

Exploring Sustainable Heat Mitigation Strategies in Residential Housing: Pre, During, and Post-Construction

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ABSTRACT

With rising urban temperatures and increasing energy demand for cooling, sustainable heat mitigation in residential buildings has become a growing concern, especially in warm climatic regions. Managing indoor heat through sustainable strategies enhances thermal comfort and supports environmental goals. Within home science, exploring such strategies contributes to SDG 7 (Affordable and Clean Energy) and SDG 11 (Sustainable Cities and Communities). This study adopted a descriptive and qualitative research design to explore sustainable heat mitigation strategies across the pre-, during-, and post-construction phases of residential housing. A narrative review approach was followed, with purposive sampling of literature from databases like Google Scholar, ScienceDirect, and institutional sources. Approximately 25 – 30 peer-reviewed studies, published between 2014 and 2024, were selected based on relevance and sustainability focus. Thematic analysis was used to identify best practices and assess their effectiveness. The reviewed literature identified various strategies, including site orientation, passive architectural features, thermally efficient materials, green roofing, ventilated façades, reflective coatings, and landscaping interventions. These strategies can help reduce indoor temperatures, lower cooling energy demands, and improve building performance. The study also noted challenges, including limited awareness and high costs. By synthesizing existing research, this study provides a multidimensional understanding of sustainable heat management in housing. It offers practical insights for architects, planners, and policymakers, supporting the integration of climate-responsive solutions in residential design.

Keywords: Sustainable Housing, Heat Mitigation Strategies, Residential Buildings, Construction Phases, Thermal Comfort.

INTRODUCTION

The increasing frequency of heatwaves and rising global temperatures, exacerbated by rapid urbanization and climate change, have made thermal comfort in residential buildings a growing concern worldwide. In warm and tropical regions, residential buildings are particularly vulnerable to excessive heat gain, which directly impacts occupant comfort, energy consumption, and public health. According to Pricilia and Philip (2025), the urban heat island (UHI) effect significantly amplifies temperatures in densely built areas, placing a higher thermal load on residential structures. Li et al. (2020) also emphasized the role of urban morphology and material choices in contributing to overheating in cities, particularly where natural ventilation is limited.

Several studies have identified that passive design strategies, such as proper orientation, insulation, reflective surfaces, and natural ventilation, can help reduce indoor temperatures (Baborska-Narozny et al., 2015; Gupta & Gregg, 2013; Sharma et al., 2018). Furthermore, research by Williams et al. (2020) reported that energy-efficient retrofitting in single-family homes could reduce indoor temperatures by up to 8.9°C. Similarly, Kenny et al., (2024) highlighted that home overheating can be mitigated through behavioral adaptations, passive strategies, and improved architectural design.

In light of these findings, understanding sustainable heat mitigation strategies in residential housing becomes crucial, not only for ensuring occupant comfort and reducing energy costs but also for aligning with the Sustainable Development Goals (SDGs), especially SDG 7 (Affordable and Clean Energy) and SDG 11 (Sustainable Cities and Communities).

The demand for energy-efficient housing has grown considerably due to climate-induced thermal stress and escalating energy demands in residential sectors. However, there remains a gap in research that integrates sustainable heat mitigation strategies across the full lifecycle of residential buildings, from pre-construction to post-occupancy phases. Most studies focus either on new construction or retrofitting, but there is limited consolidated evidence covering all phases of residential development in warm climate contexts.

This study builds upon a range of prior research efforts. For example, Akshaya et al. (2017) analysed the thermal performance of buildings based on orientation, suggesting significant differences in internal heat gain depending on the building's facing direction. Das et al. (2023) validated the effectiveness of traditional clay pot roof construction as a passive insulating solution, showing an apparent reduction in indoor temperatures in Sylhet, Bangladesh. Similarly, Taleghani et al. (2019) discussed green roofing and landscaping as viable post-construction strategies for enhancing outdoor and indoor thermal conditions.

Given this background, there is a critical need to review and synthesize best practices and innovative solutions that span all phases of construction. This study, therefore, aims to contribute to academic discourse and practical implementation by examining a wide range of sustainable heat mitigation strategies within the scope of residential housing through a holistic, lifecycle-based framework.

OBJECTIVES OF THE STUDY

The objectives of the study were:

- a. To explore innovative approaches and best practices for mitigating heat in residential housing during pre-, during, and post-construction phases.
- b. To assess the effectiveness of sustainable heat mitigation strategies in enhancing thermal comfort in residential buildings.

METHODOLOGY

This study employed a descriptive and qualitative research design to explore sustainable heat mitigation strategies in residential housing. Literature was selected through purposive

sampling from academic databases and institutional reports, focusing on studies published between 2013 and 2024. Approximately 25 – 30 peer-reviewed sources addressing the pre-, during, and post-construction phases were reviewed. This study is based entirely on a narrative review of published literature and did not involve human participants. Therefore, Institutional Review Board (IRB) or Research Ethics Board (REB) approval and informed consent were not required. Thematic analysis was used to identify effective practices, innovative approaches, and their relevance to Sustainable Development Goals, particularly SDG 7 (Affordable and Clean Energy) and SDG 11 (Sustainable Cities and Communities).

FINDINGS AND DISCUSSION

The reviewed literature identified a comprehensive range of sustainable strategies used to mitigate heat in residential buildings across pre-, during-, and post-construction phases. Below is a structured presentation of findings across each phase:

Pre-Construction Phase: Strategic Design Interventions

- **Building Orientation and Layout:** Proper building orientation significantly affects thermal performance. Through simulations, Sharma et al. (2016) demonstrated that optimal building orientation can reduce solar heat gain and cooling loads in Indian cities. Akshaya et al. (2017) also found that orienting homes with key spaces like bedrooms towards cooler directions improved indoor thermal conditions.
- **Site Planning and Climate Responsiveness:** Studies such as “Optimizing residential building orientation: A model-based approach to improve comfort and efficiency” by Poddar et al. (2024) emphasized the importance of wind direction and sun path in site planning. East-west building orientation reduced thermal discomfort. Passive solar principles discussed by Cillari et al. (2020) reinforced this.
- **Landscaping and Water Elements:** Vegetation around buildings was shown to support shading and reduce local temperatures through evapotranspiration. Eilia Jafar (2024) also highlighted that incorporating water bodies near windows can help reduce air temperature near the façade.

According to Das et al. (2023), the use of clay pots is a traditional method for improving thermal insulation in residential roofing systems, particularly in the Sylhet region of Bangladesh. The results indicated that clay pots embedded within the roof structure can help reduce indoor heat gain due to their natural insulating properties. The air trapped inside the pots acts as a thermal buffer, effectively lowering the roof surface temperature and, consequently, the house's internal temperature. This passive cooling approach helps maintain thermal comfort indoors without relying on energy-intensive mechanical cooling systems.

During Construction Phase: Material and Structural Implementation

- **Material Choices and Installation Quality:** Williams et al. (2020) assessed "light" and "deep" retrofits. Williams et al. (2020) reported that light retrofits such as reflective roofs and insulation reduced indoor temperatures by 3–5.5°C, while deep retrofits combining wall insulation and air sealing reduced them by 4.3–8.9°C.

- **Cool Roofs and Insulated Walls:** Cool roofs with high reflectivity can substantially reduce solar absorption. According to Taleghani et al. (2019), reflective coatings applied during construction reduced sensible heat flux by up to 320 W/m².
- **Post-Construction Phase: Retrofitting and Operational Strategies**
- **Color-Based Heat Absorption:** Surface color significantly impacts thermal gain. According to Layak Architect (2023), buildings painted black may absorb up to 98% of solar radiation, whereas white, yellow, and blue surfaces absorb considerably less. This finding underlines the importance of color choice in thermal management.
- **Cool Roofs and Reflective Coatings:** Post-construction application of reflective materials further reduced indoor heat. According to Gupta and Gregg (2013), white roofs and cool paints could reduce indoor temperatures by 2.5°C or more.
- **Natural Ventilation and Night Flushing:** Ventilation strategies, especially night-time air flushing and cross-ventilation, were highly effective in passive cooling (Gupta & Gregg, 2013).
- **Green Infrastructure:** According to Taleghani et al. (2019), green infrastructure measures, including green roofs and additional street trees, can help reduce peak air temperatures by 1–2°C, increase latent heat flux, and improve thermal comfort.
- **Retrofitting Existing Homes:** Retrofitting was a practical solution for older homes. Strategies included adding external insulation, sealing air leaks, and installing shading devices (Alrasheed&Mourshed, 2023).

CONCLUSION

The present study systematically explored sustainable heat mitigation strategies across the pre-, during-, and post-construction phases of residential housing, drawing upon findings from approximately 30 peer-reviewed studies published between 2014 and 2024. The evidence suggests that climate-responsive design strategies can enhance thermal comfort, help reduce indoor heat gain, and potentially lower cooling energy demand while supporting environmental sustainability.

In the pre-construction phase, orientation emerged as a key variable. Studies by Sharma and Rakshit (2016) and Akshaya et al. (2017) suggest that minimizing east and west solar exposure can help reduce solar heat gain, lowering internal temperatures by over 15%. Proper orientation, combined with passive design elements like window placement and zoning, enhances solar control and thermal efficiency.

In the construction phase, the integration of high-albedo cool roofs and continuous insulation systems was shown to reduce indoor temperatures by 3–5.5°C, as demonstrated by Williams et al. (2020). Advanced simulations using EnergyPlus and ENVI-met suggest that combining envelope insulation, air sealing, and reflective materials may improve building performance across multiple climate zones (Taleghani et al., 2019). Moreover, previous studies suggest that measures such as thermal bridging control and smart ventilation systems can reduce energy demand by up to 37% annually (Gupta & Gregg, 2013).

In the post-construction phase, practical retrofitting interventions, including reflective coatings and green infrastructure, have been reported to be effective. Das et al. (2023)

showed that traditional terracotta pots integrated into roofing systems lowered indoor heat by 2–3°C, while Taleghani et al. (2019) and Layak Architect (2023) reported that green roofs and street trees can reduce ambient temperatures through evapotranspiration and shading. When used with passive shading, natural ventilation strategies like night flushing and cross-ventilation resulted in additional temperature drops of 2–2.5°C (Gupta & Gregg, 2013; Alrasheed&Mourshed, 2023).

Overall, the study concludes that a phased and integrative approach to heat mitigation—anchored in site-sensitive design, material efficiency, and passive climate control—may contribute to improved thermal and energy performance in residential housing. This multifaceted framework aligns with the goals of SDG 7 and SDG 11, supporting energy-efficient, liveable, and climate-resilient communities. The reviewed literature provides useful insights for architects, urban planners, policymakers, and homeowners seeking long-term and sustainable solutions to combat overheating in residential environments.

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