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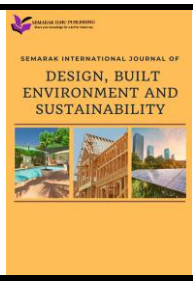

Sustainable Affordable Housing: Global Trends, Policy Gaps, and Game Changing Practice

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ABSTRACT

The global housing crisis is increasingly compounded by the need for sustainability, yet balancing affordability with environmental responsibility remains a significant challenge. Many affordable housing projects fail to integrate sustainable practices due to cost concerns, leading to long-term inefficiencies and negative environmental impacts. This study aims to explore trends, efficiency, and policy gaps in sustainable affordable housing through a comprehensive analysis of global practices. The objectives are threefold: (1) to identify key trends in sustainable affordable housing policy, (2) to evaluate the efficiency of current practices, and (3) to identify policy gaps and highlight best practices for future development. Utilizing a mixed-methods approach, this study employs bibliometric analysis to map influential research, a systematic literature review (SLR) to critically assess the existing body of knowledge, and document analysis to evaluate policy frameworks and real-world implementations. Finding reveals three critical themes in the field namely energy and construction cost efficiency, financial accessibility, and sustainable house design. Innovative approaches such as modular construction, smart energy management system, and the integration of renewable energy technologies are improving sustainable affordable housing. This study also finds the significant gaps particularly in policy integration, financial mechanisms, and scalability. Recommendations for future development include stronger green building regulations, targeted financial incentives for sustainable materials, and community-centered approaches to ensure long term affordability and inclusivity.

1. Introduction

The shortage of sustainable affordable housing is a critical issue that affects environmental, economic, and social stability. Rapid urbanization has intensified demand for affordable homes, but

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existing housing markets often fail to provide options that are both affordable and environmentally sustainable. High costs associated with green building practices and limited financing options make sustainable housing financially inaccessible for low- and middle-income populations. This issue is compounded by environmental impacts from traditional construction practices, which contribute significantly to carbon emissions and waste. Additionally, marginalized communities face disproportionate barriers to accessing affordable, sustainable housing, deepening social inequalities. Policy gaps and regulatory challenges further complicate development efforts, while cultural resistance and technological gaps hinder the adoption of green technologies. Addressing this issue requires collaborative approaches across sectors to balance affordability with sustainability, ensure social inclusivity, and promote accessible financing solutions. Without action, the sustainable affordable housing shortage will continue to undermine sustainable development goals globally.

Sustainable affordable housing is an innovative approach that seeks to merge economic accessibility with environmental sustainability [1,2], ensuring that low- and middle-income families have access to quality living spaces. This concept emphasizes the importance of designing homes that are not only affordable but also energy-efficient and environmentally friendly [3]. Key strategies include utilizing renewable energy sources like solar power, which can significantly reduce electricity costs and the community's carbon footprint by installing photovoltaic panels on rooftops and employing passive design techniques such as daylighting and cross ventilation to minimize reliance on artificial heating and cooling systems [4-6]. The use of sustainable materials, including the reuse of existing building materials, further enhances the environmental benefits by reducing waste and resource consumption [7,8]. Additionally, achieving certifications like Leadership in Energy and Environmental Design (LEED) demonstrates a commitment to sustainable practices, thereby increasing the project's attractiveness to potential residents [9,10]. Socially, sustainable affordable housing fosters community cohesion by promoting designs that encourage interaction among residents while providing easy access to essential services [11]. Despite challenges such as higher initial costs and a general lack of awareness among consumers, strategic partnerships between government entities and private developers can facilitate the integration of sustainable features into affordable housing projects 24. Ultimately, this approach not only addresses the urgent need for affordable housing but also contributes to broader environmental goals and enhances the quality of life for residents.

Recent policy innovations have demonstrated that sustainability and affordability can coexist. Governments and organizations have introduced various incentives to promote green affordable housing, such as grants, low-interest loans, and tax credits aimed at developers who incorporate sustainable practices into their projects. Standards like LEED and the Passive House standard have been adapted for affordable housing, showcasing successful integration of sustainability into economically viable models. Public-private partnerships have also emerged as a critical mechanism for driving these developments, leveraging resources from both sectors to achieve common goals. Despite these advancements, significant challenges persist. One major obstacle is the higher initial costs associated with sustainable building practices [12-14], which can deter investment in affordable housing projects. Regulatory barriers further complicate the implementation of sustainable practices, as do gaps in awareness and technical expertise among developers. For instance, many developers may lack knowledge about sustainable construction techniques or the benefits they offer in terms of long-term savings. Additionally, there is often a misconception that affordability and sustainability are mutually exclusive constraints rather than complementary goals. The analysis identifies research gaps in sustainable affordable housing, including high initial costs, scalability challenges, limited resident engagement, dependency on government funding, and the need for localized frameworks. Addressing these gaps requires innovative financial mechanisms, inclusive community participation,

and tailored guidelines to enhance scalability and effectiveness in diverse socio-economic and cultural contexts.

2. Methodology

2.1 Material and Methods

This study outlines three specific objectives, each necessitating a distinct method for thorough analysis, as summarized in Table 1.

Table 1
Summary of research objectives and methodologies

Research Objectives	Research Method	Type of Analysis
To identify key trends in sustainable affordable housing	Quantitative	Scientometric analysis
To evaluate the efficiency of current practices	Quantitative	Systematic literature review analysis
To identify policy gaps and highlight best practices for future development	Qualitative	Document analysis

This paper adopts a thorough methodological framework, incorporating both scientometric and systematic literature review and document analysis. To address Research Objective 1, scientometric analysis is applied to investigate recent trends in sustainable affordable housing research over the past decade, shedding light on publication patterns within this area. In support of Research Objective 2, systematic literature review analysis is employed to evaluate deeper into the existing literature, offering a critical examination of key insights and evaluating the effectiveness of current SAH practices. Research Objective 3 focuses on identifying policy gaps and outlining best practices to inform future developments through the document analysis. This in-depth review seeks to enhance understanding of the current research landscape and pinpoint areas that warrant further exploration.

Bibliometrics primarily involves structuring, managing, and analyzing bibliographic data from scientific publications [15-17]. This encompasses basic descriptive details such as journals, publication dates, and author classifications, along with advanced techniques like document co-citation analysis [18]. A thorough literature review necessitates an iterative approach, including identifying relevant keywords, conducting literature searches, and performing in-depth analyses to compile a complete bibliography and ensure credible results [19]. The Scopus database is utilized in bibliometrics to enhance data reliability [20-22].

The PRISMA framework, on the other hand, highlights the significance of randomized investigation assessment surveys, which play a crucial role in systematic analysis reports across diverse study designs [23]. This systematic literature review employs two comprehensive databases, Scopus and Mendeley. However, it is important to acknowledge that no single database, including Scopus and Mendeley, is entirely exhaustive. This section also details four primary stages: identification, screening, eligibility, and data extraction. Additionally, only articles published in rigorously peer-reviewed academic journals were included, while books and lecture notes were deliberately excluded to maintain a high standard of publication quality.

2.2 Identification

The systematic review approach in this study includes three core stages to select relevant papers. In the initial stage, keywords were identified, and related terms were explored using tools such as thesauruses, dictionaries, encyclopedias, and past studies. Once the terms were defined, search

phrases were formulated for the Scopus and Mendeley databases (refer to Table 2). During this first phase of the systematic literature review (SLR), the study retrieved 234 papers from Scopus and 147 from Mendeley.

Table 2
The search strings

Scopus	Mendeley
TITLE-ABS-KEY (“sustainable affordable house" OR "sustainable affordable home" OR "green affordable housing" OR "sustainable house" OR "affordable house”) AND (policy OR guideline OR program) AND PUBYEAR > 1999 AND PUBYEAR < 2025 AND (LIMIT-TO (DOCTYPE, "ar”)) AND (LIMIT-TO (LANGUAGE, "English”)) AND (LIMIT-TO (PUBSTAGE, "final”)) AND (LIMIT-TO (SRCTYPE, "j”)) AND (LIMIT-TO (OA , "all"))	("sustainable affordable house" OR "sustainable affordable home" AND (guideline OR program)

2.3 Screening

The screening process involves reviewing a collection of potentially relevant research materials to determine their relevance to the selected research question(s). For instance, one criterion applied in this process is selecting materials that focus on sustainable affordable housing. At this stage, any duplicate entries are removed from the initial list. After excluding 338 articles, 43 articles proceeded to a second round of screening, where they were evaluated based on specific inclusion and exclusion criteria (see Table 3). The primary criterion used was research articles, serving as the main source of valuable information. In addition, the review included secondary sources such as reviews, meta-syntheses, meta-analyses, books, book series, chapters, and conference papers not addressed in the latest studies. Only English-language publications were considered, and the methodology was applied to studies from 1999 to 2025.

2.4 Eligibility

At the eligibility stage, also referred to as the third level, 43 articles were obtained. Each article's title and key content were carefully examined to ensure they met the inclusion criteria and aligned with the objectives of this study. As a result, 32 articles were excluded due to their irrelevance to the study topic, mismatched titles, study areas, and abstracts, or restrictions on full-text access based on empirical evidence. At the time of this publication, 11 articles remained available for analysis.

For this scientometric analysis, data from the Scopus database spanning 1999 to 2025 were utilized. The collected information included publication year, author, title, journal, keywords, and citations, all in PlainText format. Data analysis was performed using mapping and clustering techniques with VOSviewer software version 1.6.19 [24] proposed the Multidimensional Scaling (MDS) method as an alternative to this software. Both methods aim to accurately depict relatedness and similarity by positioning objects in a low-dimensional space, where distances indicate similarity [25]. VOSviewer effectively normalizes co-occurrence frequencies by generating similarity measures such as cosine and Jaccard indexes [24]. To enhance accuracy in representing relationships among items, the software calculates association strength (ASij) from Eq. (1).

$$AS_{ij} = \frac{c_{ij}}{\omega_i \omega_j} \quad (1)$$

Meanwhile, the systematic literature review employed an integrative analysis to evaluate various research methodologies, encompassing quantitative, qualitative, and mixed-method studies. This analytical process allowed the authors to systematically uncover critical issues and subtopics within the broader context of SAH. Using a structured data collection method, the themes were built upon a comprehensive review of 11 carefully selected articles, as depicted in Figure 1. This in-depth analysis enabled the authors to gather comments and information that aligned with the current study's objectives. In the subsequent phase, after establishing foundational groupings, the authors further examined the specific challenges and barriers to achieving SAH. Through this examination, three core issues emerged namely energy and construction cost efficiency, financial accessibility, and sustainable house design. These topics underscore the fundamental obstacles impeding progress in sustainable housing and highlight the areas needing improvement to enhance affordability and accessibility in this field.

From this stage onward, the authors further developed themes, concepts, or ideas for each identified topic. The author, in collaboration with co-authors, worked to establish themes grounded in evidence. A log was maintained throughout the data analysis process to capture relevant analyses, reflections, insights, and extrapolations for interpreting the data. The authors reviewed the findings to identify any inconsistencies in the theme development process and discussed any conceptual differences. Over time, the initial designs were adjusted to ensure consistency. Experts in sustainability, housing and policy conducted an analysis to validate the identified issues. This expert evaluation process ensures that each sub-theme is relevant, clear, and meaningful, thereby establishing domain validity. The author adapted their conclusions in response to feedback from readers and expert recommendations.

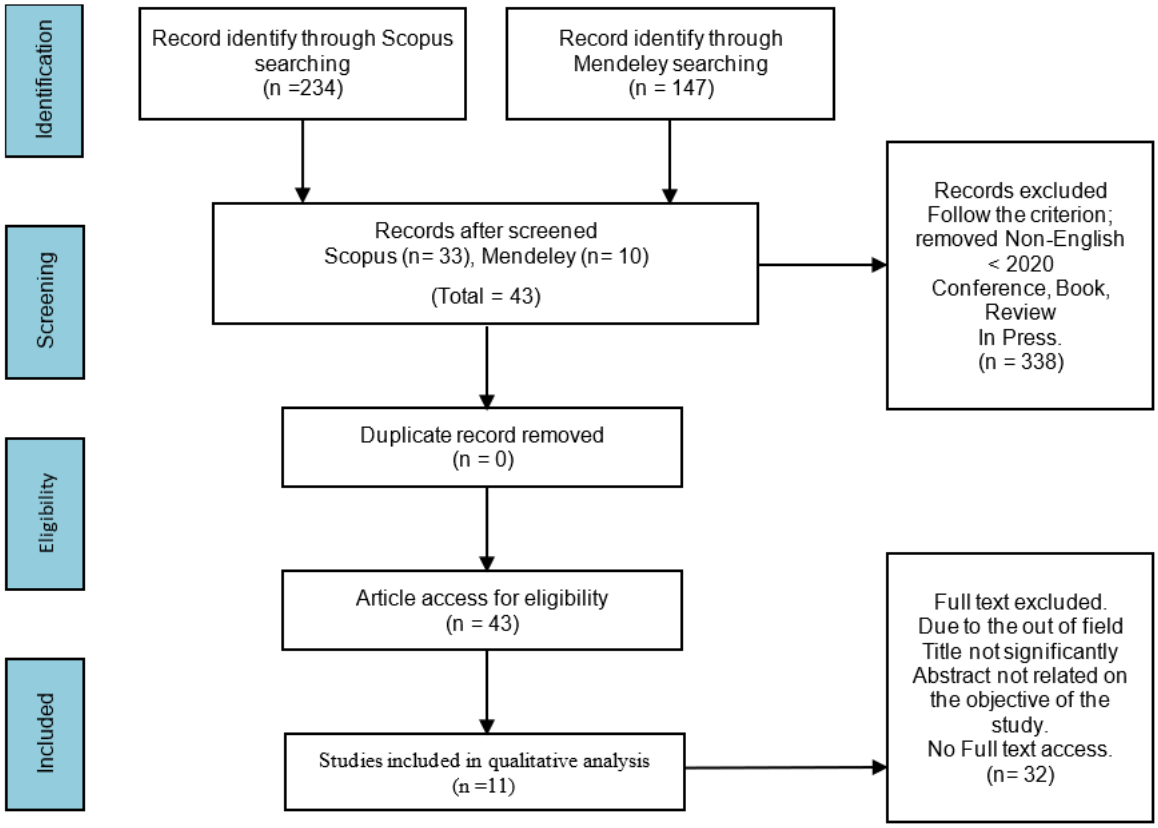

Fig. 1. Flowchart of the proposed search strategy for the SLR [23]

3. Analysis

3.1 Scientometric Analysis

3.1.1 Co-occurance and all keywords

The bibliometric map, as shown in Figure2, showcases the co-occurrence of keywords in the field of sustainable affordable housing, highlighting several distinct clusters that reveal the thematic areas within the research domain. The blue cluster, which features terms like "affordable housing," "sustainability," and "housing policy," points to a strong research focus on affordability issues and policy frameworks that support sustainable housing practices. The green cluster includes keywords such as "housing," "construction," and "developing countries," indicating an emphasis on construction practices and the challenges faced in sustainable housing development, particularly in less economically developed regions. The red cluster is centered around terms like "houses," "architectural design," and "greenhouse gases," reflecting a research concentration on the technical, design, and environmental aspects of housing, especially related to energy conservation and emissions. The yellow cluster, with keywords like "energy efficiency" and "climate change," highlights studies that explore the intersection between sustainable housing, energy use, and the broader environmental impact. Additionally, a smaller light-yellow cluster focuses on aspects like "social housing" and "thermal comfort," pointing to niche areas of research concerned with social housing needs and the living conditions that ensure comfort and sustainability. Collectively, these clusters underline a comprehensive view of the sustainable affordable housing field, connecting affordability, environmental concerns, design practices, and policy measures in a global context.

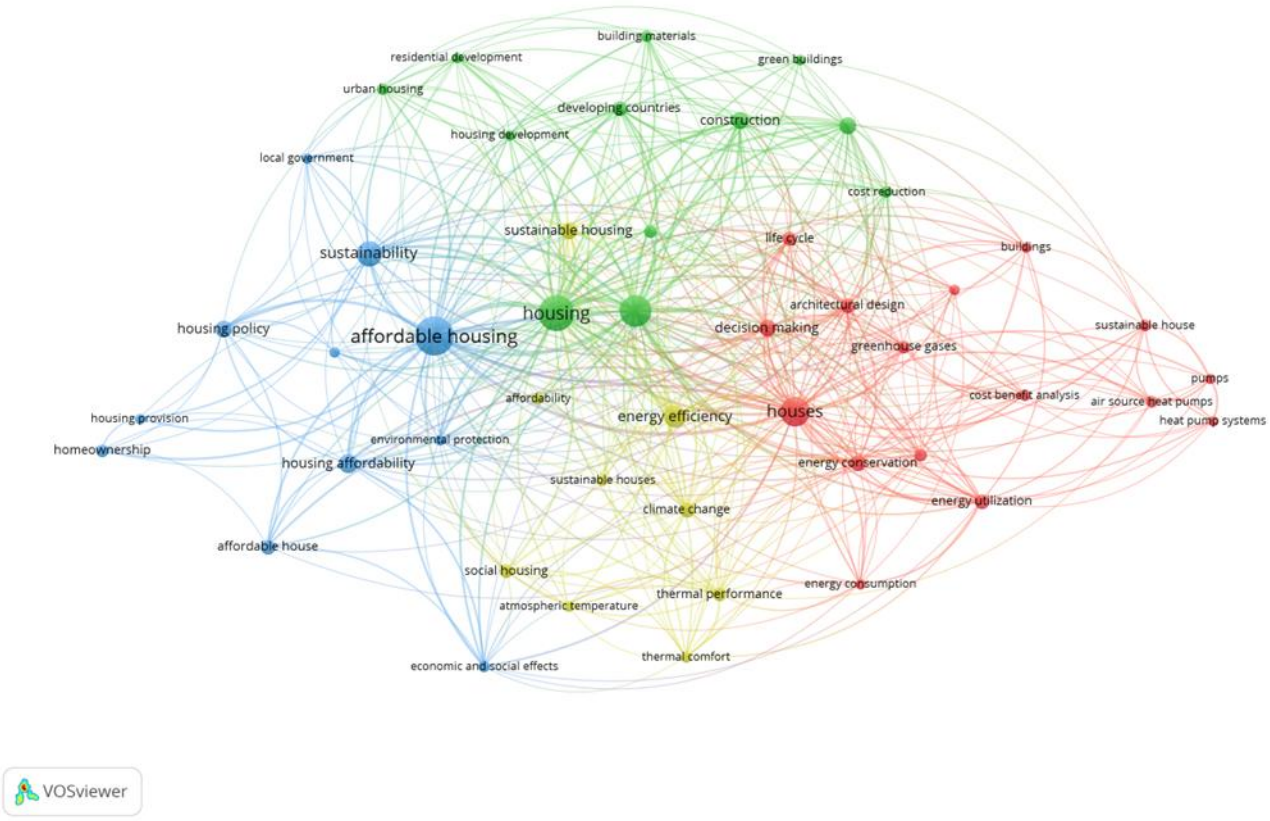

Fig. 2. Visualization of the co-occurrence of keywords in sustainable affordable housing

3.2 Systematic Literature Review Analysis

Through a systematic literature review (SLR), three critical themes have been identified to evaluate the efficiency of current practices in sustainable affordable housing: efficiency of energy and construction costs, enhancing financial accessibility, and sustainable house design. These themes offer an analytical framework for assessing how well existing housing practices meet the intertwined goals of affordability and sustainability, ultimately contributing to the creation of housing solutions that are economically viable, accessible, and environmentally responsible.

3.2.1 Efficiency of energy and construction costs

Building upon the interconnected strategies for sustainable and affordable housing, it is important to explore how these approaches reinforce each other and their broader implications for long-term urban development. The emphasis on optimising energy use, reducing construction costs, and incorporating sustainable practices reflects a comprehensive understanding of the multi-layered challenges that modern housing sectors face.

India's focus on leveraging locally sourced materials and efficient construction methods showcases how resourcefulness can drive sustainability. The use of load-bearing structures and block-based masonry, such as Hollow CC and HF Fly Ash blocks, demonstrates a practical approach to balancing cost and environmental impact. These solutions are vital not only for lowering initial expenses but also for fostering an adaptable construction model that can be replicated in various contexts. By aligning construction practices with local economic and material realities, India sets an example of how nations can scale up affordable housing while considering ecological concerns [26]. Sri Lanka's pathway to sustainable housing highlights the significance of adopting transformative technologies. Prefabricated modular construction, though not widely implemented, offers a strong solution to high construction costs and inefficient energy use. The considerable cost savings and reductions in labour expenses, alongside a 16% decrease in embodied energy, make modular construction a key strategy for developing countries seeking effective solutions. By incorporating these practices, Sri Lanka can address both economic and environmental sustainability, creating a model that encourages faster and more sustainable development. The challenge lies in building an ecosystem that supports these innovations through policy incentives, technological investment, and skill development within the construction sector [27].

The issue of informal settlements adds another layer to the discussion on housing sustainability. The overcrowded and unsafe conditions often found in these urban areas underline the need for solutions that meet affordability criteria while integrating essential services such as water, sanitation, and reliable energy. The incorporation of renewable energy, particularly solar power, offers a practical strategy to enhance these communities. Countries such as Uganda and Indonesia have demonstrated that integrating solar energy can transform informal settlements into self-sustaining urban spaces. This strategy not only reduces initial and operational energy costs but also aligns with global environmental goals by significantly cutting greenhouse gas emissions. Upgrading informal settlements with renewable energy technologies can lead to a higher quality of life, economic stability, and environmental resilience, thereby fulfilling UN Sustainable Development Goal 11 [28].

The adoption of smart home energy management systems complements these efforts by addressing inefficiencies in energy use that arise from outdated technologies. Furthermore, equipping residential buildings with real-time energy monitoring and management tools can significantly enhance energy consumption patterns, leading to reduced utility costs and more sustainable living conditions. These smart systems optimise energy use, ensuring minimal disruption

to residents, and support a shift towards more resilient housing that can adapt to changing energy demands. With the use of DSE controllers and advanced communication networks, smart home solutions provide a scalable model for enhancing both energy efficiency and cost-effectiveness. When these strategies are combined, the potential for transformative change in the housing sector becomes evident. Innovative construction techniques, modular methods, renewable energy integration, and smart technologies form a comprehensive approach that addresses affordability, energy efficiency, and sustainability in a cohesive way. The broader implications of adopting these strategies include fostering economic growth, supporting local economies through material sourcing, and contributing to global environmental initiatives. Each strategy, while impactful on its own, becomes even more effective when implemented as part of an integrated system that reinforces other sustainable practices.

Collectively, these measures support the creation of urban environments where housing is affordable, energy-efficient, and environmentally sound. Policymakers play a crucial role in facilitating this transformation by crafting regulations that encourage innovation, providing incentives for sustainable construction, and investing in the technological infrastructure needed for large-scale adoption. Public-private partnerships and community engagement are also essential in scaling these solutions, ensuring that they are both practical and adaptable to local needs. Achieving sustainable affordable housing is not a solitary effort but a collaborative process that bridges innovative construction methods, renewable energy initiatives, and energy-efficient technologies. This integrated approach paves the way for more resilient, equitable, and sustainable urban development. By embracing these interconnected strategies, countries can create housing that not only meets current needs but also anticipates future challenges, securing a balanced, sustainable, and prosperous urban future.

Table 3
Summary of efficiency of energy and construction costs

Authors	Current practice	Type of solution	Benefit of improvement
[26]	Common practices in India, include load-bearing structures up to three stories and block-based masonry, which are relatively efficient but vary in terms of embodied energy and cost-effectiveness	Hollow CC block masonry is recommended to reduce embodied energy, while HF Fly Ash block-based masonry is the most cost-effective solution. These methods support sustainable, locally adapted construction techniques	Sustainable construction improvements boost cost-efficiency, lower environmental impact, and support scalable affordable housing solutions, effectively addressing urban population growth while balancing economic and ecological needs
[27]	Sri Lanka's construction industry lags behind other developing countries due to slow adoption of technologies like prefabricated modular construction, limiting potential cost savings and energy efficiency gains	Adopting modular construction, particularly prefabricated volumetric techniques, within Sri Lanka's construction industry could result in substantial cost savings and improved resource utilisation	Introducing modular construction could reduce total construction costs by 32%, labour costs by 36%, and embodied energy by 16%, enhancing both affordability and sustainability in the housing sector
[28]	Existing approaches to informal settlements are insufficient, leaving many urban residents in overcrowded, insecure conditions without adequate water, sanitation, or basic facilities.	Proposed solutions include upgrading informal settlements and incorporating solar energy to create green, affordable housing	Upgrading informal settlements and integrating solar energy improves living conditions, increases energy access, and reduces dependence on non-renewable resources.

3.2.2 Enhancing financial accessibility

Enhancing financial accessibility to promote sustainable affordable housing (SAH) is a multifaceted endeavour that requires targeted strategies and collaborative efforts. Addressing the barriers to affordable housing finance is essential for low- and middle-income households, who often face significant challenges in securing suitable housing. Implementing innovative financial mechanisms such as affordable microloans, government-backed subsidies, and interest rate support can lower the cost threshold for homeownership and rental access, fostering a more inclusive and accessible housing market. In the context of South Asia, financial accessibility remains uneven, with countries like India making strides in developing a financial market for SAH, while others, such as Pakistan and Bangladesh, continue to struggle due to inadequate funding and weaker financial infrastructures. A comprehensive financing framework designed to bolster SAH, including Credit Link Subsidy Schemes, energy-efficient mortgages, and strategic Public-Private Partnerships (PPPs) has been proposed [29]. These measures are intended to improve financial accessibility and support the sustainability of affordable housing by leveraging diverse funding models and cooperative efforts. Advancing SAH financing through enhanced credit subsidies, dedicated energy-efficient financing, and expanded PPPs can significantly increase access for low-income populations. Such initiatives not only contribute to financial inclusivity but also align with environmental sustainability, curbing slum growth and promoting equitable urban development across the region [29].

Similarly, in Indonesia, efforts to improve housing finance for low-income community's face challenges such as limited financial accessibility, insufficient funding, and high property prices. The SiKasep Housing Subsidized KPR Information System represents an innovative approach to overcoming these barriers by integrating leadership, effective communication, and active community involvement. Some scholars highlight that government backing and technological advancements support this digital platform, which streamlines housing subsidy processes and enhances access to financial resources [30]. By fostering greater community participation and reinforcing policy implementation, platforms like SiKasep contribute to more effective and equitable fulfilment of housing needs. Such technological integration is a step forward in supporting sustainable affordable housing and addressing long-standing financial access issues.

While affordability and financial mechanisms are crucial, the physical location of housing also plays a significant role in economic sustainability. Affordable housing for the poorest often suffers from inefficiencies related to their locations, which are frequently distant from employment centres. This results in high transportation costs and undermines economic stability [31]. A strategic focus on location-based planning can mitigate these issues by ensuring that affordable housing is developed in areas with diverse land use and close proximity to work opportunities. This reduces commuting distances, lowers transportation expenses, and enhances overall economic sustainability for low-income households. Underscores that such location-based approaches lead to multiple benefits, including reduced transport costs, improved income stability, and better infrastructure access, thus enhancing financial accessibility and promoting long-term economic viability [31].

These examples illustrate that enhancing financial accessibility in sustainable affordable housing involves addressing a complex set of economic, technological, and spatial factors. In South Asia and Indonesia, developing innovative financial tools and leveraging technology can greatly improve affordability and inclusivity. Meanwhile, location-based strategies are essential to ensure that housing supports economic sustainability. Collectively, these approaches reinforce that financial accessibility must be part of an integrated framework that aligns economic strategies with sustainable and socially inclusive housing practices. By addressing these diverse challenges, policies

can create a more robust pathway to sustainable and financially accessible housing that benefits communities and supports sustainable development objectives as shown in Table 4.

Table 4
Summary of enhancing financial accessibility

Author(s)	Efficiency of Current Practice	Type of Solution	Benefit of Improvement
[29]	Current practices in Green Affordable Housing (GAH) adoption show variability in efficiency across different South Asian economies. While India has made progress in establishing a financial market for GAH, Pakistan and Bangladesh face challenges due to inadequate funding and weaker financial infrastructure. Overall, current practices are insufficient in uniformly addressing GAH adoption in the region.	The solutions proposed include a comprehensive financing framework to support GAH. This framework incorporates Credit Link Subsidy Schemes, energy-efficient mortgages, and Public-Private Partnerships (PPPs) for housing investments to boost the adoption and sustainability of affordable housing initiatives.	Improvements in GAH financing, such as enhanced credit subsidies, energy-efficient funding, and partnerships, would lead to better financial accessibility and support for low-income groups. This, in turn, fosters environmental sustainability and helps mitigate urbanization challenges, reducing slum growth and promoting more equitable and sustainable urban development.
[30]	The current practices in housing finance policies for Low-Income Communities (MBR) are moderately effective due to challenges such as limited access to housing, inadequate finance availability, and unaffordable prices. However, initiatives like SiKasep show potential in improving access through targeted strategies.	The solution discussed is the SiKasep Housing Subsidized KPR Information System Application, which incorporates strategies like leadership approaches, effective communication, and community involvement, supported by government backing and technology proficiency.	Improvements in housing finance policies through innovative systems like SiKasep benefit sustainable affordable housing by enhancing financial accessibility, increasing community engagement, and fostering better policy impact, ultimately ensuring more effective fulfillment of housing needs for low-income communities.
[31]	Current practices in affordable housing for the poorest are partially efficient. Although housing quality, rental prices, and tenure security are satisfactory, housing locations are often inaccessible for work, leading to high transportation costs and reduced economic sustainability.	Affordable housing in accessible locations with diverse land use and reduced commuting distances. This solution emphasizes location-based planning to improve economic sustainability for low-income households.	Locating affordable housing in accessible areas reduces transportation costs, enhances income stability, improves infrastructure, and shortens commute times. This approach supports economic sustainability and improves the overall affordability for the poorest.

3.2.3 Sustainable house design

Sustainable house design focuses on creating living spaces that minimise environmental impact while enhancing economic and social benefits. This approach involves the integration of energy-efficient materials, renewable energy sources, and innovative construction methods to reduce resource consumption and promote long-term sustainability. However, in many regions, achieving truly sustainable housing requires overcoming significant challenges related to traditional practices, regulatory support, and technological advancements.

In Brazil, for instance, the construction of low-income housing often relies on conventional, intuitive methods that lack comprehensive sustainability assessments. This results in suboptimal environmental and economic outcomes. Some highlight that incorporating Life Cycle Assessment (LCA) and Life Cycle Cost Assessment (LCCA) into the design process can help address these shortcomings [32]. Utilising tools such as Autodesk Revit and the Tally application, these assessments enable a detailed evaluation of construction materials and processes. The analytic hierarchy process (AHP) has been shown to be effective in selecting sustainable solutions, with light steel frame houses identified as a particularly beneficial option. Implementing LCA, LCCA, and Building Information Modelling (BIM) during the design phase can lead to significant improvements, including reduced environmental impact, enhanced thermal comfort, shorter construction timelines, and improved cost-effectiveness. This integrated approach creates housing solutions that better meet the economic and environmental needs of low-income communities.

Similarly, the construction industry in Kuwait faces inefficiencies in adopting sustainable housing practices. Although there is potential to incorporate traditional and environmentally friendly design elements, obstacles such as a lack of incentives, access to affordable sustainable materials, and advanced technology impede progress. The reliance on subsidised energy and water further diminishes the urgency for sustainable adoption [33]. Proposed strategies to improve sustainability include incorporating passive solar systems, solar panels, and alternative air conditioning methods. Integrating traditional vernacular designs that reflect the cultural context also supports eco-friendly building practices. The importance of government involvement through eco-regulations and comprehensive planning to promote these sustainable measures [33]. Enhancing sustainable housing design in Kuwait would reduce energy use, lower carbon emissions, and promote culturally relevant architecture that aligns with the nation's heritage. Stronger policies and regulations could bridge the gap between design ideals and practical implementation, fostering greater adoption of sustainable practices that benefit society and the environment. In India, affordable housing units (IAHUs) present a different set of challenges, particularly with the built-up-to-carpet area ratio, which varies from 1.30 to 1.62. This variability affects construction costs and embodied energy, as higher ratios lead to greater material consumption and increased expenses. Efficient architectural planning is needed to optimise this ratio, emphasising the design of common circulation spaces to lower resource consumption [34]. By adopting architectural designs that reduce the built-up-to-carpet area ratio, significant benefits can be achieved, including reduced construction costs ranging from INR 13,425.00 to 20,138.00 per m^2 and lower embodied energy between 4 and 6.5 GJ per m^2. These improvements support sustainability by enhancing material efficiency, decreasing energy consumption, and maximising usable space for residents. This approach not only fosters affordability but also aligns with sustainable development goals, contributing to eco-friendly construction practices.

In the broader Middle East region, building design and construction face energy inefficiencies due to the heavy reliance on active cooling systems, without considering the building form, orientation, or suitable envelope materials. This issue is particularly pronounced in areas with extreme climates, such as Oman [35]. Incorporating passive environmental design strategies offers a promising solution. These strategies involve creating eco-houses that employ sustainable architectural principles, use locally sourced materials, and address the technical, climatic, and socio-cultural needs of the region. An exemplary model is The Research Council of Oman's eco-house project at Sultan Qaboos University, which illustrates the effective application of passive design. Climate-responsive design strategies can lead to reduced energy consumption, improved thermal comfort, and cost-effective housing solutions. The use of local materials not only enhances sustainability but also supports local economies. These advancements contribute to creating residential buildings that are functional, energy-efficient, and well-suited to their environment, promoting long-term

sustainability. Sustainable house design across different regions shares common themes of overcoming traditional practices, integrating modern assessment tools, and adopting context-specific strategies. While Brazil benefits from adopting LCA, LCCA, and BIM for low-income housing, Kuwait requires stronger regulatory support and the incorporation of traditional designs. India can enhance affordability and efficiency through optimised architectural planning, and the Middle East, particularly Oman, showcases the potential of passive environmental design. Together, these examples highlight that sustainability in housing is multifaceted, requiring tailored approaches to meet environmental, economic, and social objectives a shown in Table 5.

Table 5
Summary of sustainable house design

Author(s)	Efficiency of Current Practice	Type of Solution	Benefit of Improvement
[32]	Current practices in the construction of low-income housing in Brazil are largely inefficient as they are often chosen intuitively or based on conventional methods without comprehensive sustainability assessments. This leads to suboptimal environmental and economic outcomes.	The solution involves integrating Life Cycle Assessment (LCA) and Life Cycle Cost Assessment (LCCA) into the decision-making process for housing design, utilizing tools like Autodesk Revit and Tally application for evaluation. The analytic hierarchy process (AHP) was used to select the most sustainable design option, which in this case highlighted light steel frame houses as a superior choice.	Improvements using LCA, LCCA, and Building Information Modelling (BIM) in the design phase lead to the development of more sustainable and efficient housing. Specifically, selecting light steel frame construction can reduce environmental impact, enhance thermal comfort, decrease construction time, and improve cost-effectiveness, ultimately resulting in better housing options for low-income communities.
[33]	Current practices in Kuwait's construction industry are inefficient in terms of sustainability. Although there is potential for incorporating traditional and sustainable design elements, there is a significant gap between sustainable design ideals and actual construction due to a lack of incentives, affordable sustainable materials, and technology. Additionally, the reliance on subsidized energy and water diminishes the motivation for adopting sustainable practices	The solutions proposed include the use of passive solar systems, solar panels, and alternative air conditioning to cut energy costs. The integration of traditional vernacular design elements as sustainable strategies is also highlighted. The study emphasizes the need for government involvement in building eco-regulations and planning to foster sustainability.	Improvement in sustainable housing design would lead to reduced energy consumption, lower carbon emissions, and the promotion of culturally expressive architecture that aligns with Kuwait's heritage. Enhanced government policies and regulations could bridge the gap between ideal designs and practical implementation, leading to a broader adoption of sustainable practices in the housing sector, ultimately benefiting society and the environment.
[34]	Current practices in Indian affordable housing units (IAHUs) show variability in efficiency. The built-up-to-carpet area ratio varies significantly (from 1.30 to 1.62), impacting the construction cost	The solution involves **efficient architectural planning of common circulation spaces** to optimize the built-up-to-carpet area ratio. This approach emphasizes the use of architectural designs that lower	Improvements in architectural design to lower the built-up-to-carpet area ratio can result in significant benefits, including **reduced construction costs** (from

	and embodied energy. Higher ratios lead to increased material consumption and higher costs, indicating a need for more efficient architectural planning.	the ratio, thereby reducing resource consumption and associated construction costs and embodied energy.	INR 13,425.00 to 20,138.00 per m²) and **lower embodied energy** (4–6.5 GJ per m²). These changes support sustainability by enhancing material efficiency, reducing energy consumption, and increasing the usable space for occupants, thereby promoting affordability and eco-friendly construction practices.
[35]	Current practices in building design and construction in the Middle East are inefficient in terms of energy use. Many buildings rely heavily on **active cooling systems** without proper consideration of building form, orientation, or appropriate envelope materials. This results in high energy consumption, especially in regions with harsh climates like Oman technology. Additionally, the reliance on subsidized energy and water diminishes the motivation for adopting sustainable practices	The solution proposed involves **incorporating passive environmental design solutions** that consider the climate and site specifics. This includes developing **eco-houses** that integrate sustainable architectural principles, use locally produced materials, and align with technical, climatic, and socio-cultural needs. The Research Council of Oman's initiative, as demonstrated by Sultan Qaboos University's eco-house project, serves as a model **planning** to foster sustainability.	Improvements through the adoption of climate-appropriate passive design strategies lead to **reduced energy consumption**, enhanced **thermal comfort**, and more **economically viable housing**. Using **locally sourced materials** further supports sustainability and local economies. These innovations create residential buildings that are functional, energy-efficient, and suited to the local environment, fostering long-term sustainability and practical implementation, leading to a broader adoption of sustainable practices in the housing sector, ultimately benefiting society and the environment.

3.3 Policy Gaps and Highlight Best Practices for Future Development

The table and accompanying analysis provide an in-depth view of the gaps and potential improvements in the implementation of sustainable affordable housing practices globally. Starting with the Evergreen Sustainable Development Standard from the United States, it serves as a model for integrating sustainability into affordable housing through energy efficiency, water conservation, and healthy living environments. However, its high initial costs and scalability issues present significant barriers. Furthermore, limited resident engagement in maintenance and operations weakens its long-term impact. Improvements could include developing cost-effective green technologies, introducing subsidies or incentives to offset upfront costs, and creating comprehensive resident engagement programs. Besides, effective stakeholder engagement in sustainable housing requires co-creation strategies such as participatory planning workshops, regular feedback sessions, and capacity-building programs for residents. Examples include integrating community-driven maintenance committees and leveraging digital platforms for ongoing communication. These

approaches ensure residents actively contribute to and sustain the success of housing projects long-term.

The Baan Mankong Program in Thailand highlights a community-driven approach to upgrading informal settlements, empowering residents through financial assistance for infrastructure and housing improvements. Despite its successes, challenges include maintaining long-term community participation and a heavy reliance on government-subsidized loans, which limits its scalability. Solutions include establishing community-based monitoring systems to ensure sustained engagement and diversifying funding through public-private partnerships (PPPs) to reduce dependency on government financing. The Housing First model, implemented across various countries, has revolutionized homelessness intervention by prioritizing housing as a basic human right without preconditions. While it effectively reduces homelessness, the model requires significant initial investment and cross-sector collaboration, which can be difficult to achieve in resource-constrained regions. To address these gaps, securing multi-year funding from international donors or housing-focused funds and simplifying collaboration models to focus on fewer, more aligned partners are suggested. Globally, the Sustainable and Affordable Housing Report provides a research-backed roadmap for integrating sustainability into affordable housing, focusing on habitability, community connectivity, and resilience to climate change. However, its universal recommendations face challenges in being adapted to diverse socio-economic and cultural contexts. Improvements include developing localized guidelines tailored to specific regional needs and conducting pilot projects to refine strategies before scaling them up.

These examples collectively underscore the progress made in integrating sustainability into affordable housing while highlighting significant policy, funding, and implementation gaps. Addressing these issues requires innovative financial mechanisms, inclusive community participation, localized adaptations of global frameworks, and strong political commitment. These improvements are vital to ensuring that sustainable affordable housing becomes achievable, particularly in the face of rapid urbanization and growing climate challenges. Through these targeted actions, sustainable affordable housing can be scaled effectively to meet the needs of vulnerable populations worldwide as shown in Table 6.

Table 6
Summary of sustainable affordable housing practices

Name of Practice/Policy/ Guideline	Type	Country	Criteria	Gap Identified	Suggestion for Improvement
Evergreen Sustainable Development Standard [36]	Sustainability Standard	USA	• Integrative process • Location & Neighborhood Fabric • Site Improvements • Water Conservation • Site Improvements • Water Conservation • Energy Efficiency • Materials • Healthy living environment • Operations & Maintenance &	High costs and difficulty in scaling projects; limited resident engagement in maintenance.	• Develop cost-effective green technologies and materials. • Create subsidies or incentives to offset initial costs. • Enhance resident engagement programs.

			Resident Engagement		
Baan Mankong Program [37]	Slum Upgrading Initiative	Thailand	• Slum upgrading • Equity /assets • Social & financial support • Government subsidized loans	Long-term community participation challenges; reliance on government-subsidized loans.	• Establish community-based monitoring systems to maintain engagement. • Diversify funding through public-private partnerships (PPPs).
Housing First [38]	Homelessness Intervention	Various	Social & financial support	High initial investment and reliance on cross-sector collaboration, limiting low-resource regions.	• Secure multi-year funding through international donors or housing-focused funds. • Simplify collaboration models to include fewer, more focused partners.
Sustainable and Affordable Housing Report [39]	Research Report	Global	Habitability & Comfort	Difficulty in adapting recommendations across diverse socio-economic and cultural contexts.	• Develop localized guidelines tailored to specific regions. • Conduct pilot projects to test and refine strategies before full-scale implementation.

4. Conclusion

Sustainable affordable housing addresses critical global challenges, including urbanization, environmental degradation, and social inequality, by ensuring that low- and middle-income populations have access to housing that is both affordable and environmentally responsible. Through systematic reviews and research, three critical themes have emerged as key evaluation metrics: efficiency of energy and construction costs, enhancing financial accessibility, and sustainable house design. These themes form the analytical framework for assessing the effectiveness of current practices and highlight the interconnectedness of affordability, sustainability, and environmental considerations. Key findings reveal that while advancements in sustainable affordable housing, such as energy-efficient technologies and innovative financial mechanisms, are evident, significant gaps remain. For instance, high construction costs, limited scalability, and inconsistent policy frameworks hinder broader adoption. Practices like the Evergreen Sustainable Development Standard in the USA showcase energy-efficient and environmentally conscious housing designs but face scalability issues

due to high costs. Similarly, Thailand's Baan Mankong Program highlights the potential of community-driven initiatives but underscores the need for long-term engagement and diversified funding sources. Policy gaps, including the need for localized guidelines and stronger financial incentives, further impede the progress of sustainable affordable housing initiatives. Future developments must prioritize innovative financial models, public-private partnerships, and community-centered approaches. Integrating these strategies can enhance scalability and adaptability, ensuring that sustainable affordable housing meets the needs of diverse socio-economic contexts. Ultimately, sustainable affordable housing is a global imperative that contributes to environmental sustainability, social equity, and economic stability. By addressing these gaps and leveraging best practices, policymakers and stakeholders can pave the way for a more inclusive and sustainable future.

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