Medicon Engineering Themes
Volume 8 Issue 1 January 2025
Article Type: Literature Review
ISSN: 2834-7218

Addressing Urban Heat through Green Building Strategies: A Comprehensive Literature Review

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Received: November 10, 2024; **Published:** January 11, 2025

Abstract

The combined effects of local warming brought on by urbanisation and global climate change are making urban heat a growing problem for many cities. Urban heat-related issues must be addressed immediately because these phenomena have substantial negative effects on the environment, the economy, society, and human health. Although buildings play a significant role in urban heat, they also offer opportunities for mitigation through the decarbonisation of the built environment. The building industry has acknowledged green buildings (GBs) as an innovative philosophy and practice. GBs have been suggested as a way to reduce the effects of urban heat islands and other heat-related issues. The purpose of this study is find the most important factors of green building which can be impactful for reducing UHI. Using an extensive literature review methodology, the study identified eighteen important references following a thorough screening of more than 1400 preliminary studies. Finally 10 papers have been selected. These sources concentrate on the ways that green buildings mitigate urban heat through different approaches, such as cutting carbon emissions, lessening the effects of artificial landscapes, and enhancing energy efficiency. Global warming mitigation, local warming mitigation, and urban heat mitigation are the three categories into which the framework created in this review divides GB's responses to urban heat challenges. Further analysis of these responses is conducted with respect to the following areas: building design, energy and water efficiency, site planning, outdoor environments, transportation, material selection, indoor environmental quality, operation management, and building life cycle, including construction and maintenance. The findings indicate that GBs significantly contribute to reducing the urban heat problem by lowering carbon emissions, minimising artificial landscapes, and promoting energy-efficient designs. This review provides a holistic analysis of the role of GBs in urban heat mitigation, aiming to inform future research and practical implementations in urban planning and green building development.

Keywords: Urban heat island; green building; mitigation strategies; green infrastructure; climate change

Abbreviations

UHI: Urban Heat Island.
UHMA: Urban Heat Mitigation and Adaptation.
HWs: Heat Waves.
GBs: Green Buildings.
GBs: Green Buildings.

AC: Air Conditioning.
CO_2: Carbon Dioxide.
SBs: Sustainable Buildings.
PHs: Passive Houses.
NZEB: Nearly Zero-Emission Buildings.
GI: Green Infrastructure.
LEED: Leadership in Energy and Environmental Design.
USGBC: U.S. Green Building Council.
CASBEE: Comprehensive Assessment System for Built Environment Efficiency.
MOHURD: Ministry of Housing and Urban-Rural Development.
BREEAM: Building Research Establishment Environmental Assessment Method.
LCA: Life Cycle Assessment.
LCC: Life Cycle Costing.
SVF: Sky View Factors.

Introduction

The substantial contribution of fossil fuels, particularly natural gas and oil, to carbon dioxide (CO_2) emissions, which are intimately associated with global warming, has led to grave environmental concerns being raised by the fast rise in fossil fuel consumption. Global anthropogenic CO_2 emissions from fossil fuels increased by 1.2% in 2017 over the previous year. These emissions are primarily the result of the USA, China, the EU28, India, Russia, and Japan. The Paris Agreement requires developed and developing nations to implement sustainable practices to mitigate climate change in response to rising global temperatures.

The management of air pollution sources is the primary goal of traditional pollution control strategies. These techniques are efficient at cutting down on new pollutants, but they are ineffective at addressing those that are already in the atmosphere. As a result, novel techniques are required to absorb and retain current pollutants like CO_2. Using green buildings (GB) is one strategy that can reduce CO_2 emissions in two ways. First, the greenery incorporated into these structures stores carbon in plants and their roots by absorbing CO_2 through photosynthesis. Second, vegetation in urban areas can lessen the amount of heat that buildings absorb [31, 33], thus lowering the energy demand for cooling. This reduction in energy consumption means fewer fossil fuels need to be burned, ultimately lowering global CO_2 emissions [12].

Green roofs (GRs) offer a sustainable long-term solution for carbon sequestration in urban areas [16, 22] Over the past decade, GRs have gained global recognition for their environmental and social benefits, helping mitigate the negative impacts of urbanisation [34, 26]. The aim of this study is to examine the role and impact of green buildings and green roofs in mitigating urban heat island effects and improving environmental quality in modern cities. The importance of this topic has intensified, especially in the current era, given climate change, rising temperatures, and environmental concerns. This research seeks to review previous studies and evaluate their findings to propose effective and practical solutions for various cities and geographical regions.

Literature Review

Green building

The growing conflict between rapid construction expansion and environmental degradation has led to a significant increase in interest in the concept of green buildings (GB) in recent years. Throughout all phases of their life cycle, including design, construction, operation, maintenance, and demolition, green buildings (GBs) are specifically made to reduce their impact on climate change and preserve natural resources. From location planning and development to maintenance and deconstruction, these buildings employ sustainable practices that efficiently manage the environment. Studies have indicated that green buildings (GBs) have several advantages, including encouraging material reuse, increasing energy efficiency, boosting ecosystems, facilitating sustainable land use, and lowering waste and CO_2 emissions. Notwithstanding these advantages, GBs encounter various obstacles impeding their extensive implementation. These consist of the absence of cutting-edge technology, protracted investment recovery times, and inadequate information sharing [13, 1]. Because of this, GBs are not yet accepted as a common architectural solution by the general public. Furthermore, a large portion of the research that has already been done on GBs is fragmented, frequently concentrating on particulars without offering a thorough analysis, and restricted to particular areas or nations, which limits its applicability globally. This paper fills these gaps by providing a comprehensive engineering perspective evaluation of GBs and examining their role as an essential tool for sustainable development. In the midst of growing concerns about climate change and greenhouse gas emissions, it seeks to create a cogent and systematic framework for researchers, architects, and investors in the construction field. Crucially, in the context of sustainable design, this study also sets GBs apart from other notions like smart buildings, passive houses, and nearly zero-emission buildings (NZEBs). Industry stakeholders can benefit from the study's practical insights on green materials, certification schemes, and GB design.

Climate change

The Human Settlements, Energy, and Industry chapter came to the conclusion that the development of settlements is likely to be significantly impacted by climate change, especially in areas that depend on natural resources or are situated in coastal or riverine regions. The main concerns were about possible detrimental effects on development, like a settlement's decreased comparative advantage for economic growth in comparison to other places. Nonetheless, it was anticipated that certain regions would benefit. According to the report, there are three main factors that make a settlement more vulnerable: its location, where flooding along rivers and coasts is most likely to occur; its economic dependence on weather-sensitive industries; and its size, where larger settlements are more likely to experience overall risks despite possibly having a higher capacity for adaptation [2, 3]. These earlier findings were reaffirmed in the 2007 chapter on Industry, Settlements, and Society, which also emphasised the possibility for adaptation and explicitly placed the impacts of climate change within the framework of socioeconomic change.

However, the report also made the case that a large number of businesses, communities, and societies are highly adaptable. The competency and capacity of individuals, communities, businesses, and local governments, as well as their access to financial and other resources, will determine how much of this adaptation is made.

These include methods for handling uncertainty, approaches to spatial and temporal variation, valuation concerns covering market and non-market effects and indirect impacts on the economy, and treatment of scenarios that involve both climate and socioeconomic projections The way various types of climate signals are treated demonstrates the obvious need to take these factors into account in quantitative city-level analyses. Most research that has been done so far has concentrated on a single topic, the most popular of which being sea level rise. This emphasis is a reflection of the fact that more than 50% of the world's population lives in major cities [4-6].

The focus on sea-level rise is more prevalent than it is on other climate variables because of a number of factors, such as how vulnerable coastal cities are already to climate variability, how certain future sea-level rise scenarios are compared to other climate variables, and how easy it is to measure potential impacts (such as the area at risk of flooding). Studies on the effects of heat extremes are second most popular, and they also carry over the results of heat stress related to current climate variability to future climate change scenarios. The existing literature, taken as a whole, shows a relatively narrow focus on particular issues, like heat waves and sea level rise, so it should only be interpreted as representative of the larger climate change priorities that cities around the world are facing. The remaining portion of this review's Section 2 offers a sector-by-sectoral overview of the literature on the effects of climate change on cities. This organisation follows the format of most of the literature that has been published thus far, concentrating on specific industries rather than providing a thorough analysis of the variety of effects on cities.

Urban Heat

The Urban Heat Island (UHI) effect refers to the phenomenon where urban areas experience higher temperatures than their surrounding rural areas. In addition to heat, other factors contributing to this temperature increase include altered precipitation patterns, extreme weather events, and elevated air pollution in urban areas [23, 7]. The difference in how solar radiation is absorbed in urban areas versus green spaces and residential districts, especially around roads, commercial, and industrial zones, is the main cause of the urban heat island effect [32, 10]. According to [28, 11, 31], the UHI effect is primarily a result of urbanisation, changes in land use, and industrialisation. It results from the replacement of heat-absorbing surfaces, the production of the UHI phenomenon affects cities worldwide, regardless of their size or location, though it is especially pronounced in megacities, particularly those in warmer climates [36, 25, 30]. The UHI effect's most notable adverse effects include rising urban temperatures, which increase the likelihood of heatwaves. In turn, heatwaves are linked to increased rates of morbidity and mortality, discomfort in people, increased summertime energy use, and decreased quality of air and water [15, 18, 12]. Heatwaves pose serious health risks, particularly to vulnerable populations like the elderly, small children, people with physical or mental disabilities, and those who cannot afford mitigating measures like air conditioning. The UHI effect is probably being exacerbated by the rise in global temperatures brought on by anthropogenic climate change, since its effects are being made worse by higher average temperatures and less precipitation. Additionally, climate change is anticipated to lead to more regular and intense heatwaves, with longer durations and more severe consequences for urban areas. Urban planning techniques have an impact on the UHI effect in addition to physical processes. The arrangement of urban areas and the UHI effect are highly correlated. The patterns of land use and land cover affect the wind and thermal properties of cities [13, 29]. Increased evapotranspiration can help mitigate the UHI effect because vegetation releases latent heat and lowers the amount of energy needed for heating. Therefore, green areas can aid in cooling the surrounding area. According to [15, 28] the natural process of tree transpiration is especially efficient at reducing temperatures. Furthermore, by converting solar radiation into other forms, vegetation helps to lessen its intensity. Reducing the production of anthropogenic heat is another method of mitigating the UHI effect. With strategies targeted at lessening its negative effects, urban planning plays a crucial role in UHI adaptation and mitigation, particularly in light of the growing effects of urban sprawl and climate change [14, 35, 27]. One of the best ways to lessen the heat stress that city people experience is to increase the amount of green space and the percentage of vegetative cover. Thus, when planning future cities, urban planners must take the UHI effect into account and look for ways to lessen its effects in already-existing urban areas.

This study highlights the growing susceptibility of cities to the negative effects of urban heat by using a literature-based approach to examine the UHI issue. In order to demonstrate the issue's global scope, it examines trends in Germany and Australia, using both countries as examples. In order to identify similarities and differences, the paper also looks at and analyses UHI vulnerability assessments that have been published in the literature. It goes over how these vulnerabilities are addressed by current mitigation and adaptation strategies in brief. In order to improve urban resilience to the UHI effect, the paper concludes that a deeper comprehension of the UHI phenomenon is required, taking into account the unique context of each city, including social factors.

The fact that most vulnerability assessments and conceptualisations have been based on developed nation cities is one of the main reasons this study has focused on developed countries. Moreover, developed nations typically possess greater resources and adaptability. On the other hand, socioeconomic characteristics like poverty, a lack of infrastructure, and restricted access to resources are strongly associated with a city's susceptibility to the urban heat island effect in developing nations. In these areas, addressing these socioeconomic issues is more important than developing mitigation strategies tailored to UHI; a more comprehensive understanding of the problem in the context of developing countries is necessary.

The UHI effect is closely related to urban sprawl, global warming, and unsustainable development practices; it is not a standalone issue. The UHI effect is predicted to worsen due to rising global temperatures, especially in cities that already experience heatwaves and high summertime energy demands. Furthermore, fast growing cities—especially those in developing countries—may be more susceptible to the negative effects of urbanisation if proper planning and funding for green infrastructure aren't provided. In light of the increasing frequency of heatwaves anticipated in future climate change scenarios, mitigating urban heat island (UHI) vulnerability is imperative for preserving public health, enhancing urban liveability, and decreasing urban energy consumption.

Developing green infrastructure and urban planning are the most promising approaches to reducing the UHI effect. A greater number of parks, green roofs, and urban forests are examples of strategies that can provide shade, lower surface temperatures, and encourage evapotranspiration cooling. In a similar vein, adding water features to urban areas can strengthen their ability to cool down and fortify them against temperature increases. In densely populated areas, wind corridors and heat-reflective building materials can improve airflow and decrease heat absorption, which further mitigates the urban heat island effect.

In conclusion, combating the UHI effect necessitates a multimodal strategy that incorporates legislative, social, and physical interventions. In order to support future urban development, urban planners must acknowledge the UHI effect and make sure that mitigation measures are included in city planning. Furthermore, a deeper comprehension of the UHI effect is required as cities grow and adjust to climate change, especially in relation to how it interacts with other urban stressors like air pollution, water scarcity, and socioeconomic inequality. Cities can become more livable, sustainable, and resilient in the face of rising global temperatures by tackling these issues.

Relationship: The vulnerability of cities to climatic change and heat urban effects

The degree to which people, natural resources, or material possessions are located in areas that are susceptible to climate changes and the effects they bring, is referred to as exposure in the context of climate change and the Urban Heat Island (UHI) effect. Both direct and indirect exposure can be taken into account, especially when defining study areas for prospective vulnerability assessments. A crucial variable in some methods' vulnerability analyses is the percentage of the exposed population or areas. Conversely, sensitivity measures how vulnerable individuals, natural resources, or material possessions are to the effects of climate change. Since relocation is usually necessary for a significant reduction in exposure, adaptation measures usually aim to reduce sensitivity. This is accomplished by using organisational, structural, and other interventions to adapt people, natural resources, and material goods to the effects of climate change.

Adaptive capacity is the capacity to manage and mitigate the negative effects of climate change by seising opportunities as they present themselves and minimising impacts by taking preventative and proactive measures. Public opinion, political will, and the availability of financial and human resources are some of the variables that affect adaptive capacity. This idea shows that whether environmental changes or natural disasters turn into risks or disasters depends critically on people's or systems' sensitivity, coping skills, and adaptive capacities not just the direct impacts of climatic changes or extreme weather events like heatwaves.

Natural disasters and direct climatic changes are the primary external aspects of climate change. On the other hand, exposure to climate change and natural hazards is sometimes considered an independent factor in natural hazard research and should be evaluated in part apart from vulnerability. Heatwaves' detrimental effects on urban health are a significant problem that will probably get worse as global warming continues [29]. Rapid urbanisation has drastically changed the local ecosystems, landscapes, and population, which may have an impact on heat vulnerability [9]. During heatwaves, heat-related health risks—such as respiratory and cardiovascular issues—are frequently the cause of death [16, 24] emphasise that while knowing a person's unique biomedical susceptibility to heat is important, location and other external factors also affect risk levels. Since not everyone is at the same risk for health problems, cities must identify the populations that are most at risk. This makes it possible for legislators and urban planners to allocate resources more effectively. For example, social disparities and heat exposure are highly correlated in Phoenix, Arizona. Richer inhabitants, according to [9], made use of their financial standing to keep low-density housing with irrigated vegetation, which helped to reduce heat stress [9].

A number of studies have determined the main risk factors for the vulnerability to heat stress. These comprise people over 65, those taking medications that impair thermoregulation, small children, those with obesity, and those with pre-existing cardiovascular or respiratory conditions [29; 17] assert that it is critical for local actors to comprehend the unique risks associated with climate change in their area and to pinpoint the factors that contribute to urban vulnerability. To effectively communicate with decision-makers, evaluate adaptation options, and develop timely and cost-effective responses, local authorities must have a deeper understanding of the drivers of climate change impacts [17].

In order to create the knowledge base required for successful adaptation management strategies, there is also a need for improved communication between climate change scientists, impact experts, and both local and national decision-makers [17, 19]. The identification of areas that are especially vulnerable needs to be part of this knowledge base [9]. A better knowledge of the factors contributing to spatial heterogeneity in heat-related deaths will aid cities in identifying the regions and demographic groups most at risk when they create plans for climate adaptation. Furthermore helping to adjust exposures to these risks will be this [29].

Policies that enhance social integration and cohesion in neighborhoods by widely disseminating knowledge about heat-stress mitigation could be one successful tactic [9]. Heat mitigation strategies need to be customized for individual vulnerable populations because vulnerability fluctuates over time and space and is not equally distributed among demographic groups [9, 23]. It is crucial to realize that a system's vulnerability is dynamic in order to handle uncertainty in an efficient manner. If a system does not adjust to new developments, it could become more vulnerable in the future even though it is currently robust.

8 vulnerability assessments need to take into account potential outcomes for a population in the event of a future disaster). This implies that vulnerability assessments should take into consideration how well societies and communities can adjust to anticipated future changes. Long-term solutions must be developed, and financial and spatial resources set aside for future adaptations, even though the scope and nature of future challenges remain uncertain. According to [18], such adaptations should ideally offer co-benefits like enhanced ecosystem services, energy security, and water security in addition to mitigating the direct and indirect effects of climate change.

Urban ecosystems require green infrastructure (GI) to perform a variety of tasks, including regulating ecosystems, mitigating urban heat island effect (UHI), adapting to climate change, and providing important benefits and values. GIs come in a variety of forms, sizes, locations, and functions. These natural components have the ability to optimize, repair, and regulate urban structures, promoting sustainable urban growth. Planning various GI types is made easier by the knowledge that the size and structure of the GI dictate its ecological functions. GI can provide ecosystem services, like shading and lowering solar radiation, that control UHI. Urban planners can more accurately forecast how GI will provide ecosystem services and how these services will be impacted by climate change by knowing the roles GI plays in mitigating UHI. Given the importance of this information for adapting to climate change, GI is an important area of study for urban ecological systems. Furthermore, the ecological advantages and values of GI offer logical cues that support the argument for its significance in UHI mitigation. These advantages not only make GI's function clearer but also present chances for public servants, urban planners, and government officials to comprehend GI's importance. By incorporating these insights into planning, cities can build effective GI to achieve the maximum ecological benefits, which is key to the sustainable development of urban ecosystems.

Relationship between urban heat and GB

The use of green buildings (GBs) has become increasingly important in tackling the twin problems of urban heat mitigation and adaptation (UHMA) and global warming. The interaction of heat waves (HWs) and urban heat islands (UHIs) exacerbates temperature increases, which pose significant threats to human health by increasing morbidity and mortality. Given that HWs are already among the deadliest natural disasters in the United States, Australia, and the United Kingdom , are anticipated to deteriorate as a result of climate change. Furthermore, by increasing energy and water consumption and putting inhabitants under thermal stress, the UHI phenomenon—where urban areas experience higher temperatures than their rural counterparts—further strains urban systems. It is imperative to lessen the effects of UHI and help cities adjust to the challenges posed by heat, especially in rapidly urbanising regions of Asia and Africa.

In order to address the causes of heat waves and urban heat islands, three main strategies have been proposed: cutting carbon emissions, putting heat adaptation plans into action, and implementing heat mitigation techniques. The first strategy aims to mitigate climate change by reducing carbon emissions, which should reduce the frequency and intensity of high-wind events. This is in line with global climate initiatives such as the United Nations Sustainable Development Goals and the Paris Agreement; however, the pace and scale of current actions are still insufficient.

Global adoption of adaptation techniques has included the widespread use of air conditioning (AC). Globally, there were 575.69 million AC units in 1990; by 2020, that number had increased to 1.93 billion, and by 2050, estimates showed that there would be 5.58 billion. Although using an air conditioner reduces heat stress, it also dramatically increases energy consumption, which exacerbates urban heat-related problems. This emphasises how urgent it is to design environments that are heat-resistant and don't rely unduly on AC-dependent solutions. The third option, known as heat mitigation, consists of a number of techniques meant to lessen heat sources and enhance heat dissipation. In order to improve shading and ventilation, these strategies include using cool materials, creating green and blue infrastructure, and strategically designing buildings and urban forms [32, 22]. Although these mitigation strategies have been developed, there is still a need for them to be implemented more effectively because of their limited widespread adoption.

By using co-benefit strategies, addressing urban heat challenges also offers chances to address other urban problems like air pollution and flooding. Urban heat stress and carbon emissions are closely related to the building and construction industry. Buildings account for 38% of the world's CO2 emissions. Nevertheless, buildings also present a great opportunity to apply heat mitigation strategies, such as cool materials, green and blue infrastructures, and passive design principles, to lower energy consumption and improve thermal comfort [20, 21, 37]. Therefore, to address the challenges posed by urban heat, innovative practices within the building and construction sector are required.

Green building (GB) techniques are widely acknowledged as a model for sustainability, providing environments that are secure, robust, and habitable. GBs offer a useful way to incorporate the previously mentioned solutions into actual situations. For example, GBs typically had temperatures 0.35°C cooler than conventional buildings, according to a study. According to [21], cities should implement deep green building (GB) design strategies, such as guaranteeing solar access for all new construction and utilising passive cooling methods to lessen the effects of UHI. These techniques can also improve indoor thermal comfort and reduce energy consumption, as demonstrated by zero-energy buildings in Stuttgart, Germany.

Mitigation of UHI is included in a number of GB assessment tools, including CASBEE-HI in Japan and LEED in the US. While CASBEE-HI assesses attempts to reduce UHI through building design, LEED suggests high albedo surfaces and vegetated roofs. UHI issues are also addressed by other tools, like BREEAM in the UK, Green Globes in the US and Canada, and DGNB in Germany. The connection between GBs and urban heat, however, is still unclear. The relationship between UHI mitigation and GB elements, such as site configuration, building form, and occupant behaviour, has only recently been explored in studies on "zero UHI impact buildings" and "microclimate neutral buildings". Green buildings (GBs) possess the capability to tackle the problem of urban heat in various ways, including enhancing the quality of indoor environment, protecting natural resources, and encouraging water and energy conservation. The full life cycle of a GB—from site planning to construction and operation—can contribute to heat mitigation and adaptation. In this regard, GBs ought to be seen as a complete UHMA solution, able to address local and global warming while simultaneously improving resistance to heat stress. In conclusion, GBs offer a holistic approach to addressing the challenges posed by urban heat. By integrating sustainable building practices with heat mitigation and adaptation strategies, GBs can contribute to global efforts to reduce carbon emissions, alleviate local heat stress, and improve the quality of life in urban environments. This study provides a framework for understanding how GBs can address UHMA throughout their life cycle, offering valuable insights for future urban planning and development.

Materials and Methods

Identification of Studies

The review followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to systematically identify and select studies on topics related to green buildings, green infrastructure, climate change, urban heat island effects, sustainable design, and related environmental factors. A comprehensive database search was conducted using key terms such as "green buildings," "green infrastructure," and "sustainable design." This initial search yielded 1446 documents.

Before Screening

Prior to the formal screening process, an initial filtering stage was conducted. A total of 511 duplicate records were removed from the database due to invalid references. Further, 436 studies were excluded based on a preliminary assessment of their low relevance to the core topics. Additionally, 364 records were removed for reasons such as duplication, lack of full text, or lack of relevance to the primary topics of interest.

Screening Process

The systematic screening process consisted of three stages, each aligned with PRISMA's structured approach:

1. *First Screening*: After initial filtering, 364 documents were identified for further screening. This pool included 220 journal articles, 4 dissertations, and 140 book chapters. During this stage, 11 records were excluded as they lacked full-text availability.
2. *Second Screening*: In this stage, documents were reviewed for scope, timeliness, and language. As a result, 56 studies were excluded for being out of scope, 15 records were excluded due to age (too old), and 41 records were removed for being in non-English languages.
3. *Third Screening*: The remaining documents underwent a full content review to assess their alignment with the objectives of this review. Only those studies that provided substantial insights into green building research, urban heat island mitigation, and sustainable design were retained.

Final Selection

After a rigorous PRISMA-compliant screening and refinement process, 10 final references were selected for in-depth review. These studies represent the most relevant, credible, and current sources in the fields of green building strategies, urban heat island mitigation, and sustainable design.

Analytical Procedure

Following the PRISMA guidelines, the final set of 10 articles was examined for redundancy, relevance, and quality. Articles deemed irrelevant, redundant, or unsuitable were filtered out, ensuring that only publications focused on determinants of green building value were retained. This methodology provided a rigorous selection process, resulting in high-quality references that align with the review's objectives and reflect the latest research in green building and environmental sustainability.

Results and Discussion

The findings from this review highlight a wide range of green building (GB) strategies that contribute significantly to mitigating urban heat problems, especially those associated with the Urban Heat Island (UHI) effect. As cities face increasing pressure from both global climate change and local urbanisation, implementing green building practices has emerged as a vital solution for enhancing environmental, social, and economic resilience. This section discusses the key factors identified in the literature and their implications for addressing urban heat challenges.

Green Roofs as a Primary Strategy

Several studies, emphasise the effectiveness of green roofs in mitigating UHI and enhancing energy efficiency. Green roofs not only reduce heat gain by absorbing solar radiation but also lead to significant energy savings during cooling seasons, as shown by the results from both individual cities and broader regional analyses. Their widespread adoption can be instrumental in addressing UHI effects, especially in dense urban environments. For example, green roofs on buildings along urban corridors [8] have been shown to substantially lower local temperatures by transforming roof areas into green spaces.

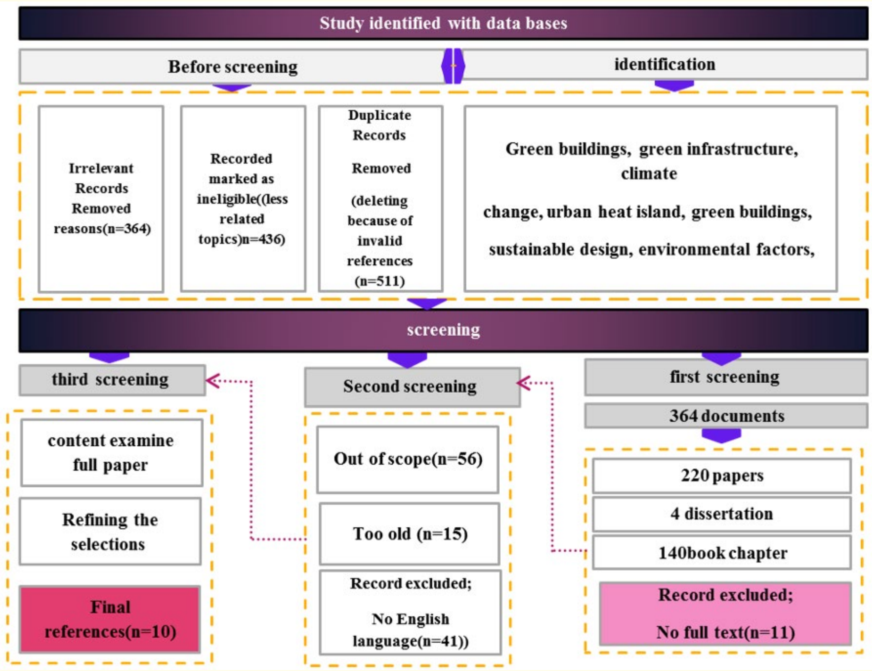

Figure 1: Analytical procedure.

Integration of Urban Forestry and Green Infrastructure

Urban forestry and green infrastructure play a crucial role in cooling urban areas. These strategies can also enhance the calibration of regional climate models by accounting for vegetation and other urban morphological factors. The use of nature-based solutions, provides a multifaceted approach to urban heat mitigation, improving public health, air quality, and overall quality of life in cities.

Energy Efficiency and Life Cycle Assessment (LCA)

A major theme emerging from the review is the integration of energy efficiency measures in green building design. Solar panels, highlighted by [8], have been shown to significantly decrease energy costs and CO2 emissions, contributing to both energy savings and carbon reduction. Additionally, life cycle assessment (LCA) practices provide a comprehensive approach to evaluating the long-term sustainability of buildings, from construction through operation and maintenance. The adoption of life cycle costing (LCC) and LCA techniques can not only enhance building performance but also demonstrate the economic benefits of green buildings to stakeholders.

Green Building Rating Systems

Rating systems, such as LEED, BREEAM, and the Green Star System, play a crucial role in encouraging the adoption of green building practices. However, challenges remain, especially in developing countries where the adoption of these systems is still limited. By improving national green building rating systems to include LCC and LCA considerations, the economic viability of green buildings can be better demonstrated, attracting more stakeholders to invest in sustainable construction. The Green Star system in Australia, for instance, provides valuable insights into overcoming the barriers to achieving green certification and sets a benchmark for evaluating green building performance globally.

Impacts on Property Value and Urban Design

The impact of green buildings on property values is another important consideration. [4] identified that green infrastructure can lead to increased land value, improved public health, and better quality of life. This finding is particularly relevant for real estate developers and urban planners, as it demonstrates the long-term financial benefits of incorporating green building principles. Moreover, urban morphology indicators such as building height, density, and sky view factors (SVF) need to be considered to effectively mitigate the UHI effect [8].

Cool Roofs and Heat-Related Mortality

The role of cool roofs in reducing heat-related mortality is significant, particularly in cities vulnerable to extreme heat events. cool roofs can offset up to 18% of heat-related mortality during summer months. This finding underscores the potential life-saving benefits of green building strategies, particularly in densely populated urban areas experiencing rising temperatures due to climate change.

Challenges and Barriers

Despite the clear benefits of green buildings, several barriers hinder their widespread adoption. One major challenge is the high transaction costs associated with green building construction, as noted by [35]. These costs can discourage developers from pursuing green building certifications, especially in regions where green infrastructure is not yet widely adopted. Additionally, there is often a lack of awareness and understanding of the full benefits of green buildings among stakeholders, which can slow progress towards greener urban environments.

Circular Economy and Sustainable Development

Finally, integrating circular economy principles into green building design, is critical for achieving long-term sustainability. By using green materials and promoting recycling and reuse, green buildings can minimize waste and reduce their overall environmental impact. This approach not only contributes to urban heat mitigation but also aligns with broader global efforts to promote sustainable development and reduce resource consumption.

Implications for Future Research and Practice

This review highlights several key areas for future research and practical applications in the field of green building and urban heat mitigation. First, more research is needed to develop region-specific green building rating systems that incorporate local climatic conditions, building types, and cultural factors. Additionally, future studies should explore the long-term economic and environmental impacts of green buildings, particularly in terms of life cycle costing and assessment.

On a practical level, urban planners, architects, and policymakers should prioritize the implementation of green building strategies, particularly in cities facing severe UHI challenges. By adopting a holistic approach that integrates energy efficiency, green infrastructure, and nature-based solutions, cities can enhance their resilience to climate change and create healthier, more sustainable urban environments.

Main green building factors
1) Factors Hindering green building performance: A review [38]
Best Factor: Green roofs lead to significant energy savings during cooling seasons.
2) Mitigating Urban Heat Island Through Green Roofs [2]
Best Factor: Widespread adoption of green roofs as a primary strategy to mitigate the Urban Heat Island (UHI) effect.
3) Green Buildings as a Necessity for Sustainable Environment Development [6]
Best Factor: Integration of green materials and circular economy principles for long-term sustainability.
4) Mitigating New York City's Heat Island with Urban Forestry, Living Roofs, and Light Surfaces [30]
Best Factor: Maintenance and life cycle assessment practices enhance the sustainability of green buildings.
5) Evolution to Emergence of Green Buildings: A Review [19]
Best Factor: Adoption of green building tools and rating systems in developing countries enhances understanding of green building practices.
6) Sustainable Development & Green Buildings [35]
Best Factor: Comparison of green buildings and conventional buildings, with an emphasis on environmental aspects over social and economic factors.
7) Developing a Research Framework for Green Maintainability of Buildings [9]
Best Factor: Integrating solar panels in green buildings can decrease energy costs and reduce CO_2 emissions.
8) Actors and Barriers to the Adoption of LCC and LCA Techniques in the Built Environment [8]
Best Factor: Urban morphology indicators (UMIs) like building height and density should be considered for UHI mitigation.
9) Evaluation of Non-Cost Factors Affecting the Life Cycle Cost [4]
Best Factor: Green infrastructure contributes to increased land value, quality of life, public health, and regulatory compliance.
10) Comparative Study of Project Management and Critical Success Factors [24]
Best Factor: Cool roofs can offset a portion of the seasonal heat-related mortality in cities affected by UHI.

Table 1: Main factors of green building.

Conclusion

This review paper systematically explores the role of Green Buildings (GBs) in addressing the growing urban heat problems caused by the dual pressures of global climate change and local urbanisation. Through an extensive screening of academic literature, this study identifies and analyses key factors contributing to urban heat, highlighting the critical need for sustainable solutions within the built environment. Green Buildings, with their innovative design principles, provide an essential pathway for mitigating the Urban Heat Island (UHI) effect and its associated environmental, economic, social, and health challenges.

The findings indicate that GBs significantly contribute to reducing the urban heat problem by lowering carbon emissions, minimising artificial landscapes, and promoting energy-efficient designs. The developed framework outlines GB responses to urban heat challenges across multiple aspects, including global and local warming mitigation, site planning, transportation, building design, energy and water efficiency, material selection, and life cycle management. By addressing these areas comprehensively, GBs can effectively reduce the adverse impacts of urban heat and enhance the sustainability of urban environments.

In conclusion, the integration of green building principles into urban development is vital for addressing the current and future challenges posed by urban heat. Policymakers, urban planners, and architects must adopt a holistic approach that incorporates GB strategies across all phases of a building's life cycle. This review provides a foundation for further research and practical applications, emphasising the importance of GBs in creating resilient and sustainable urban spaces capable of mitigating the negative impacts of urban heat.

Acknowledgements

The authors would like to acknowledge all individuals and institutions who contributed indirectly to this research through their insights and expertise. Their contributions helped to enrich the depth and quality of this study.

The authors declare no conflicts of interest related to the publication of this article.

References

1. Akbari H, Pomerantz M and Taha H. "Cool surfaces and shade trees to reduce energy use and improve air quality in urban areas". Solar Energy 70.3 (2001): 295-310.
2. Alqahtani A and Whyte A. "Department of Civil Engineering, Curtin University, Perth, Australia". Evaluation of Non-cost Factors Affecting the Life Cycle Cost: An Exploratory Study (2013).
3. Arabi R., et al. "Mitigating urban heat island through green roofs". Current World Environment 10.Special-Issue1 (2015): 918-927.
4. Barrette J., et al. "Dynamics of dead tree degradation and shelf-life following natural disturbances: can salvaged trees from boreal forests "fuel" the forestry and bioenergy sectors?". Forestry an International Journal of Forest Research 88.3 (2015): 275-290.
5. Bungau CC., et al. "Green buildings as a necessity for sustainable environment development: dilemmas and challenges". Sustainability 14.20 (2022): 13121.
6. Chew MYL, Conejos S and Asmone AS. "Developing a research framework for the green maintainability of buildings". Facilities 35.1/2 (2017): 39-63.
7. Chow WT., et al. "Urban heat island research in Phoenix, Arizona: Theoretical contributions and policy applications". Bulletin of the American Meteorological Society 93.2 (2012): 289-299.
8. D'Incognito M, Costantino N and Migliaccio GC. "Actors and barriers to the adoption of LCC and LCA techniques in the built environment". Built Environment Project and Asset Management 5.2 (2015): 202-216.
9. EEA. "Climate change: the cost of inaction and the cost of adaptation". European Environment Agency.
10. Escobedo FJ, Kroeger T and Wagner JE. "Urban forests and pollution mitigation: Analysing ecosystem services and disservices". Environmental Pollution 159.8-9 (2011): 2078-2087.
11. Frontczak and Isopescu DN. "The impact of green building principles in the sustainable development of the built environment". IOP Conference Series Materials Science and Engineering 399 (2018): 012026.
12. Gago EJ., et al. "The city and urban heat islands: A review of strategies to mitigate adverse effects". ideas.repec.org (2013).
13. Gartland LM. "Heat Islands". 9781849771559Heat islands: Understanding and mitigating heat in urban areas (2012).
14. Getter KL., et al. "Carbon sequestration potential of extensive green roofs". Environmental Science & Technology 43.19 (2009): 7564-7570.
15. Hallegatte S and Corfee-Morlot J. "Understanding climate change impacts, vulnerability and adaptation at city scale: an introduction". Climatic Change 104.1 (2010): 1-12.
16. Hsieh CM and Huang HC. "Mitigating urban heat islands: A method to identify potential wind corridor for cooling and ventilation". Computers Environment and Urban Systems 57 (2016): 130-143.
17. Ken CW., et al. Factors Affecting Green Buildings Value: A Review 9 (2020): 1466-1467.
18. Khan J., et al. "Evolution to Emergence of Green Buildings: A review". Administrative Sciences 9.1 (2019): 6.
19. Khan JS., et al. "Evolution to Emergence of Green Buildings: A Review". Renewable (2021).

20. Kumar P., et al. "Urban heat mitigation by green and blue infrastructure: Drivers, effectiveness, and future needs". The Innovation 5.2 (2024): 100588.
21. Lehmann S. "Urban heat island mitigation through green building design". Journal of Urban Sustainability 12.2 (2014): 55-73.
22. Nasrin Rastinifard, Narges Fakhri Mastanabad and Mahmoud Jomehpour. "Strategic Planning for Sustainable Development of Suburban Communities with the Participatory Approach (Emphasis on Environmental and Physical Assessment): The Case of Shahriar City". Research on Humanities and Social Sciences (2024).
23. Oke TR. "The energetic basis of the urban heat island". Quarterly Journal of the Royal Meteorological Society 108.455 (1982): 1-24.
24. Pheng Low SP, Gao S and Tay WL. "Comparative study of project management and critical success factors of greening new and existing buildings in Singapore". Structural Survey 32.5 (2014): 413-433.
25. Ramamurthy P and Sangobanwo M. "Inter-annual variability in urban heat island intensity over 10 major cities in the United States". Sustainable Cities and Society 26 (2016): 65-75.
26. Rastinifard N and Jomehpour M. "Investigating urban resilience in case of climate change: A case study of region 12 of Tehran". World Journal of Advanced Research and Reviews 22.1 (2024): 1857-1866.
27. Rebetez M, Dupont O and Giroud M. "An analysis of the July 2006 heatwave extent in Europe compared to the record year of 2003". Theoretical and Applied Climatology 95.1-2 (2008): 1-7.
28. Rizwan AM, Dennis LYC and Liu C. "A review on the generation, determination and mitigation of Urban Heat Island". Journal of Environmental Sciences 20.1 (2008): 120-128.
29. Rosenthal JK, Kinney PL and Metzger KB. "Intra-urban vulnerability to heat-related mortality in New York City, 1997-2006". Health & Place 30 (2014): 45-60.
30. Rosenzweig Cynthia., et al. Mitigating New York City's Heat Island with Urban Forestry, Living Roofs, And Light Surfaces (2005).
31. Santamouris M., et al. "On the impact of urban heat island and global warming on the power demand and electricity consumption of buildings—A review". Energy and Buildings 98 (2014): 119-124.
32. Santamouris M, Synnefa A and Karlessi T. "Using advanced cool materials in the urban built environment to mitigate heat islands and improve thermal comfort conditions". Solar Energy 85.12 (2011): 3085-3102.
33. Shafique M, Kim R and Rafiq M. "Green roof benefits, opportunities and challenges - A review". Renewable and Sustainable Energy Reviews 90 (2018): 757-773.
34. Sinha A, Gupta R and Kutnar A. "Sustainable development and green buildings". Drvna Industrija 64.1 (2013): 45-53.
35. Stewart ID and Oke TR. "Local climate zones for urban temperature studies". Bulletin of the American Meteorological Society 93.12 (2012): 1879-1900.
36. Wang D., et al. "Urban green infrastructure: bridging biodiversity conservation and sustainable urban development through adaptive management approach". Frontiers in Ecology and Evolution (2024): 12.
37. Yen TK., et al. "Factors Hindering green building performance: A review". Sains Humanika 8.4-3 (2016).

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