

## Role of Green Buildings in Urban Heat Island Mitigation: Environmental Science Evidence

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### ABSTRACT

The Urban Heat Island (UHI) effect has been exacerbated by rapid urbanization and climate change leading to higher temperatures in urban centers than in the adjacent countryside and a great deal of environmental, social, and communal health issues. This review is a critical analysis of green buildings as a successful and sustainable approach of countering UHI based on environmental science. The review is a synthesis of the empirical data that have been gathered in recent times by satellite-based and field-based studies in both mega cities and developing urban centers to determine the effect of green building interventions on urban thermal environments. Major mechanisms mentioned are the utilization of green rooftops and vertical greening systems, light-colored and cool building materials, plant-based shading, and passive design, such as natural ventilation and optimum building orientation. Results in the various climatic areas have shown that green buildings also help achieve quantifiable declines in land surface and near-surface air temperatures, especially in warmer seasons, as well as enhance thermal comfort and minimize cooling energy requirements in indoor environments. In addition to heat mitigation, green buildings have a variety of co-benefits, such as reducing greenhouse gas emissions, increasing biodiversity in urban areas, improving air quality, and having positive effects on individual health. Nevertheless, the review also reveals the main constraints, including high initial expenses, maintenance needs, climatic dependence,

and policy constraints, especially in the developing nations. This review provides insights into the importance of green buildings as climate-resilient solutions to the well-being of the environment by identifying current gaps in the body of research and the future directions, which include long-term monitoring, region-specific designs, and policy-supported implementation framework. In general, green buildings come out as a major element of sustainable urban development policies that need to be put in place to develop thermally comfortable, resilient, and environmentally sustainable cities.

**Keywords:** Urban Heat Island, Green Building, Environmental Sustainability, Urban Climate, Passive cooling, Climate resilient City.

## 1. INTRODUCTION

The urbanization process has become one of the most important factors of the environmental change of the twenty-first century, which has dramatically changed the natural scenery and the local climate. One of the most significant effects of uncontrolled urban development is the Urban Heat Island (UHI) phenomenon, a phenomenon whereby urban areas are much hotter than the rural areas surrounding them. This change in temperature is mainly explained by the anthropogenic alteration of the surface of the Earth, high-manmade construction, and distorted energy ratios in urban areas. Due to the ever-increasing human populations in cities worldwide, UHI effects are becoming more pronounced in terms of the extent, intensity and the spatial coverage caused by them, and present serious environmental, social and human health issues (Agan et al., 2021; Fadhil et al., 2023; Jabbar et al., 2023). Urban Heat Island is a phenomenon that is described as an accumulation and retention of heat in urban areas because of the substitution of natural land cover with impervious surfaces in the form of concrete, asphalt and metal. These substances are of high thermal mass and low albedo which allows them to take in significant quantities of solar radiation throughout the day and gradually expel stored warmth throughout the night. The urban areas therefore tend to be warmer at night even after the sun has gone down resulting in high nocturnal temperatures and increased thermal discomfort. Research on environmental science has distinguished UHI into the surface, atmospheric and subsurface heat islands, which play varying roles in the changes in microclimate in cities. Surface UHI has

been widely observed and recorded by using thermal imaging by satellite, with large temperature variations observed between built-in areas and greenery (Agan et al., 2021; Vujovic et al., 2021; Ziaemehr et al., 2023). The causes of UHI are properly connected with the phenomena of the intensive urbanization, particularly in the cities of developing and highly populated areas. Expansions of impervious surfaces reduce natural cooling (evapotranspiration), and the clearing vegetation eliminates shade and control of humidity. The dense city models and skyscrapers interfere with the circulation of the wind, thereby inhibiting natural air-conditioning and storing heat in urban canyons (Imran et al., 2021; Kong, 2025). Moreover, the man-made warming in cities is also worsened by anthropogenic heat emissions caused by vehicles, industrial processes, air conditioning systems, as well as energy-consuming infrastructure. Avoidable factors that amplify the Urban heat Island effect include poor urban planning, poor distribution of green spaces, and use of construction materials that trap heat, especially in cities that have unplanned developments (Alexandra & Philip, 2025; Irfeey et al., 2023).

The UHI phenomenon has been rejuvenated in the climate change arena because it is a compounding effect on the urban thermal stress. Increased temperature of the world, more frequent heatwave, and different precipitation patterns contribute to the amplification of urban heat exposure (Bahi et al., 2019). The residents of urban areas particularly vulnerable groups like the aged, children, and low-income communities are at greater risks of heat-related diseases, decreased productivity, and high mortality rates. Environmentally, enhanced urban heat creates greater cooling energy requirements, greenhouse gases, poor air quality, and urban ecosystem disturbances. Therefore, UHI is an actual localized climatic abnormality but also serves as a key enhancer of the effects of climate change in urban areas (Heaviside, 2020; Roberts et al., 2023). Green buildings have become an attractive environmental response to these increasing challenges with regard to mitigating urban heat and the resilience of climate. Green buildings are constructed in a way that they reduce environmental effects by using energy efficient systems, environmentally sustainable materials and incorporating natural features like vegetation and water features (Cao, 2025; Cuce et al., 2025). The main features such as green roofs, vertical gardens, reflective surfaces, natural ventilation, and an

optimal building orientation are important in controlling the temperatures of buildings and in minimizing the absorption of heat. Green buildings also decrease ambient urban temperatures by facilitating evapotranspiration, surface albedo, and thermal insulation, as well as improving microclimatic conditions (Fleck et al., 2022; Lin & Li, 2025). Green buildings have proven to be a viable UHI mitigation measure that is supported by evidence in environmental science. Empirical research points to the fact that green rooftops may considerably lower the surface and near-surface temperatures, and vegetated facades increase the airflow and shading. Furthermore, green buildings do not highly depend on mechanical cooling systems hence using less energy and consequently there is a reduction in carbon emissions (Lukinov et al., 2024; Rastinifard & Ramezani, 2024). In addition to thermal regulation, such structures deliver numerous co-benefits, such as better thermal comfort at the indoor level, better urban biodiversity, stormwater management, and better human health. Consequently, green buildings are now becoming recognized as parts of sustainable city development and climate change adaptation models (Gil-Ozoudeh et al., 2023; Schmidt & Walz, 2021).

The purpose of this review is to synthesize and critically review the available literature in the field of environmental science on the role of green buildings in reducing the Urban Heat Island effect. The proposed review concentrates on the processes by which green building strategies impact the thermal environment in cities, assesses the results of various climatic and geographical settings, and reveals the major gaps in the current research. Additionally, the review will identify research gaps and provide future directions as to how the concept of green building can be incorporated into urban planning and policy formulation.

## **2. Urban Heat Island Effect: Environmental Background**

The Urban Heat Island (UHI) effect is a phenomenon that has been extensively reported in the literature and is marked by much higher temperatures in cities than in the rural or peri-urban surroundings of said city. This difference in temperature is caused by massive anthropogenic alteration of the natural landscapes and change in the surface-atmosphere energy interactions (Imran et al., 2021; Roth, 2020). Using the environmental science perspective, UHI can be generally categorized into surface UHI and atmospheric UHI, which also connect and interact to form urban

thermal conditions. Surface UHI is defined as the high temperature of land surfaces due to the presence of heat-trapping substances including asphalt, concrete and rooftops that can be successfully detected through the satellite-based remote sensing. Atmospheric UHI on the other hand happens in the urban air layer and is affected by the storage and release of heat in built environments, decreased wind motion as well as anthropogenic heat emissions (Diem et al., 2024; Huang et al., 2020; Somantri & Himayah, 2024). The latter types of UHI are especially high in cities of high density, in which natural land cover has been changed significantly into impervious covers that interfere with natural cooling mechanisms, like evapotranspiration and regulation of soil moisture. The impervious materials do not only receive a lot of the solar radiation during the day but also emit stored heat gradually at night resulting in continued high temperatures and minimal cooling at night (Ge et al., 2020; Soydan, 2020). At the same time, vegetation loss is also a factor in UHI intensification, as vegetation is known to offer shade, promote evapotranspiration, and regulate microclimatic processes; the loss of vegetation will destroy natural cooling systems and expose surfaces to direct amounts of sunlight. The other large source is the anthropogenic heat, produced by automobile traffic, industrial activities, air conditioning, and energy intensive urban components which directly contribute to the thermal energy of the urban atmosphere and also increase the ambient temperature further.

The net effect of these environmental influences is not limited to the rise in temperature and the effects they have on urban systems are massive (Fadhil et al., 2023; Yan et al., 2020). High urban temperatures interfere with urban ecosystems by changing species assembly, habitat unfitness, and thermal stress on plants and animals, thus endangering the biodiversity in cities. In terms of public health, UHI worsens the human health hazards especially when it comes to heat waves by augmenting instances of heat exhaustion, heatstroke, cardiovascular stress, and death, especially to those groups such as the elderly and children who are vulnerable (Iungman et al., 2023; Ramly et al., 2023). The UHI effect also has a great impact on the pattern of energy consumption, because urban temperature rises higher, which in turn results in more cooling which results in more electric power usage, peak loads, and even more greenhouse gas emissions due to power production. UHI also has

negative impacts on air quality, by increasing the rate at which ground-level ozone and other secondary pollutants are produced under high-temperature conditions and low air circulation in urban canyons minimizes the dispersion of pollutants (Singh & Sharston, 2022; Tian et al., 2021). All of these interrelated environmental effects make the Urban Heat Island phenomenon a key issue in environmental management of cities and explain why the response to it requires urgent attention to address the problem of sustainable and climate-reflective solutions.

### **3. Green Buildings: Concept and Environmental Framework**

Green buildings are the concept of a combination of planning, design, building, and maintenance of built environments that has the ultimate goal of reducing adverse effects on the environment and maximizing resource use and occupant comfort. Green buildings are buildings that maximize the consumption of energy, water, materials, and land during their life cycle, minimize waste, emissions, and ecological degradation (Gil-Ozoudeh et al., 2022a; Karimi et al., 2023). As compared to the traditional buildings where most of them focus on short-term economic benefits, green buildings have a comprehensive approach to embracing the long-term environmental sustainability, responsiveness to climatic conditions, and conservation of ecosystems. The main postulates of the green building design are based on energy efficiency, passive adaptation to climatic conditions, selection of sustainable materials and incorporation of natural features in the constructed environment. These principles are the maximization of natural light and airflow, the use of high performance insulation and reflectivity, the use of renewable energy systems and the use of vegetation (green roofs, vertical gardens and landscapes) to control microclimates (Cao, 2025; Manuel et al., 2024). Green buildings save the use of mechanical heating and cooling systems, which minimizes energy usage and consequent greenhouse gas emissions by ensuring that the building design is in line with the local climatic conditions. Green buildings are very important in the framework of sustainable urban development, especially in addressing the environmental crisis associated with uncontrolled urbanization, especially the issue of urban heat stress, the depletion of resources, and global warming (ABBASOVA, 2020; He, 2024). The extensive application of green buildings at the urban scale avoids urban heating, improves air quality, and increases the capacity to manage

extreme weather conditions, and at the same time promotes social sustainability by improving the level of indoor comfort and healthier living conditions. Environmental performance of green buildings is usually evaluated by means of various environmental performance indicators such as energy use intensity, carbon footprint, thermal performance, water efficiency, indoor environmental quality, as well as the impact urban microclimate. These indicators offer objective proof of the role of a building in the sustainability of the environment and its efficacy in mitigating urban environmental problems including the Urban Heat Island effect (Cuce et al., 2025; Leal Filho et al., 2021; Marando et al., 2022). In order to standardize to encourage sustainable construction practices on a global scale, various green building certification systems have been established with the most known ones being Leadership in Energy and Environmental Design (LEED), Building Research Establishment Environmental Assessment Method (BREEAM), and Green Star. These certification systems consider buildings in various sustainability standards, such as energy efficiency, water management, material sustainability, and environmental quality and are used as guidelines to the environmentally responsible building (Marchi et al., 2021). Together, the idea and the environmental model of green buildings emphasize the meaning of such solutions as climate-sensitive ones, as they help in balancing the architectural innovations with environmental science, making them vital elements of the sustainable and heat-resistant urban systems.

Green buildings are holistic approach to planning, designing, construction and operation of built environment whose primary objective is to minimize the negative impacts on the environment, and achieve maximum resources and human health. The term green building is used in environmental science to describe those buildings, which optimize their energy, water, materials and land use, reduce waste generation, emission levels and environmental degradation (Çiner & Doğan-Sağlamtimur, 2019). Unlike the traditional buildings that are normally guided by the immediate economic gains, green buildings presuppose a comprehensive strategy, which considers the sustainability of the environment in the long run, sensitivity to the climatic conditions, and conservation of the ecosystem. Energy efficiency, passive adaptation to climatic conditions, ecological choice of materials and incorporation of

the elements of nature into the created environment are the main principles of green building design. These precepts comprise the maximization of natural lighting and ventilation, the use of the best insulation and reflective material, renewable energy systems, and the use of vegetation using green roofs, vertical gardens, and landscaping space to control micro climates (Akram et al., 2023; Olabi et al., 2025). Green buildings minimize the reliance on mechanical heating and cooling systems by ensuring that the building design is in tandem with the local climatic conditions, which means that there is a reduction in energy use and the generation of greenhouse gases (Gil-Ozoudeh et al., 2022b). Green buildings are important elements in the overall context of sustainable urban development to curb the environmental issues brought about by rapid urbanization with specific reference to heat stress in the city, depletion of resources and climatic change. The large-scale implementation of green buildings at the city level helps to decrease urban temperatures, improve air quality, and increase the resilience to extreme weather conditions, as well as to promote social sustainability due to greater comfort in indoor conditions and healthier lifestyle (Rastinifard & Ramezani, 2024). Green buildings can have their environmental performance measured with a variety of environmental performance indicators, such as energy use intensity, carbon footprint, thermal performance, water efficiency, indoor environmental quality, and urban microclimate impact.

The indicators provide a measurable data on the contribution of a building to environmental sustainability, and the responsiveness of the building to urban environmental challenges such as the Urban Heat Island effect. Several green building assessment programs have been developed to support and normalize sustainable building in the global context with the most recognized being Leadership in Energy and Environmental Design (LEED), Building Research Establishment Environmental Assessment Method (BREEAM) and Green Star. Such certification systems evaluate buildings in a few sustainability criteria, including energy efficiency, water management, material sustainability and environmental quality, and serve as a comparative measure of the environmentally responsible building (Da Silva & Ramirez, 2021; Rodrigues et al., 2023; Tang et al., 2020). The idea and ecological paradigm of green buildings combined emphasize the

importance of being climate-oriented resources bridging architectural innovations on the one hand, and environmental science on the other, which makes them a necessary element of sustainable and heat-resistant urban settings (He, 2024).

#### **4. The UHI Mitigation mechanisms using Green Buildings**

Green roofs and vertical greening systems display one of the most promising mechanisms by which green buildings reduce the Urban Heat Island effect by changing the surface energy balance and increasing the natural cooling processes. Planted roofs and facades facilitate evapotranspiration, where plants generate moisture to the atmosphere, thus cooling down the environment and lowering the ambient temperatures. This cooling system is biologically engineered to reduce the temperature of the roof surface considerably than in normal bare roofs, which can be exposed to a lot of solar radiation and therefore, absorb and store a lot of solar energy (Bakhshoodeh et al., 2022; Lin & Li, 2025). Environmental research has repeatedly shown that green roofs are capable of lowering roof temperature by several degrees in peak summer weather conditions and help to lower the temperature of surrounding air, especially in built-up urban centers. Vertical greening systems, such as green walls and living facades, have the added advantages of shading building facades, minimize heat gain by walls and provide thermal comfort to pedestrians. Field measurements and remote sensing studies (empirical) point to the cumulative cooling potential of such systems with a particular emphasis on their application on a large scale (at the urban neighborhood level) (Dong et al., 2020; Salonen et al., 2022; Susca et al., 2023). Another vital UHI mitigation approach in green building processes is the use of high-albedo and cool architectural materials. Reflective roofing and facade surfaces are created to reflect more incoming solar energy instead of absorbing it, thus restricting the amount of surface heating and consequent heat loss into the urban atmosphere. Cool roofs especially have demonstrated to have much lower surface temperatures compared to the dark colored roofs that are normally placed in the same climatic conditions (Sedaghat & Sharif, 2022). Environmental studies comparing cool materials to traditional construction materials show that the solar heat gains reduction is significant, and hence, the cooling needs of the indoors are reduced, and thus lower urban ambient temperatures. Even thermal stress at urban scale can be reduced using these

materials by reducing the amount of heat stored inside building envelopes, and are particularly effective in hot and arid climates with high solar radiation intensity (Zeeshan & Ali, 2022). In Figure 4.1, it is evident that there are several interrelated ways that green buildings suppress urban heat such as evapotranspiration, surface reflectivity, shading, and passive cooling techniques.

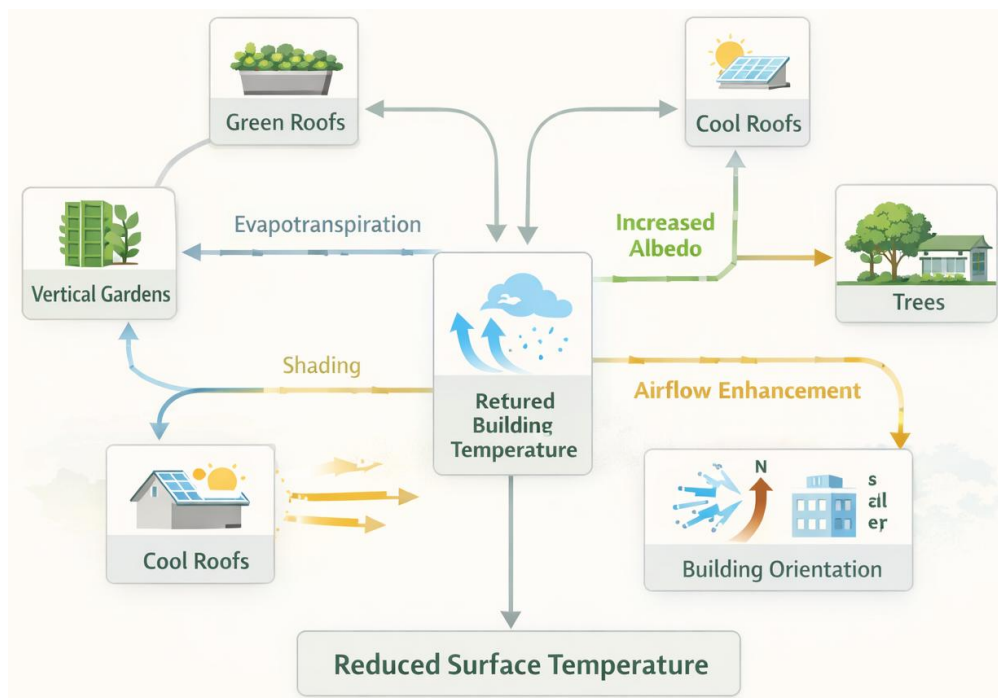


**Figure 4.1 Key mechanism by which the green building elements can help in reducing Urban Heat Island.**

Vegetation incorporation and urban shading in the green building design also contribute to the mitigation of UHI by modifying microclimatic conditions and reestablishing the ecological functions in urban setting. The use of trees, inner gardens, green walls, and open spaces is also direct shading that minimizes surface and air temperature and enhance human thermal comfort. The vegetation also plays an essential role of a natural thermal controller by blocking the sun radiation and raising the humidity by evapotranspiration and slowing the speed of winds in a controlled way that adds to thermal comfort. In addition to thermal regulation, urban vegetation linked to green buildings assists in carbon sequestration and thus assisting in the mitigation process of climate change by absorbing carbon dioxide in the atmosphere (Ferrini et al., 2020; Sanju, 2025). All these ecological advantages

support the idea that green buildings are multifunctional systems which consider the local heat stress issues and the sustainability of the environment as a whole.

Besides material and vegetation-based buildings, natural ventilation and building orientation are crucial in urban heat retention reduction through passive design patterns. Appropriate orientation of building with the current wind directions helps to improve airflow, which enables the natural dissipation of heat in both the interior and exterior (Danjuma et al., 2025). Cross-ventilation is assisted through the use of architectural features like operable windows, ventilation shafts, atriums, and shaded openings to decrease the use of mechanical cooling systems. Passive cooling methods such as stack ventilation, or night-time cooling, can allow buildings to release heat built up in the buildings during cooler seasons, reducing thermal loads in general. Through the incorporation of natural ventilation concepts in the construction of green buildings, urban settings can be in a better position to enjoy better heat dissipation, low-energy usage and a higher ability to withstand the effects of increasing temperatures due to climate change (Ahmed et al., 2021; Iskandar et al., 2025; Stasi et al., 2024). All these interrelated processes show that green buildings are a climate-responsive system that can alleviate the Urban Heat Island effect using scientifically-based environmental processes.

## **5. Environmental Science Evidence from Case Studies**

Case studies of environmental science, conducted in a variety of urban settings, can greatly promote the enforcement of green buildings in the context of reducing the Urban Heat Island effect. Research carried out in mega cities, which have built environments that are dense (that is, with high anthropogenic emission of heat) and where surface and ambient temperature are measurably reduced as green building strategies to reduce heat emission and green buildings such as green roofs, reflective surfaces, and extensive vegetation cover are implemented (Dong et al., 2020; Lukinov et al., 2024). Using remote sensing data over major metropolitan areas has shown that neighborhoods that have greater proportions of green buildings have lower land surface temperatures than the areas around the conventional urban areas, especially in extreme summer seasons. These findings are also supported through the use of complementary field-based measurements which record lower roof and wall temperatures, better indoor thermal comfort and local cooling influences at the

level of the pedestrians (Đorđević, 2021; Smith et al., 2023). In emerging cities, where urbanization is usually quick and unplanned, causing a rise in heat stress, empirical literature identifies green buildings as an important means of countering the increase in urban temperatures despite infrastructure and resource limitations. Such cities have shown that, even when only some elements of green buildings are implemented, such as rooftop vegetation and high-albedo surfaces, there can be significant temperature benefits and an improvement in microclimatic conditions (Cuce et al., 2025; Herath et al., 2023). The quantitative data of temperature reductions in both developed and developing cities generally show reductions of several degrees at the surface level up to quantifiable changes in near-surface air temperatures, which highlights the compound effect of these measures when done on a large scale. Thermal imaging using satellites has been especially useful in the spatial distribution of heat, and hotspots of cooling related to green infrastructure as well as detailed measurements of diurnal changes in temperature and human thermal comfort on the ground (Budzik et al., 2025; Garcia, 2023). Notably, further research on the environment also indicates that there are considerable seasonal and geographical differences in the performance of UHI mitigation and that the maximum cooling effect was achieved during warmer seasons and in climates with high solar radiation (Han et al., 2023; Khan et al., 2023).

Conversely, it is possible that the cooling magnitude can be lessened in colder months or moist areas that require climate sensitive green building designs. Taken together, these case study results indicate that green buildings provide scientifically proven, adaptable, and regionally sensitive strategy of mitigating urban heat stress in a broad spectrum of urban settings (Rahman et al., 2022). A bar-wise comparison of land surface temperatures under different urban green cover levels is shown in the figure 5.2 The lowest vegetation cover (5-10%) has the highest surface temperatures reaching to about 43-45 °C, which is a severe condition of Urban Heat Island. With the expansion of the green cover to 20-30%, the surface temperatures reduce significantly to approximately 34-38 °C. Further diminution is also seen at elevated vegetation cover (40-50%), where the surface temperatures of land is less than 30-32 °C showing the intensified cooling power by means of urban greenery by shading and evapotranspiration.

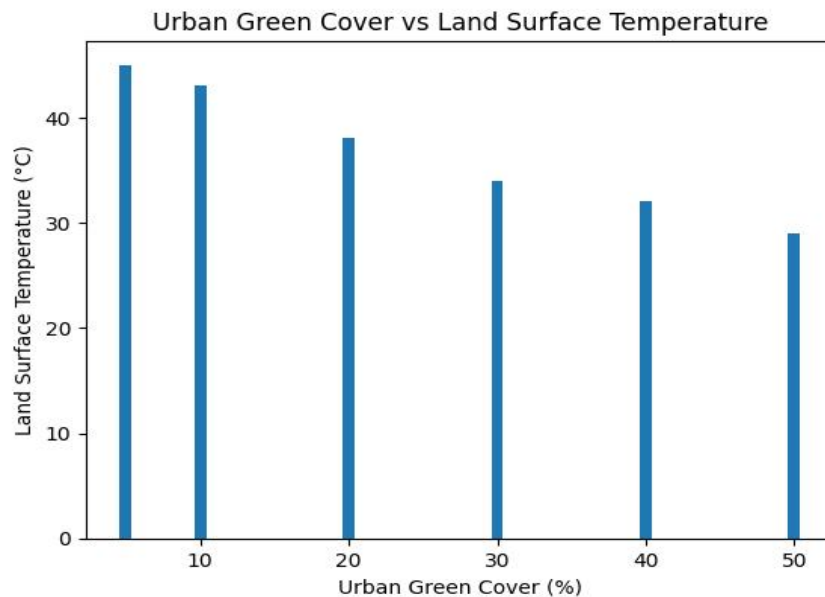


**Figure 5.2** *Variation in land surface temperature (°C) across different levels of urban green cover (%), indicating progressive reduction in urban heat intensity with increasing vegetation.*

## 6. Co-Benefits of Green Buildings Other than Heat Mitigation

In addition to direct benefits related to the reduction of the Urban Heat Island effect, green buildings offer a broad spectrum of co-benefits that contribute to environmental sustainability, human well-being, and urban resilience to a great extent (ABBASOVA, 2020). Among the most outstanding advantages is the lower level of energy required especially in cooling since green buildings utilize passive design layouts, high-performance insulation, reflective surfaces and natural ventilation to ensure comfortable interiors. These buildings reduce peak loads of electricity by reducing the use of air conditioning systems and help stabilize, and make urban energy systems more efficient. Intimately associated with energy efficiency is the enhancement of the indoor thermal comfort, where green buildings are developed to balance the interior temperatures, ideal levels of humidity, and well-improved airflow, which make the working and living conditions in green buildings healthier and more comfortable. This increased indoor comfort does not only increase the productivity and satisfaction of the occupants but also decreases susceptibility to extreme heat events, particularly to sensitive populations (Du, 2024; Flores-Larsen & Filippin, 2021; Gil-Ozoudeh et al., 2022b). Moreover, the use of less

energy in green buildings directly reduces greenhouse gas emissions by the fact that lower electricity generation by using fossil fuels creates less carbon dioxide and other climate-inducing gases. Green buildings also provide better urban biodiversity by means of vegetation which comes in the form of green roofs, green wall and landscaped areas that provide homes to birds, insects, and other urban wildlife (Shafique et al., 2020). The vegetated features are capable of renewing the ecological processes in the cities, aiding the pollination, and enhancing the resilience of urban ecosystems. Green buildings have a huge health benefit in terms of public health in that exposure to extreme heat is reduced, the quality of the indoor air is adopted and people are able to interact with the green areas, which has been linked with reduced level of stress, improved mental health and reduced cases of heat-related diseases (Paniccià et al., 2024; Rojas-Rueda, 2021). All these co-benefits show that green buildings are not just thermal controls, but they are solutions to environment, energy, ecological and health problems that are all integrated in cities. The summary of the multidimensional co-benefits of green buildings in Figure 6.3 shows that they do not simply contribute to the heat mitigation but also to the sustainable and healthy urban setting.



***Figure 6.3 Environmental, energy, and public health co-benefits of green buildings in urban systems.***

## 7. LIMITATIONS AND CHALLENGES

Although the environmental advantages of green buildings are proven, there are a number of limitations and challenges still preventing their wide adoption and success to reduce the impact of the Urban Heat Island effect. The major obstacles include the fact that initial cost of construction of green technologies, special materials and design skills is high and may deter use especially when working in a resource constrained environment. Moreover, its maintenance, particularly of the green roofs and vertical greening systems, involves long-term financial investment, technical expertise, and institutional support to maintain good performance. Green building strategies are also climatically dependent because cooling benefits differ in different regions depending on temperature, humidity, solar radiation, and seasonal variations, making it difficult to directly transfer design solutions. Moreover, the absence of standardized measurement methods to evaluate the performance of mitigation of UHI is a source of inconsistency in the reported results and cross-study comparisons. There are additional policy and implementation hindrances such as weak regulatory frameworks, low awareness, incentives, and integration of urban planning that further limit the large-scale adoption of green building practices in many developing countries.

To solve these issues, specific research and planning are necessary, and a number of gaps in research and possible future directions are outlined. Long-term environmental monitoring is urgently required to determine the long-term thermal, ecological, and energy performance of green buildings in diverse climatic conditions. Increased connectivity of smart city technologies, sensor networks and data-driven urban management systems can contribute to more effective monitoring in real time and performance optimization. Future studies must focus on region-oriented green building designs to consider the local climate, socio-economic status, and material availability in an attempt to maximize performance. Green buildings have to be mainstreamed in the urban development strategies by the development of policy-driven implementation frameworks that are backed by incentives, regulations, and capacity-building programs. Finally, it will be necessary to encourage interdisciplinary research at the border between environmental science, architecture, urban planning, research of public health and policy development that will enable

holistic and scalable solutions to the problem of urban heat.

## 8. CONCLUSION

The phenomenon of Urban Heat Island that is caused by a high level of urbanization, impervious, vegetation loss, and anthropogenic heat is a severe menace to urban ecosystems, human health, energy usage, and air quality. Green buildings have been proved to be efficient in minimizing UHI through evapotranspiration, reflective surfaces, vegetation-based shading and passive cooling leading to measurable lowering of surface and ambient temperatures and thermal comfort within buildings. Green buildings have a wider sustainability benefit, such as reduced energy consumption and greenhouse gas emissions, increased biodiversity, and improved environmental quality that are fundamental to climate change adaptation and reduction. Green buildings as climate-resilient solutions have the potential to mitigate the urban thermal vulnerability, and enhance livability when combined with enabling policies, geographically specific designs and long-term city planning. Green building principles can be mainstreamed with support of interdisciplinary research and smart city integration as a viable way into sustainable, thermally comfortable, and resilient urban futures.

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Online ISSN

3007-3197

Print ISSN

3007-3189

<http://amresearchreview.com/index.php/Journal/about>

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Online ISSN

3007-3197

Print ISSN

3007-3189

<http://amresearchreview.com/index.php/Journal/about>

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