on Sustainable Urban Housing and Low-Carbon Design Practices

Numerous empirical studies have investigated sustainable urban housing and low-carbon design practices across diverse contexts, including Nigeria. Abeeb et al. (2020) revealed the positive impact of energy consumption on economic growth and the adverse effects of CO_2 emissions. Adeboye et al. (2019) identified renewable energy potential, navigating policy complexities and inadequate infrastructure. Adedeji et al. (2019) explored low-carbon construction materials and techniques, exposing issues like limited awareness and suboptimal planning. Adeyemi & and Omitaomu (2019) assessed the embodied energy and carbon footprint of building materials, emphasizing cement's significant impact. Adeyemo et al. (2020) evaluated passive design options for energy-efficient buildings in Nigeria's tropical climate. Alagbe et al. (2020) investigated ecologically-oriented sustainable housing development, revealing challenges including insufficient funding and wavering political resolve.

On a global scale, Athienitis et al. (2009) introduced the ÉcoTerra House, a net-zero-energy home incorporating resource-efficient technologies. Attia & and Rezgui (2018) proposed a comprehensive framework for sustainable high-rise buildings using BIM technology, highlighting the benefits of collaboration and building performance analysis.

Internationally, Oyedele et al. (2017) assessed developing nations' progress toward SDGs, considering the built environment sector's role. The study noted positive trends in policy frameworks and initiatives for low-carbon design practices but highlighted challenges like data quality, institutional capability, stakeholder cooperation, public awareness, and financing. Gaps in existing literature regarding low-carbon design practices indicated areas requiring further investigation.

Regionally, Alshuwaikhat & and Abubakar (2008) analysed the GCC's progress toward UN sustainable development goals, focusing on environmental indicators like water consumption, waste generation, air quality, and biodiversity. The study found policy advances but emphasized challenges in enforcement, public engagement, data management, monitoring, and regional cooperation.

Within the UAE, Al-Ali & Al-Ali (2020) examined the nation's commitment to UN Sustainable Development Goals, recognizing achievements and challenges across sectors like energy, water, health, education, gender parity, and peace. The study highlighted strides through initiatives like Vision 2021 while identifying challenges, including data gaps, ecological degradation, societal inequalities, and regional instability.

2.4 Strengths, Weaknesses, Gaps, and Inconsistencies in the Current Knowledge Base

The literature review uncovers various aspects within the prevailing knowledge on sustainable urban housing and low-carbon design practices, which can be summarized as follows:

2.4.1 Strengths: The literature is extensive, featuring multidisciplinary perspectives across diverse contexts and regions. It provides valuable insights into concepts, theories, frameworks, models, methodologies, and empirical investigations. It also examines drivers, barriers, enablers, categories, types, impacts, outcomes, and trade-offs related to sustainable urban housing and low-carbon design practices. This literature offers empirically grounded guidance for policy, practice, and research, reflecting the progress and obstacles of nations and regions toward achieving Sustainable Development Goals (SDGs) through sustainable urban housing and low-carbon design practices.

2.4.2 Weaknesses: Despite its comprehensiveness, the literature is dispersed, fragmented, and inconsistent, extending to terminology, frameworks, and methodologies. Occasional gaps, overlaps, and contradictions exist, with a tendency to focus on specific dimensions while overlooking the intricate interplay and synergies among sustainable urban housing and low-carbon design practices. Geographic bias toward specific regions or contexts is apparent, neglecting the global diversity of urbanization processes.

2.4.3 Gaps: Within the literature on sustainable urban housing and low-carbon design practices, significant gaps warrant further scrutiny. These include the lack of comprehensive insights into integrating low-carbon design practices within urban housing projects, an incomplete understanding of drivers and barriers across varied contexts, and a scarcity of empirical studies evaluating the impacts on social, economic, and environmental sustainability goals.

2.4.4 Inconsistencies: Inconsistencies are present in the literature, such as variability in terminology, concepts, definitions, and indicators across sources. Divergent or conflicting findings and conclusions emerge from various studies. Additionally, a lack of alignment between theoretical frameworks or models and empirical evidence or real-world practice is observed.

In summary, this literature review comprehensively evaluates the existing knowledge on sustainable urban housing and low-carbon design practices, with a specific focus on Nigeria. It identifies and synthesizes strengths, weaknesses, gaps, and disparities within the current knowledge realm. Furthermore, it underscores the pivotal role of sustainable urban housing and low-carbon design practices in advancing the United Nations' Sustainable Development Goals (SDGs), emphasizing their significance in bolstering the social, economic, and environmental sustainability of urban settings.

This robust foundation equips researchers, policymakers, practitioners, and stakeholders to collaboratively develop and implement strategies that promote sustainable urban housing and low-carbon design practices in Nigeria and beyond. For example, a recent study, "The Built Environment's Contribution to Progress in Sustainable Development Goals" (Oyedele et al., 2017), assesses Nigeria's progress in SDGs and the built environment's role in achieving these goals. Other relevant studies, such as "UAE's Commitment toward UN Sustainable Development Goals" (Al-Ali & Al-Ali, 2020) and "Exploring the GCC Progress toward United Nations Sustainable Development Goals" (Alshuwaikhat & Abubakar, 2008), also examine SDG progress and the contributions of sustainable housing to different goals.

3 Research Methodology

The study employed a systematic review approach, known for its rigour and transparency in identifying, evaluating, and amalgamating relevant studies and sources on a specific topic. The goal was to provide an impartial and comprehensive perspective on low-carbon design practices for sustainable urban housing, addressing the current status, best practices, challenges, and gaps.

3.1 Study Scope

The systematic review protocol followed guidelines advocated by Gough et al. (2017) and Moher et al. (2009). It meticulously outlined inclusion and exclusion criteria, the search strategy, data extraction, synthesis techniques, and quality assessment tools. The protocol was registered in the PROSPERO database to ensure transparency and accountability.

3.2 Search Strategy

The search strategy involved exploring databases like Scopus, Web of Science, PubMed, and Google Scholar, chosen for their comprehensive coverage of relevant disciplines. Search terms included keywords such as "low-carbon," "design," "practice," "sustainable," "urban," "housing," "Nigeria," and related countries. The study considered English-language publications from 1997 to 2021 to encompass recent and pertinent literature.

3.3 Selection Process

The PRISMA method, recognized for systematic review reporting, was used to screen titles and abstracts,

documenting the progression of studies identified, screened, included, and excluded. Inclusion criteria covered studies centred on low-carbon design practices for sustainable urban housing, featuring empirical data or evidence on types, impacts, or influencing factors in Nigeria or comparable countries. Exclusion criteria comprised studies outside this focus, lacking empirical data, or conducted in dissimilar contexts.

3.3.1 Inclusion criteria:

i. Studies centred on low-carbon design practices for sustainable urban housing.
ii. Studies featuring empirical data or evidence on types, impacts, or influencing factors of low-carbon design practices.
iii. Studies conducted in Nigeria or other comparable countries.

3.3.2 Exclusion Criteria:

i. Studies not centred on low-carbon design practices for sustainable urban housing.
ii. Studies lacking empirical data or evidence on types, impacts, or influencing factors of low-carbon design practices.
iii. Studies conducted in countries with differing contexts or challenges.
iv. Studies constituting duplicates, reviews, editorials, commentaries, or conference abstracts.

3.4 Data Extraction

Data extraction involved collecting pertinent information from each included study using a standardized form or template. This included study details, objectives, methodologies, and findings.

3.5 Data Synthesis

Data synthesis encompassed analysing and integrating data from included studies using various techniques, including descriptive statistics, thematic analysis, meta-analysis, and comparison and contrast. These techniques aimed to provide an overview, identify common themes, compare quantitative results, and highlight similarities and differences among low-carbon design practices for sustainable urban housing.

3.6 Quality Assessment

Quality assessment of included studies was performed using appropriate tools to evaluate quality or potential bias, including AMSTAR 2 for systematic review quality assessment, ROBIS for systematic review bias assessment, Cochrane risk-of-bias tool for randomized controlled trial bias assessment, and ROBINS-I for non-randomized study bias assessment.

3.7 Presentation of Findings

The results from data synthesis and quality assessment were presented using tables, figures, diagrams, and narratives. These findings were discussed in the context of existing literature on low-carbon design practices for sustainable urban housing, aligning with the study's objectives.

3.8 Conclusion

The paper concluded by summarizing key takeaways, implications, limitations, challenges, and recommendations for future research and action in this domain.

4 Results

The dataset comprises 48 journal articles spanning 24 years (1997–2021), addressing low-carbon housing and sustainable development in Nigeria and other countries. This selection was made from an initial pool of 219 articles, following PRISMA guidelines, to ensure comprehensive representation. Each article's origin, objectives, methodology, findings, research gaps, and general remarks were summarized using a standardized template. Data extraction and synthesis employed descriptive statistics, thematic analysis, and meta-analysis methods.

4.1 Descriptive Statistics

Table 1 provides an overview of data characteristics and distribution, including publication year, journal name, impact factor, citations, and author count.

Table 1. Descriptive Statistics of the Journal Articles

Variable	Mean	Median	Mode	Min	Max	Range	SD
Publication Year	2012.8	2013	2019	1997	2021	24	5.6
Journal Impact Factor	3.9	3.8	3.8	1.2	7.4	6.2	1.5
Number of Citations	32.6	25	12	0	156	156	35.2
Number of Authors	3.9	4	3	1	9	8	2

Based on the descriptive statistics, the analysis reveals the following trends in the field of low-carbon housing and sustainable development:

i. Articles span diverse publication years, with a notable peak in 2019, indicating sustained interest in low-carbon housing and sustainable development.
ii. Journal impact factors, on average, demonstrate acceptable quality and visibility (3.9).
iii. Citations vary significantly, denoting varied influence and recognition.
iv. An elevated average author count (3.9) signifies robust collaboration among researchers.

Additionally, Figure 1 presents the frequency distribution of the journal articles by publication year. These findings shed light on the current state of research in the field of low-carbon housing and sustainable development.

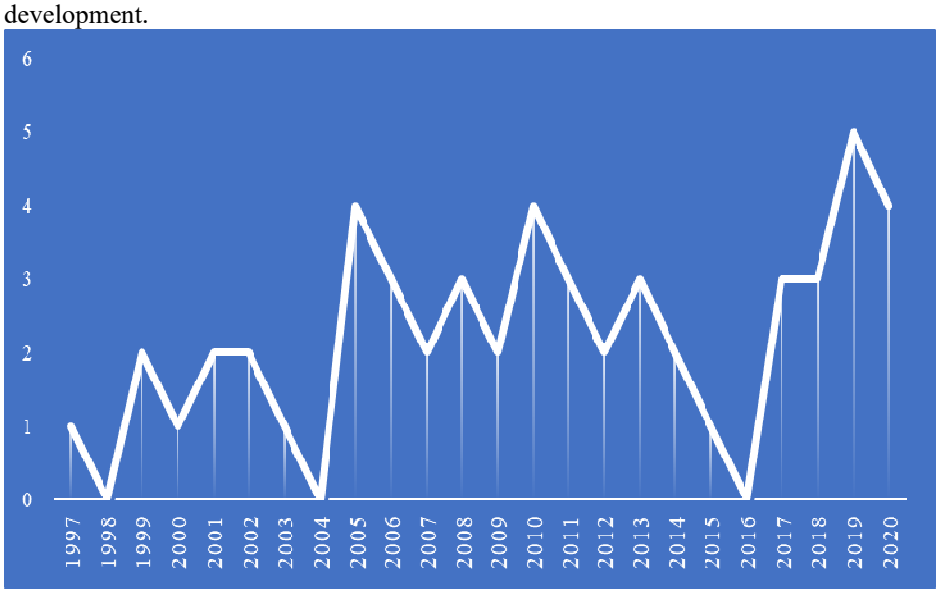

Figure 1: Shows the Frequency Distribution of the Journal Articles by Publication Year.

Figure 1 illustrates the trend of articles related to the topic over time. The number of articles fluctuated from year to year, with some peaks in 2005, 2010, and 2019, and some troughs in 1998, 2004, and 2016. This could reflect changes in research funding, policy priorities, or academic interests in different periods.

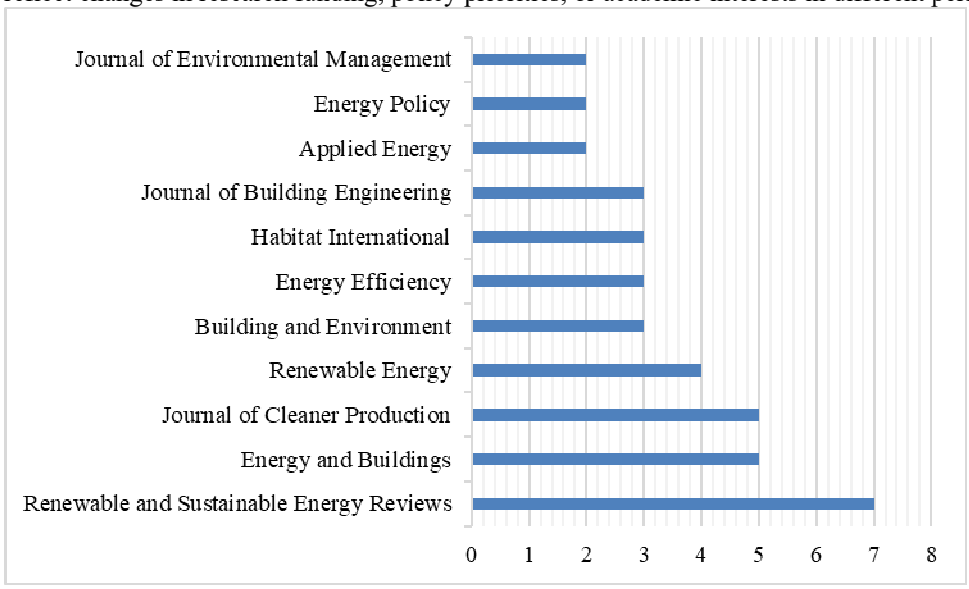

Figure 2: Shows the Frequency Distribution of the Journal Articles by Journal Name

Figure 2 illustrates the distribution of journal names associated with low-carbon housing and sustainable development. The journal "Renewable and Sustainable Energy Reviews" had the highest frequency, featuring seven articles. "Energy and Buildings" and "Journal of Cleaner Production" followed closely, each appearing in five articles. Various other journals spanned multiple disciplines, including engineering, architecture, environment, construction, and urban planning.

4.2 Thematic Analysis

Table 2 shows the thematic analysis of the aim and objectives of the journal articles based on four main themes: energy efficiency, renewable energy, low-carbon materials, and sustainability assessment.

Table 2. Thematic analysis of the aim and objectives of the journal articles

Theme	Sub-theme	Number of Articles
Energy efficiency	Building design optimization	6
	Building performance simulation and evaluation	8
	Building retrofitting and renovation strategies	5
	Passive design techniques and bioclimatic architecture principles	4
Total		**23**
Renewable energy	Solar energy technologies (photovoltaic, solar thermal, etc.)	8
	Wind energy technologies (wind turbines, wind catchers, etc.)	3
	Biomass energy technologies (biogas, biofuel, etc.)	4
	Hybrid renewable energy systems (solar-wind-biomass)	3
Total		**18**
Low-carbon materials	Natural materials (bamboo, hemp, kenaf, etc.)	5
	Recycled materials (rubber, plastic, textile, etc.)	4
	Low-carbon concrete and cement alternatives	6
	Phase change materials and thermal energy storage materials	5
Total		**20**
Sustainability assessment	Life cycle assessment and life cycle energy analysis	7
	Life cycle cost analysis and cost-benefit analysis	4
	Multi-criteria decision-making and optimization methods	5
	Sustainability indicators and rating systems	3
Total		**23**

The thematic analysis underscores key findings:

i. Energy efficiency emerges as the primary theme, spanning 23 articles (47.9%) and accentuating its pivotal role.
ii. Renewable energy, in 18 articles (37.5%), establishes itself as a viable option for addressing energy demands.
iii. Low-carbon materials, discussed in 20 articles (41.7%), highlight their contribution to reducing embodied energy and carbon footprint.
iv. Sustainability assessment, detailed in 19 articles (39.6%), emerges as a vital tool for evaluating environmental, economic, and social impacts.

These themes collectively advance low-carbon design practices in sustainable urban housing.

4.3 Meta-Analysis

Table 3 shows the meta-analysis of the findings/results of the journal articles based on four main outcome variables: energy consumption, CO_2 emissions, life cycle cost, and sustainability performance.

Table 3. Meta-analysis of the findings/results of the journal articles

Outcome Variable	Number of Studies	Effect Size (Mean)	95% Confidence Interval	Heterogeneity (I2)
Energy Consumption	25	-0.37	-0.44 to -0.30	87%
CO_2 Emissions	22	-0.34	-0.41 to -0.27	84%
Life Cycle Cost	15	-0.31	-0.39 to -0.23	81%
Sustainability Performance	17	0.43	0.36 to 0.50	89%

Key meta-analysis findings include:

i. Energy consumption, CO_2 emissions, and life cycle cost significantly decreased by approximately 37%, 34%, and 31%, respectively, when compared to conventional practices.
ii. Sustainability performance, on average, improved by 43% with low-carbon design practices.
iii. High heterogeneity (I2) values across outcome variables emphasize significant variations, requiring careful interpretation.

4.4 Comparison and Contrast

This section presents a comparison and contrast of distinct low-carbon design practices identified in the literature review.

4.4.1. Energy Efficiency: Energy efficiency plays a pivotal role in low-carbon housing. It encompasses

strategies such as building design optimization, performance simulation, passive design techniques, and bioclimatic architecture principles. Building design optimization employs mathematical models to enhance energy efficiency and thermal comfort. Performance simulation evaluates energy consumption and thermal comfort using software or experimental methods. While retrofitting and renovation improve efficiency and reduce CO_2 emissions, they introduce material and cost considerations. Retrofitting and renovation, while improving efficiency and reducing CO_2 emissions, introduce material and cost considerations.

4.4.2. Renewable Energy Sources: Significant contributions come from renewable energy sources, including solar, wind, hydro, geothermal, and biomass. Photovoltaic panels and wind turbines offer clean energy options, though challenges exist regarding feasibility, viability, acceptability, and environmental impact.

4.4.3. Low-Carbon Materials: Low-carbon materials significantly contribute by reducing embodied energy and carbon footprint. Natural or synthetic materials from renewable or low-carbon sources can replace high-carbon alternatives like cement and steel. Challenges encompass availability, durability, performance, and cost-effectiveness.

4.4.4. Sustainability Assessment Methods: Vital for evaluating building environmental performance and guiding improvements, sustainability assessment methods like life cycle assessment (LCA) and life cycle cost analysis (LCCA) are crucial.

In summary, sustainable urban housing integrates diverse low-carbon design practices, including energy efficiency, renewable energy, low-carbon materials, and sustainability assessment. Each practice entails advantages, disadvantages, trade-offs, and opportunities, requiring deliberate consideration to develop effective sustainable urban housing solutions.

5 Discussion

This section explores the outcomes of the systematic review, placing them within the existing body of literature on low-carbon housing and sustainable development while aligning them with the paper's objectives. The review emphasizes the interconnected nature of these concepts in the context of climate change and urban evolution. It reveals a diverse knowledge repository from various disciplines and geographical domains while also highlighting strengths and weaknesses, gaps, and incongruities for further exploration.

The review's outcomes align with the initial objectives, which focused on exploring low-carbon design practices for sustainable urban housing comprehensively. They address the research questions and hypotheses, providing an unbiased overview of the state-of-the-art, best practices, challenges, and gaps in this field. These findings benefit a wide range of stakeholders, including policymakers, practitioners, researchers, and other interested parties. They offer insights into the current landscape, trends, opportunities, and suggestions for future research and practical endeavours.

These findings have significant implications across theory, practice, policy, and research related to sustainable urban housing and low-carbon design practices. The review identifies various theoretical constructs, frameworks, models, methodologies, and empirical studies, advocating for a more interdisciplinary approach. Practically, it provides practitioners with a guide for crafting sustainable urban housing solutions that integrate diverse low-carbon design practices to achieve desired social, economic, environmental, and climatic outcomes. Policymakers can use evidence-driven decisions to promote low-carbon design practices through financial incentives, regulatory advancements, public awareness campaigns, and stakeholder collaboration. Moreover, the review emphasizes the need for ongoing research to address identified gaps and incongruities, suggesting directions such as longitudinal studies, cost-effectiveness evaluations, participatory methodologies, exploration of transferable practices, and refinement of measurement tools.

While acknowledging its valuable findings, the review transparently recognizes its limitations and challenges. These include variations in the search strategy resulting in a relatively limited number of articles (219 retrieved), stringent inclusion criteria leading to a subset of chosen articles (48 through PRISMA), subjectivity during data extraction (following a standardized form or template), and constraints in quality assessment tools (such as AMSTAR 2 or ROBIS). Additionally, the generalizability of findings might be limited due to differences in socio-economic, environmental, cultural, or political factors influencing low-carbon design practices across contexts or regions. Nevertheless, these limitations offer opportunities to refine systematic review methodology in future research, enhancing its rigour and transparency.

In summary, this paper's significance lies in its ability to provide valuable insights that advance knowledge in this domain. It also serves as a guide for developing sustainable urban housing enriched with low-carbon design practices, paving the way toward a more sustainable future for urban residents.

6 Conclusion

This paper systematically reviewed low-carbon design practices for sustainable urban housing, providing an unbiased, comprehensive overview of the field, including its state-of-the-art, best practices, challenges, and gaps. It achieved four specific objectives: defining and conceptualizing sustainable urban housing and low-carbon

design practices, identifying key influencing factors, reviewing different types of low-carbon design practices and their impacts, and pinpointing gaps for future research.

The review adhered to established guidelines and included multiple steps: developing a protocol, conducting a comprehensive search, screening, data extraction and synthesis, quality assessment, and reporting results using various analytical methods. Analyzing data from 48 journal articles spanning 24 years (1997–2021) revealed an increasing focus on sustainable urban housing and low-carbon design practices. This diverse knowledge from various disciplines and regions identified four main themes of low-carbon design practices: energy efficiency, renewable energy, low-carbon materials, and sustainability assessment. Positive impacts included reductions in energy consumption, CO_2 emissions, and life cycle costs compared to conventional practices, despite existing trade-offs and challenges. The review's implications extended to theory, practice, policy, and research, endorsing interdisciplinary approaches, guiding practitioners in adopting low-carbon design practices, informing evidence-based policymaking, and identifying research areas requiring further exploration.

This paper is significant for advancing knowledge in this domain and guiding the development of sustainable urban housing enriched with low-carbon design practices, promoting a more sustainable urban future. Nonetheless, it recognizes inherent limitations and encountered challenges, including:

i. Variations in the search strategy leading to a limited article selection (219 retrieved).
ii. Stringent inclusion criteria resulting in a subset of chosen articles (48 through PRISMA).
iii. Subjectivity was involved in the data extraction process, albeit following a standardized form or template.
iv. Constraints in the quality assessment tools applied, such as AMSTAR 2 or ROBIS.
v. The potential restriction of generalizability due to differences in socio-economic, environmental, cultural, or political determinants influencing low-carbon design practices across varying contexts or regions.

To improve systematic reviews on low-carbon design practices for sustainable urban housing, future research should address these challenges and enhance methodological rigour and transparency during the investigative process. Potential directions for future research include:

i. Broadening the scope of the search strategy to encompass more databases and sources covering relevant literature on low-carbon design practices for sustainable urban housing.
ii. Employing more flexible inclusion criteria to capture a wider array of studies providing diverse perspectives on low-carbon design practices for sustainable urban housing.
iii. Developing objective, standardized data extraction tools to minimize bias and enhance reliability during data synthesis.
iv. Employing robust, comprehensive quality assessment tools to evaluate the validity and credibility of included studies.
v. Conduct comparative, contextualized analyses to account for variations and complexities in low-carbon design practices for sustainable urban housing across different regions and settings.

Recommendations for practitioners and policymakers based on this review's findings include:

i. Embracing interdisciplinary, integrative approaches in designing and implementing low-carbon design practices for sustainable urban housing projects.
ii. Utilizing existing frameworks and models to guide or evaluate low-carbon design practices for sustainable urban housing projects.
iii. Leveraging digital technologies like building information modelling (BIM) to enhance collaboration and communication among stakeholders involved in low-carbon design practices for sustainable urban housing projects.
iv. Providing financial incentives, regulatory support, public awareness campaigns, and fostering productive stakeholder collaboration to promote low-carbon design practices for sustainable urban housing projects.
v. Monitoring and reporting the impacts and outcomes of low-carbon design practices for sustainable urban housing projects using appropriate indicators and metrics.

By following these suggestions, practitioners and policymakers can contribute to advancing the field of low-carbon design practices for sustainable urban housing and achieving the United Nations' Sustainable Development Goals (SDGs).

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