Policy Journal of Social Science Review
ISSN (Online): 3006-4635
ISSN (Print): 3006-4627
https://journalofsocialsciencereview.com/index.php/PJSSR
Vol. 2 No. 4 ,(Fall-2024)

Policy Journal of
Social Science Review

Let's Start!

Roof Gardens Improve the Energy Efficiency and Ecological Sustainability of Buildings

Ar. Nida Jawad[1]
Dr. Amna Jahangir[2]

Policy Journal of Social Science Review
ISSN (Online): 3006-4635
ISSN (Print): 3006-4627
https://journalofsocialsciencereview.com/index.php/PJSSR
Vol. 2 No. 4 ,(Fall-2024)

Roof Gardens Improve the Energy Efficiency and Ecological Sustainability of Buildings

Ar. Nida Jawad	Associate Professor, Department of Architecture, Comsats University Islamabad, Islamabad Campus. Email: jawad.nida@gmail.com
Dr. Amna Jahangir	Assistant Professor, School of Architecture, University of Lahore.

Abstract

Peak energy utilization, air contamination, and the urban heat island effect are all major concerns during the cooling and warming seasons. Green roofs can address these challenges and promote sustainable development in buildings. Green roofs offer numerous operational and environmental benefits, including improved energy efficiency, better rain water management, reduced urban heat island effects, lower air, atmosphere and sound pollution, and increased urban wildlife habitats. This article explores the benefits of green roofs and their impact on building energy efficiency, drawing from current literature and evidence. Green roofs can improve building energy performance and indoor air quality, according to research.

Keywords: Roofs gardens, Green roof, Encouraging energy efficacy, Urban heat island effect, Air contamination

OVERVIEW

Following the Industrial Revolution, more people moved into cities as a result of the industrial development of human advancement, which accelerated the growth of urban areas. As a result of developers having to build more structures due to population growth, more green spaces were destroyed and turned into built environments[1]. The growth of built-up areas devoid of sufficient greenery has altered the material and energy flow through the urban ecology, leading to a number of environmental issues. Building roof surfaces can effectively be used to lower the air and surface temperatures in urban areas because they make up 20–25% of all urban surfaces[2].Installing living vegetation on roofs, or "green roof systems," could lessen the detrimental effects that buildings have on local environment[3].

The origins of green roofs can be found in ancient Babylon's Hanging Gardens built in the year 605[4]. More recently, European nations have developed a strong environmental defence due to their dense populations and relatively high levels of industrialization, much ahead of

POLICY JOURNAL OF SOCIAL SCIENCE REVIEW
HTTPS://JOURNALOFSOCIALSCIENCEREVIEW.COM/INDEX.PHP/PJSSR
Policy Journal of Social Science Review
ISSN (Online): 3006-4635
ISSN (Print): 3006-4627
https://journalofsocialsciencereview.com/index.php/PJSSR
PJSSR
Vol. 2 No. 4 ,(Fall-2024)

North Americans in terms of consciousness. Europeans have now built and maintained green roofs for 40 years, both technically and practically. Germany has been recognized as a global leader in green roof technology because one in seven new roofs there are green[5]. Despite initially costing more to build than traditional roofs, green roofs can end up being more cost-effective over time due to the energy savings and extended lifespan of roof membranes.

ROLE OF ROOFS GARDENS

In essence, a modern green roof is a roof with drainage systems and vegetation on top of a waterproofing layer. Usually, a green roof is made up of five main elements, which are positioned in ascending order: a roofing membrane, also known as membrane protection and a roof barrier. , vegetation, growth substrate, drainage layer, and insulation[6]. A typical green roof cross-section is shown in Figure 1[7]. Green roofs can be broadly classified into two categories: intensive and

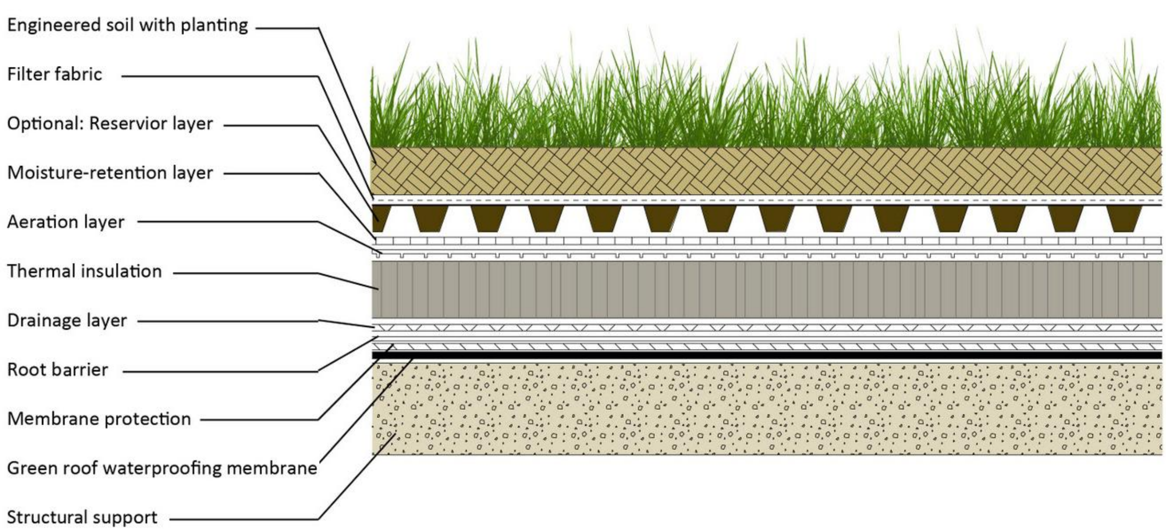

Fig 1: Typical Green Roof Section

Intensive green roofs typically need substrate depths of 150–1200 mm and are frequently intended as public spaces. As a result, they might include trees and shrubs that resemble ground-level landscaping. Because more robust structures are necessary to support the weight, intensive roofs tend to be pricier compared to extensive roofs. Conversely, a large green roof necessitates a growing medium that ranges from 50 to 150 mm deep to support vegetation. By restricting the class of plants that can be put on the roof, this regulation limits the load of the vegetative roof on the structure. The affordability, lightweight construction,

POLICY JOURNAL OF SOCIAL SCIENCE REVIEW
HTTPS://JOURNALOFSOCIALSCIENCEREVIEW.COM/INDEX.PHP/PJSSR
Policy Journal of Social Science Review
ISSN (Online): 3006-4635
ISSN (Print): 3006-4627
https://journalofsocialsciencereview.com/index.php/PJSSR
Vol. 2 No. 4 ,(Fall-2024)

shallow soil depth, and low maintenance requirements of extensive green roofs make them more popular than intense roofs. A 3rd type of green roof is called partial-intensive. Semi-intensive green roofs combine aspects of extended and intense varieties, with the extensive component making up no more than 25% of the overall green roof area[8].

THE ECOLOGICAL ADVANTAGES OF GREEN ROOFS

Green roofs have numerous advantages for the environment. Green roofs offer many advantages over traditional roofs, in addition to creating a more pleasant atmosphere. They have the following advantages: enhancement of urban wildlife habitats, reduction of air and noise pollution, mitigation of the effects of urban heat islands, and better storm water management.

ENHANCEMENT OF RAINWATER CONTROL

The rise in urban development has led to a reduction in storm water infiltration due to the expansion of hard, impermeable surfaces [9]. The ability of green roofs to collect rainwater, postpone runoff until after heavy rain events, and evapotranspiration moisture back into the atmosphere makes them perfect for storm water management[10].The rate of drainage is influenced by rainfall patterns, plant species, roof slope, and substrate depth. The effect of green roofs on storm water management has been the subject of numerous research. Research indicates that specific green roofs can retain rainfall between 66% and 69% when the substrate exceeds 10 cm[11]. Rainfall retention ranges from 25% to 100% for substrates that are shallower. Up to 60% to 79% of yearly building runoff can be reduced by green roofs[12]. Additionally, a simple 10% conversion of roofs to green roofs could result in a 2.7% reduction in regional runoff [13]. It is found that total runoff is typically higher on steeper slopes and with shallower substrates[14].

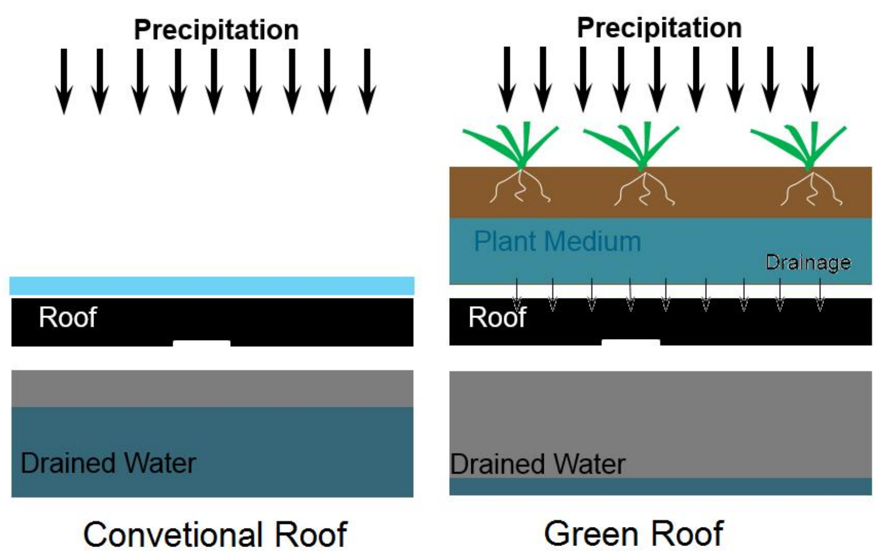

Fig 2: Rainfall Retention of Conventional and Green Roof[15]

Policy Journal of Social Science Review
ISSN (Online): 3006-4635
ISSN (Print): 3006-4627
https://journalofsocialsciencereview.com/index.php/PJSSR
Vol. 2 No. 4 ,(Fall-2024)

The quality of the water is just as crucial as the quantity of rainwater that is collected. According to certain research, modern roofing materials` contribute metal or chemical components to runoff water even despite the roofing system. Green roofs release fewer chemical compounds into the water, although all artificial roofing materials affect runoff[16].

REDUCED IMPACT OF URBAN HEAT ISLANDS

In comparison to suburban surroundings, urban areas are typically warmer, a phenomenon known as the Urban Heat Island (UHI)[17]. Figure 3 shows how UHI occurs. The main factors contributing to the Urban Heat Island Effect (UHI) include changes to the urban landscape and the extensive installation of built surfaces, such as asphalt roads and building materials, in place of natural vegetation[18]. The high solar heat retention capacity, limited permeability, and advantageous thermal qualities for energy storage of urban surfaces raise air temperatures in urban regions. Through plant evapotranspiration and decreased heat absorption, green roofs have been shown to be a successful strategy for lowering the Urban Heat Island Effect. The temperature of the adjacent air and the roof surface are lowered as a result. Additionally, the green roof reduces anthropogenic heat by producing a cooler surface at roof level, it lessens the need for air conditioning when the temperature is greater than usual. The Urban Heat Island Effect is lessened as a result of the combined effect. A few research have examined how green roofs can lower UHI. According to Bita et al the average surface temperature in New York City would drop by an estimated 0.1 to 0.8 degrees Celsius if 50% of rooftops were greened[19]. According to Yupeng et al Toronto, Canada, might see a 0.5–2°C drop in average temperatures if 30–100% of its rooftops were greened[20].

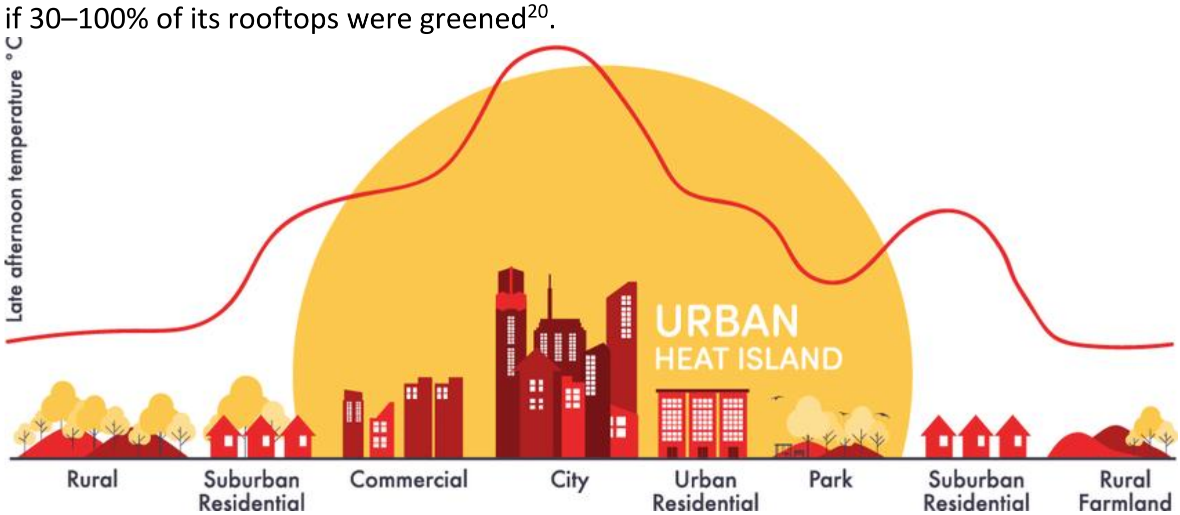

Fig 3:

Fiqure 3. Urban Heat Island Effect

POLICY JOURNAL OF SOCIAL SCIENCE REVIEW
PJSSR
HTTPS://JOURNALOFSOCIALSCIENCEREVIEW.COM/INDEX.PHP/PJSSR
Policy Journal of Social Science Review
ISSN (Online): 3006-4635
ISSN (Print): 3006-4627
https://journalofsocialsciencereview.com/index.php/PJSSR
PJSSR
Vol. 2 No. 4 ,(Fall-2024)

MINIMISING POLLUTANTS IN THE AIR

One of the major threats to public health is air pollution, particularly in metropolitan areas. Two important ways that green roofs help to lower air pollution are:

1. Decreasing the urban heat island effect and enhancing the energy efficiency of buildings reduces the dependence on system heating and cooling, which subsequently lowers carbon dioxide emissions from power plants[21].

2. Carbon dioxide is taken up from the atmosphere by plants' photosynthesis process, which then transforms it into biomass. Studies have been done to look at how green roofs affect air pollution levels[22].

Yang et al. estimated the amount of air pollutants removed by green roofs in Chicago using a bigleaf dry deposition model. The results indicated that green roofs could substantially decrease air pollution levels in Chicago[23]. Additionally, using the Forest Service's Urban Forest Effects (UFORE) dry deposition model, Yang investigated how green roofs affected air pollution. This model evaluated NO2, SO2, CO2, PM10 (particles smaller than 10 mm), ozone, and their concentrations and hourly reduction rates in addition to their economic worth. According to the findings, extensive green roofs can improve air quality as an additional strategy to lower pollution, but intense green roofs with trees and plants are much more beneficial[24].

DIMINUTION OF POLLUTION FROM NOISE

Especially in enclosed areas like airports and industrial zones, as well as along long street canyons and tall buildings, elevated noise levels in urban areas can be a major problem. The growing ground and vegetation can better absorb sound waves than concrete surfaces[25]. Thus, installing green roofs in place of traditional roofs could lessen noise pollution from surrounding roadways and other urban sources. The effects of intensive and extensive green roofs on sound pressure were investigated. There is a direct connection among the amount of roof covered by plants and the fall in sound pressure on the side of the structure that faces away from the noise source [26]. The many interactions with the substrate components of green roofs attenuate sound waves as they enter the pore space. The substrate depth could be increased by up to 15–20 cm to improve noise suppression. Roofs with deeper substrate layers had no extra benefits. Several factors influence noise reduction, including the canyons' width to height ratios, front elevation absorption, diffuse reflection, and building-induced sound refraction. Noise levels within a building are also influenced by the insulation of the façade, whether windows are open or closed, and the volume of sound outside[27].

SAFEGUARDING ECOLOGY

Birds, butterflies, beetles, spiders, and other invertebrates can find food, shelter, and nesting chances on green roof[28]. Research is being done on green roofs in Chicago and Europe to determine their special capacity to establish peaceful, workable habitats for endangered species[29]. Based on these studies, green roofs serve as an elevated urban environment that can provide unique protection against human disturbance, noise from traffic, and ground-level predators[30].These findings have encouraged national and local conservation organizations to advocate for green roofs, especially in Switzerland and the United Kingdom[31].

BUILDING ENERGY PERFORMANCE

Green roofs enhance the building envelope's energy efficiency and lower the energy demand on space conditioning in buildings by lowering heat flux and solar reflectivity, increasing insulation, soil thickness, evapotranspiration, and indoor air temperature, in addition to the previously listed environmental advantages.

DROP IN THE AMOUNT OF SOLAR REFLECTION AND HEAT FLOW

During the summer, a green roof maintains a temperature of just 27 °C, in contrast to a black roof, which can reach surface temperatures as high as 80 °C[32]. Green roofs provide cooling effects due to two primary factors:

1. Loss of latent heat
2. An increase in the reflection of solar radiation.

Kasera et al describes albedo as the ratio of total reflected to incident electromagnetic radiation[33]. While roofs made of bitumen, tar, or gravel generally have an albedo range of 0.1 to 0.2, various research studies have shown that green roofs can cool as effectively as the best white roofs, achieving similar albedo levels of 0.7 to 0.85[34].

CONTROLLING THE INDOOR TEMPERATURE

Indoor air temperatures rise as a result of solar absorption via the roof.

Because of this, more energy is needed, and more air conditioning is used. By forming a buffer zone between the roof and the sun's rays and providing shade, a green roof keeps its surface from warming. An investigation of how green roofs affect indoor air temperature and the need for heating and cooling was carried out by Tiziana[35]. They evaluated the soil surface temperatures and green roof vegetation using a construction code combined with a model of the thermal behavior of a green roof. It was discovered that the green roof decreased the temperature fluctuation amplitude of the roof slab by 30 ^{0}C throughout the summer. The green roof, they found, lowered the annual energy demand by 6% and lowered the inside air temperature by 2 °C during the summer[36].

EXTRA INSULATION

A green roof's improved insulating qualities could lower a building's yearly energy use. By providing thermal mass, a green roof not only reduces the building's heat loss in the winter and gain in the summer, but it also helps maintain consistent interior temperatures throughout the year. Two Athens buildings with comparable insulating qualities—one with a green roof, however—were examined in this study. Three days in July were used to record the interior temperatures of these structures. When there was a green roof, the indoor air temperature was above 30 °C 68% of the time, but only 15% of the time. The daily average, highest, and lowest recorded temperatures were 2, 3, and 1 ◦C lower, respectively[37].

THE WATER CONTENT AND DEPTH OF THE SOIL

The amount of solar radiation that reaches the roof deck is influenced by two primary factors: soil media and leaf foliage. The heat transfer through the roof of an individual plant falls more with more foliage density, which leads to a greater drop in surface temperatures [38]. The thermal characteristics of the soil, particularly for green roofs, affect heat transfer in addition to vegetation and may therefore have an impact on building energy use[39]. Ten separate green roof soil media samples including varying amounts of sand, expanded compost, and pumice were assessed by Annie et al. They investigated the fact that composition and moisture content had a significant impact on thermal characteristics. In contrast to a scenario where water was introduced, the values for thermal conductivity and specific heat capacity for dry samples were 0.25–0.34 W/(m K) and 830–1123 J/(kg K), respectively. While thermal emissivity remained mostly constant independent of moisture content, albedo decreased as surface soil moisture rose. Based on the findings, building energy modelling green roofs must take moisture content into account, including both bulk and surface moisture[40].

CONCLUSION

In contemporary cities, there are numerous extensive environmental issues. A number of environmental issues at the building and urban levels are thought to be effectively resolved by green roofs. Green roofs provide a number of advantages over traditional roofs, in addition to creating a more comfortable atmosphere. This involves decreasing air and noise pollution, boosting urban biodiversity by establishing habitats for wildlife, minimizing runoff and enhancing water quality to improve stormwater management, and lowering heat absorption and evapotranspiration to address the Urban Heat Island Effect. Beyond these environmental advantages, green Roofs can improve a building's energy efficiency by decreasing heat flow and solar reflectance, raising the interior temperature, boosting insulation, and increasing the moisture content and thickness of the soil. A green roof has been shown to lower indoor air temperatures by 2 °C and lower annual energy use by 6% during the summer. Furthermore, the effectiveness of green roofs in the winter has been demonstrated. The following areas require more research in order to evaluate and understand how green roofs affect a building's energy and environmental performance:

ISSN (Online): 3006-4635
ISSN (Print): 3006-4627
https://journalofsocialsciencereview.com/index.php/PJSSR

Vol. 2 No. 4 ,(Fall-2024)

- Green roofs require the right solutions, which include high-performance soils, drainage layers, and vegetation that is well-suited. Different climates may require different solutions.
- It is necessary to create more intricate green roof models that take into account not only heat and mass transfer phenomena but also plant physiology.
- Urban air quality, and consequently public health and quality of life, are enhanced by green roofs; nevertheless, these advantages require more precise measurement.

REFERENCES

1. Jabbar, M., Yusoff, M. M., & Shafie, A. (2022). Assessing the role of urban green spaces for human well-being: A systematic review. GeoJournal, 1-19.
2. Wang, X., Li, H., & Sodoudi, S. (2022). The effectiveness of cool and green roofs in mitigating urban heat island and improving human thermal comfort. Building and Environment, 217, 109082.
3. Dimitrijević-Jovanović, D., Živković, P., & Stevanović, Ž. (2018). The impact of the building envelope with the green living systems on the built environment. Thermal Science, 22(Suppl. 4), 1033-1045.
4. Mallgrave, H. F. (2021). Building Paradise: Episodes in Paradisiacal Thinking. Routledge.
5. Shafique, M., Kim, R., & Rafiq, M. (2018). Green roof benefits, opportunities and challenges–A review. Renewable and Sustainable Energy Reviews, 90, 757-773.
6. Cascone, S. (2019). Green roof design: State of the art on technology and materials. Sustainability, 11(11), 3020.
7. https://architizer.com
8. Owaisi, S., Jawadeh, A., & Taha, S. (2018). Structural And Environmental Design, a study of using green roofs system in construction.
9. Chithra, S. V., Nair, M. H., Amarnath, A., & Anjana, N. S. (2015). Impacts of impervious surfaces on the environment. International Journal of Engineering Science Invention, 4(5), 27-31.
10. Pumo, D., Francipane, A., Alongi, F., & Noto, L. V. (2023). The potential of multilayer green roofs for stormwater management in urban area under semi-arid Mediterranean climate conditions. Journal of Environmental Management, 326, 116643.
11. De-Ville, S., Menon, M., Jia, X., Reed, G., & Stovin, V. (2017). The impact of green roof ageing on substrate characteristics and hydrological performance. Journal of Hydrology, 547, 332-344.
12. Soulis, K. X., Ntoulas, N., Nektarios, P. A., & Kargas, G. (2017). Runoff reduction from extensive green roofs having different substrate depth and plant cover. Ecological Engineering, 102, 80-89.

13. Nguyen, C. N., Muttil, N., Tariq, M. A. U. R., & Ng, A. W. (2021). Quantifying the benefits and ecosystem services provided by green roofs—A review. Water, 14(1), 68.
14. Zhang, Q., Miao, L., Wang, X., Liu, D., Zhu, L., Zhou, B., ... & Liu, J. (2015). The capacity of greening roof to reduce stormwater runoff and pollution. Landscape and Urban Planning, 144, 142-150.
15. https://www.eng.uwo.ca/research/greenroof/
16. Hachoumi, I., Pucher, B., Vito-Francesco, D., Prenner, F., Ertl, T., Langergraber, G., ... & Allabashi, R. (2021). Impact of green roofs and vertical greenery systems on surface runoff quality. Water, 13(19), 2609.
17. Ibrahim, S. H., Ahmat, N. I., Julaihi, W., Koesmeri, D. R., & Zaini, A. A. (2019). Comparison on climatic variables of rural, suburban and urban areas in relation to urban heat Island (UHI) phenomenon. J. Eng. Sci. Technol., 14(5), 3007-3027.
18. https://forumias.com/blog/urban-heat-island-and-its-impact/
19. Alizadehtazi, B., Stolper, J., Singh, K., & Montalto, F. A. (2024). Microclimatic implications of a large-scale green roof and high-rise redevelopment in New York City. Building and Environment, 250, 111113.
20. Wang, Y., Berardi, U., & Akbari, H. (2016). Comparing the effects of urban heat island mitigation strategies for Toronto, Canada. Energy and buildings, 114, 2-19.
21. He, B. J. (2022). Green building: A comprehensive solution to urban heat. Energy and Buildings, 271, 112306.
22. Tan, T., Kong, F., Yin, H., Cook, L. M., Middel, A., & Yang, S. (2023). Carbon dioxide reduction from green roofs: A comprehensive review of processes, factors, and quantitative methods. Renewable and Sustainable Energy Reviews, 182, 113412.
23. Yang, J., Yu, Q., & Gong, P. (2008). Quantifying air pollution removal by green roofs in Chicago. Atmospheric environment, 42(31), 7266-7273.
24. Yang, L. (2021). Quantifying the effect of air particle pollution mitigation by dry deposition in Chinese residential areas (Doctoral dissertation, Cardiff University).
25. Lercher, P. (2019). Noise in cities: urban and transport planning determinants and health in cities. Integrating Human Health into Urban and Transport Planning: A Framework, 443-481.
26. Van Renterghem, T., Hornikx, M., Forssen, J., & Botteldooren, D. (2013). The potential of building envelope greening to achieve quietness. Building and Environment, 61, 34-44.
27. Shishegar, N. (2012). Green roofs: Enhancing energy and environmental performance of buildings. In International Conference on Clean E-nergy.

28. Wang, L., Wang, H., Wang, Y., Che, Y., Ge, Z., & Mao, L. (2022). The relationship between green roofs and urban biodiversity: A systematic review. Biodiversity and Conservation, 31(7), 1771-1796.
29. Lehmann, S. (2021). Growing biodiverse urban futures: Renaturalization and rewilding as strategies to strengthen urban resilience. Sustainability, 13(5), 2932.
30. Partridge, D. R. (2020). Urban Green Roofs as Wildlife Habitat (Doctoral dissertation, Fordham University).
31. Wilkinson, S. J., & Dixon, T. (Eds.). (2016). Green Roof Retrofit: building urban resilience. John Wiley & Sons.
32. Bevilacqua, P., Mazzeo, D., Bruno, R., & Arcuri, N. (2017). Surface temperature analysis of an extensive green roof for the mitigation of urban heat island in southern mediterranean climate. Energy and Buildings, 150, 318-327.
33. Kasera, S., Nayyar, A., & Sharma, D. TheEnergy Consumption Performance of Roof Garden.
34. Susca, T. (2019). Green roofs to reduce building energy use? A review on key structural factors of green roofs and their effects on urban climate. Building and environment, 162, 106273.
35. Eksi, M., Rowe, D. B., Wichman, I. S., & Andresen, J. A. (2017). Effect of substrate depth, vegetation type, and season on green roof thermal properties. Energy and Buildings, 145, 174-187.
36. Santamouris, M. (2014). Cooling the cities–a review of reflective and green roof mitigation technologies to fight heat island and improve comfort in urban environments. Solar energy, 103, 682-703.
37. Sfakianaki, A., Pagalou, E., Pavlou, K., Santamouris, M., & Assimakopoulos, M. N. (2009). Theoretical and experimental analysis of the thermal behaviour of a green roof system installed in two residential buildings in Athens, Greece. International Journal of Energy Research, 33(12), 1059-1069.
38. Tariku, F., & Hagos, S. (2022). Performance of green roof installed on highly insulated roof deck and the plants' effect: An experimental study. Building and Environment, 221, 109337.
39. He, Y., Yu, H., Ozaki, A., Dong, N., & Zheng, S. (2017). Influence of plant and soil layer on energy balance and thermal performance of green roof system. Energy, 141, 1285-1299.
40. Block, A. H., Livesley, S., & Williams, N. S. (2012). Responding to the urban heat island: a review of the potential of green infrastructure.