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Green Roofs as a Pathway to Achieving Net-Zero Carbon in Construction

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ABSTRACT

The construction sector accounts for a substantial portion of global energy consumption and carbon emissions, contributing to both embodied and operational carbon footprints. According to the 2015 Paris Agreement, many countries worldwide are collaborating to achieve net-zero emissions by 2050. In the construction industry, green roofs offer promising potential as a substantial structure for integrating into buildings, helping to achieve net-zero emissions. This study aims to evaluate how green roof design variables influence their effectiveness in achieving net-zero carbon goals within the construction sector. A structured review of relevant scholarly and government literature was conducted to assess the features and the relationship between green roofs and net-zero carbon. Findings indicate that substrate depth (intensive or extensive) and vegetation properties (albedo, leaf area index, evapotranspiration, etc.) contribute to the efficiency of green roofs in carbon mitigation toward net-zero in construction. This review addresses a general knowledge gap in leveraging the natural carbon-eliminating properties (both indirect and direct) of green roofs for net-zero carbon goals.

Keywords: Green roof; net-zero carbon; Construction; Carbon Emissions; Vegetation; Substrate

INTRODUCTION

The world faces an urgent responsibility to address the harm caused by human activities, as the human ecological footprint continues to grow and carbon emissions surge (1). Among the industries contributing to this problem, the construction sector accounts for approximately one-third of cumulative greenhouse gas (GHG) emissions worldwide and roughly 40% of total global energy use (2, 5). GHGs, primarily CO_2 (approximately 64% of total emissions), significantly contributing to global warming (3, 4). As cities continue to grow and the United Nations projects that approximately 68% of the world population will live in urban areas by 2050, addressing the construction industry's dependence on carbon-intensive, fossil fuel-driven practices has become increasingly urgent (6, 7).

Within that 40% of global energy-related carbon emissions, 11% comes from embodied carbon, the emissions tied to material extraction, manufacturing, and transportation (8, 9), while the remaining comes from operational carbon, largely driven by heating, ventilation, and air conditioning (HVAC) systems (9, 12). On top of that, sourcing building materials often involves habitat fragmentation, deforestation, and other environmental consequences to add to the problem (10). Tackling both embodied and operational carbon is essential if the construction sector is to meet the net-zero targets set out in the 2015 Paris Agreement (11, 15).

One strategy that has attracted growing attention

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is the integration of green roofs into building design. Green roofs are vegetated roofing systems built from multiple layered components, including vegetation, growth substrate, filter fabric, drainage elements, root barrier, insulation layer, waterproofing membrane, and roof deck, that work together to reduce carbon emissions through both direct sequestration and indirect reductions in energy demand (5, 13, 14, 17, 18, Figure 1). They are recognized as nature-based solutions (NBS), and cumulatively, approaches like these could contribute 30 to 37% of the carbon reductions needed to meet Paris Agreement targets by 2030 (19). Green roofs are generally divided into two categories: extensive systems, with substrate depths of 2 to 20 cm that support low-maintenance vegetation like grasses and sedums, and intensive systems, with depths greater than 20 cm that can support shrubs and trees with greater carbon sequestration potential (20, 21, Figure 2). They directly mitigate carbon through photosynthetic CO_2 uptake, and indirectly through the substrate's low thermal conductivity and high thermal mass alongside the vegetation's albedo, shading, and evapotranspiration properties, with the indirect pathway typically having the larger overall impact (5, 22, 23, 24, 25, 26).

Net-zero carbon refers to the point at which the carbon being emitted is balanced out by an equivalent amount being removed from the atmosphere (27, Figure 3). These emissions come from both natural processes and human activities, with the combustion of fossil fuels being the most significant contributor, and can be offset through carbon-capture technologies and broader sustainability efforts (6, 28). The goal is not necessarily to eliminate emissions entirely, but rather to stabilize and gradually reduce atmospheric carbon levels, preventing further damage, which is the main principle of the Paris Agreement's 1.5°C warming target (15, 16).

While both green roofs and net-zero carbon have each been considerably researched, relatively little work has explored how they can work together, introducing the research gap of using green roofs to achieve net-zero carbon that this literature review will address (29). Current approaches like Carbon Capture and Storage (CCS), which involves separating CO_2, pressurizing it, and storing it underground, are valuable but only cover

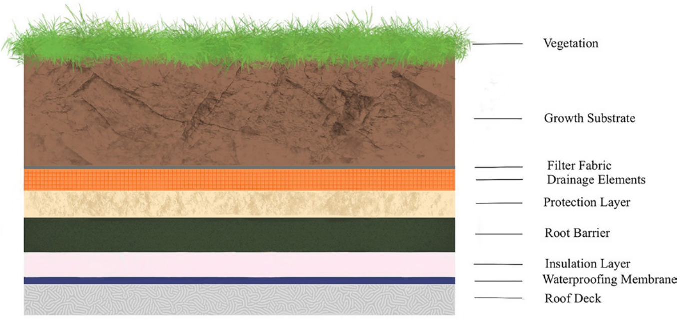

Figure 1. *Structural composition of a typical green roof system, illustrating key functional layers (18). The vegetation and substrate layers are the primary components responsible for carbon sequestration and thermal regulation, contributing to both direct and indirect carbon reductions in buildings (18). Created by Author (2025).*

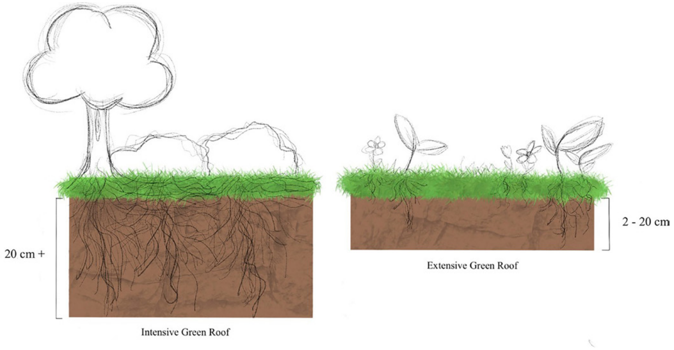

Figure 2. *Comparison of intensive and extensive green roof systems based on substrate depth, vegetation type, and structural requirements. Intensive green roofs (left) are characterized by deeper substrate layers (>20 cm), allowing for larger vegetation such as shrubs and trees, increased carbon storage, and enhanced thermal insulation (21). Extensive green roofs (right) have shallower substrate depths (2–20 cm), supporting low-maintenance vegetation such as grasses and sedums, with reduced structural load but lower carbon sequestration and insulation capacity (20). Created by Author (2025).*

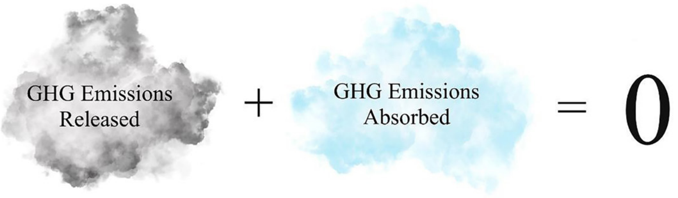

Figure 3. *Conceptual representation of net-zero carbon, where total GHG emissions released are balanced by an equivalent amount of emissions absorbed or offset, resulting in a net value of zero (27). In the construction sector, this balance can be achieved through a combination of emission-reduction strategies and carbon-sequestration mechanisms, such as those provided by green roof systems (6). Created by Author (2025).*

roughly one-fifth of the reductions needed under the Paris Agreement, showing that additional strategies are needed (5, 30). European nations have made meaningful progress following the 2019 European Green Deal, including biomass combustion with post-combustion capture at 0.9 $MtCO_2$/year, but there is still a long way to go before 2050 targets are within reach (31, 32, 33). In the construction sector, progress on embodied carbon depends on addressing transportation, manufacturing, materials, and demolition, while progress on operational carbon depends on smarter HVAC use, energy efficiency, and the everyday choices of building occupants (2, 34, 35, 36, Table 1). Encouraging more sustainable behaviors among residents will be an important consideration going forward (37, 38). This review aims to evaluate how green roof design variables, particularly substrate depth and vegetation characteristics, influence their effectiveness in reducing both types of carbon emissions, and to communicate why green roofs deserve a more prominent role in the effort toward net-zero carbon construction (39).

METHODS AND MATERIALS

This literature review is the culmination of comprehensive searches across peer-reviewed databases. 81 scholarly articles from ScienceDirect, MDPI, ResearchGate, PubMed, and other reliable sources were used. The referenced literature publications were thoughtfully chosen through searches tailored to specific topics relevant to the input keywords.

Search Strategy

Searches were conducted using keyword combinations with Boolean operators, including: “green roofs” AND “net-zero carbon,” “green roofs” AND “carbon sequestration,” “extensive green roofs” OR “intensive green roofs,” “green roofs” AND “substrate,” and “green roofs” AND “vegetation.” Articles published between 2010 and 2025 were given preference based on their reliability and accuracy. In determining relevance, articles were initially evaluated based on their titles and abstracts before the full text was analyzed. Sources were screened in two stages: titles and abstracts were first evaluated for relevance, followed by full-text review of qualifying articles. 152 articles were screened, with 81 included in this review. Inclusion criteria consisted of peer-reviewed studies focusing on green roof performance, carbon sequestration, or energy impacts in urban environments. Excluded studies include those not related to green roof systems, articles lacking quantitative data, non-English publications, articles beyond the scope of the keywords, and sources lacking sufficient methodological rigor (Diagram 1).

RESULTS AND DISCUSSION

How Can Green Roofs Contribute to Achieving Net-Zero Carbon Goals?

Green roofs have many environmental benefits, including improving biodiversity, increasing oxygen levels, and adding aesthetic appeal (40). Green roofs can effectively reduce carbon emissions because they are

Table 1. *Comparison of embodied and operational carbon emissions in the construction sector, highlighting differences in release processes and contributing factors. Embodied carbon refers to emissions generated during material extraction, manufacturing, transportation, construction, and demolition, whereas operational carbon results from building use, including HVAC systems, energy consumption, and occupant behavior (35, 36). This distinction is essential for achieving net-zero carbon, as both emission sources must be addressed through reduction and mitigation strategies. Created by Author (2025).*

	Embodied Carbon	Operational Carbon
Release Process	Released in the process of constructing and demolishing buildings	Released as a result of operating buildings
Contributing Factors	● Transportation ● Manufacturing ● Materials ● Destruction ● Placement	● HVAC systems ● Energy usage ● Resident behavior

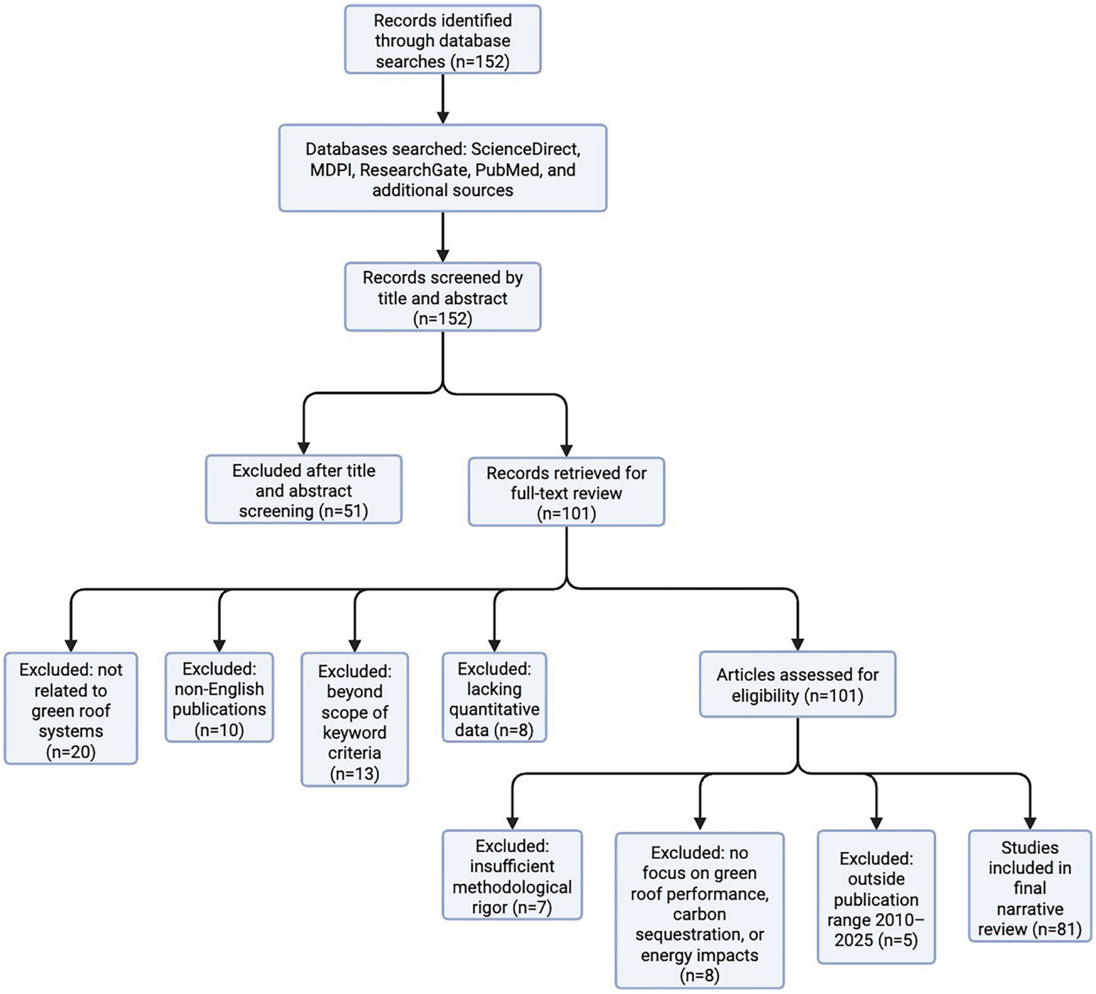

Diagram 1. *Flowchart illustrating the multi-stage search and screening strategy employed in this narrative review, detailing the databases queried, total records identified, and sequential exclusion criteria applied at the title-and-abstract and full-text review stages, culminating in the 81 articles included in the final synthesis. Created by Author in BioRender.com (2025).*

composed primarily of soil layers and vegetation (41). In line with the Paris Agreement, green roofs can help work towards achieving the global objective of net-zero carbon emissions, which would ultimately limit the increase in global temperature to 1.5˚C by 2050 (41). Using green roofs is now a strategy that can be applied to both newer and older buildings, which is especially important given the growing need to eliminate carbon emissions when the proper variation is used (42). Green roofs can hence reduce carbon emissions while meeting the consistently growing demand for residential and commercial buildings in expanding urban areas (43). While most studies consistently report that green roofs contribute to carbon mitigation, the extent of this benefit varies significantly with system design, climate conditions, and building characteristics (41, 43). This variation highlights the need to assess more critically which design factors most strongly influence performance rather than simply assuming uniform effectiveness.

However, their use is primarily dependent on the engineering and construction of buildings and on whether the public chooses to employ them (44). The construction industry can progress closer to creating net-zero carbon buildings if green roofs, which lower carbon emissions and boost a building's capacity to absorb carbon, become more widely used. These vacant building spaces can be transformed to benefit the environment and climate by turning otherwise dull, inactive rooftops into green roofs that reduce carbon emissions and add decorative value. With more in-depth research and advocacy, green roofs have promising potential to become standard elements of more eco-friendly construction, leading to net-zero carbon, in the near future.

Green Roof Mechanisms

As mentioned earlier, two main types of carbon reduction can be achieved through green roofs: direct and indirect carbon reduction (39). This section will delve more deeply into the mechanisms that underlie green roofs' ability to mitigate carbon emissions, examining the internal processes within the various components of green roofs. The ability of green roofs to reduce carbon emissions is a complex process that involves not only direct and indirect carbon reductions but also significant carbon and energy exchange among the various factors contributing to the success of each carbon elimination strategy (45).

Biological Processes

In direct carbon reduction by green roofs, CO_2 is exchanged in a cyclical manner, moving among vegetation, substrate organisms, and the atmosphere (46). This occurs due to two biological processes: photosynthesis and cellular respiration (47, 48). For plants on green roofs, the two biological processes, photosynthesis and cellular respiration (also called autotrophic respiration), both take place (49). In contrast, in soil-dwelling organisms, cellular respiration, also known as heterotrophic respiration, is the only process because there are no chloroplasts (50).

CO_2 is absorbed and converted into oxygen (O_2) during photosynthesis, thereby improving atmospheric air quality and directly reducing carbon emissions (51, Figure 4). On the other hand, cellular respiration takes oxygen (O_2) and converts it into CO_2, releasing more CO_2 into the atmosphere (52, Figure 5).

However, in plants, photosynthesis usually occurs at a faster rate than cellular respiration, resulting in more CO_2 being absorbed and O_2 being released than CO_2 is emitted (53). Still, the net CO_2 uptake is the combined result of these two biological processes, which occur simultaneously on green roofs (54). The net CO_2 uptake can also be known as the net primary productivity (NEP), which can be expressed as NEP = GPP - Reco, where GPP is the gross primary productivity into the ecosystem, and CO_2 is removed from the atmosphere and converted (54). R_{eco} is the ecosystem respiration, where organisms perform autotrophic or heterotrophic respiration, converting organic carbon into CO2 and emitting it into the atmosphere (54). This equation will be used to determine the optimal material and composition for green roofs. Although several studies suggest that photosynthesis generally exceeds respiration in overall impact, resulting in net carbon uptake, this balance is highly context-dependent and can vary significantly across vegetation types, climates, and substrate conditions (53, 54). In some cases, increased microbial activity in the substrate may offset some carbon gains, suggesting that direct carbon sequestration alone may not always be sufficient to achieve net-zero targets (54).

$$NEP = GPP - R_{eco} \text{ (54)} \qquad \text{(Equation 1)}$$

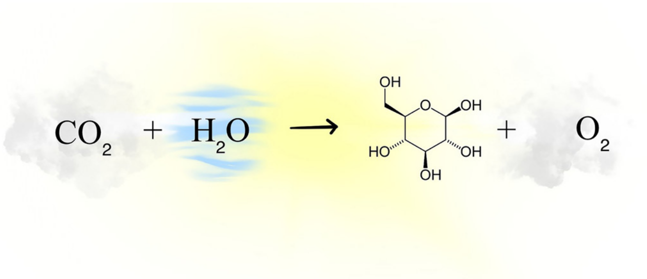

Figure 4. *Representation of the photosynthesis process, in which carbon dioxide (CO_2) and water (H_2O), using light energy, are converted into glucose ($C_6H_{12}O_6$) and oxygen (O_2) (51). This process is the primary mechanism by which vegetation on green roofs sequesters CO_2 from the atmosphere, contributing to direct carbon reduction in urban environments. Created by Author (2025).*

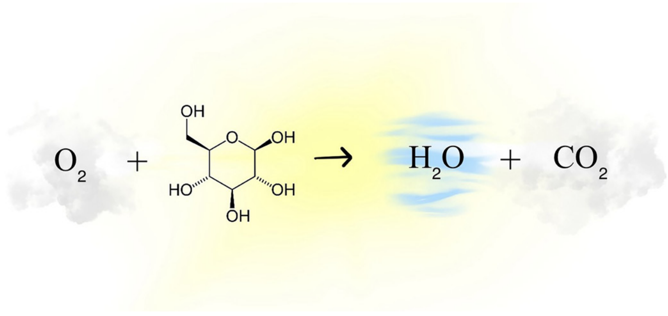

Figure 5. *Representation of the cellular respiration process, in which glucose ($C_6H_{12}O_6$) reacts with oxygen (O_2) to produce carbon dioxide (CO_2) and water (H_2O), releasing energy; in green roof systems, cellular respiration occurs in both plant tissues and soil microorganisms, contributing to CO_2 emissions (52). The net carbon uptake of green roofs depends on the balance between this process and photosynthesis, as described by net ecosystem productivity (NEP) (54). Created by Author (2025).*

Physical Processes

Delving deeper into the indirect carbon mitigation of green roofs, we will explore how they can serve as a natural insulating material and reduce energy use. These green roofs have natural insulating properties, as their vegetation and substrate have physical properties that help retain heat (41). This ability to insulate is the primary way green roofs reduce carbon emissions, since it significantly reduces the energy used in their respective buildings, especially HVAC systems (40). While many studies emphasize insulation as the primary contributor to indirect carbon reduction, the extent of energy savings varies significantly across building types and climates (23, 55). This indicates that the effectiveness of green roofs in reducing operational emissions must be evaluated in its respective context rather than assumed to be generalized universally. First off, the soil substrate layer can provide insulation due to its physical properties, particularly its low thermal conductivity and high thermal mass (23). Essentially, the substrate layer resists heat transfer and can carry a large amount of heat without significant temperature fluctuations (23). Next, regarding the vegetative layer of green roofs, vegetation also helps reduce heat gain by buildings (55). This is primarily due to its high albedo, indicating the highly reflective properties of the vegetation; shading, where the plants reduce the amount of solar radiation that reaches the actual roof's surface; and latent heat flux (energy exchange across state-of-matter changes) from the evapotranspiration process, where water transpired from plant stomata pores and is evaporated from liquid water into water vapor into the atmosphere (22, 23, 56). Green roofs usually have an albedo of between 0.7 and 0.85, while white roofs have an albedo of 0.8 (57). Because white is the most reflective color for sunlight and heat, plants and vegetation on green roofs are also highly effective at keeping surfaces cooler (58).

Green Roof Design

The design and implementation of the different components in green roofs are essential for their application to net-zero carbon (59). A green roof's performance in mitigating carbon is greatly dependent on its vegetation and substrate (59). These are critical in determining how effective green roofs are for this purpose (59). Accordingly, for optimal performance, it is essential to consider the most suitable design and materials for a green roof, especially when tailoring it to its respective structure and location (20).

Substrate

One of the most determining factors of a green roof's overall performance is substrate depth (59). To reiterate, extensive roofs, which have more shallow depths and correspondingly require less maintenance, and intensive roofs, which are deeper and require more maintenance, are the two main types of green roofs (20, 21, 60, 61).

Both types of green roofs have their own benefits and drawbacks, depending on their features (20, Table 2). Extensive roofs, ranging from 2 to 20 centimeters in depth, are easier and more cost-effective to install due to their size (20). Since they are less soil-heavy, they are also more suitable for buildings that may not be as structurally supported by a heavier roof, making them more applicable to older structures (62).

Additionally, because there is less substrate, there are correspondingly fewer soil-dwelling organisms that participate in heterotrophic respiration, releasing carbon while reducing it by decomposing organic matter into stable carbon forms (63). For the same reason, there is faster drainage with less maintenance, thus reducing the risk of waterlogging (64, 65). However, extensive green roofs have lower stormwater retention, resulting in less evapotranspiration cooling and water purification than intensive green roofs (66). It also results in reduced carbon storage in the substrate and reduced biodiversity, as vegetation is supported (67). Because of their shallow depth, extensive green roofs are also less insulating, resulting in reduced energy use (59).

On the other hand, intensive green roofs, typically more than 20 centimeters in depth, are more challenging to install and more costly, as they require more materials (20). Because they are thicker than extensive green roofs, these roofs are also significantly heavier and are typically applicable only to newer buildings with greater structural integrity and support for heavier roofs (62). For this reason, earlier buildings usually have structures that are not as strong and thus not suitable for this type of green roof (62). Still, their increased depth is beneficial because it reduces energy expenditure for HVAC systems by improving insulation and reducing thermal fluctuations (68). To continue, deeper intensive green roofs can sustain a wider variety of vegetation, from those with short roots to those with long roots (67). This, in turn, results in increased biodiversity (67). The significant volume of substrate also enables better carbon sequestration and storage of carbon and biomass (69).

Additionally, a deeper substrate means greater stormwater retention, which increases evapotranspiration

Table 2. *Comparison of extensive and intensive green roof systems based on substrate depth, associated benefits, and limitations. Extensive green roofs (2–20 cm) are lighter, more cost-effective, and suitable for existing structures but provide lower carbon storage, insulation, and environmental performance (20, 59, 62–67). In contrast, intensive green roofs (>20 cm) support greater vegetation diversity, carbon sequestration, and thermal insulation, though they require higher structural capacity, cost, and maintenance (20, 62, 67–69). This trade-off highlights the importance of substrate depth as a key design variable influencing the effectiveness of green roofs in achieving net-zero carbon goals. Created by Author (2025).*

	Extensive Green Roofs	**Intensive Green Roofs**
Substrate Depth	2 - 20 cm	> 20 cm
Benefits	● Cost-effective ● Requires less structural stability from buildings ● More applicable to older structures ● Reduced heterotrophic respiration ● Faster drainage ● Reduced waterlogging risk	● Higher stormwater retention ● Increased evapotranspiration cooling ● Increased water purification ● Increased carbon storage ● Increased biodiversity ● Increased insulation
Drawbacks	● Lower stormwater retention ● Reduced evapotranspiration cooling ● Reduced water purification ● Reduced carbon storage ● Reduced biodiversity ● Reduced insulation	● More expensive ● Requires more structural stability from buildings ● Less applicable to older structures ● Increased heterotrophic respiration ● Slower drainage ● Increased waterlogging risk

and enhances its cooling abilities (64, 65). However, the risk of waterlogging increases with a deeper substrate, requiring more frequent maintenance, such as regular irrigation (64, 65). With more space, there is more organic matter and soil-dwelling organisms in the substrate, resulting in higher carbon emissions from heterotrophic respiration and more stable carbon pools (63). Despite this, intensive green roofs are generally more effective at carbon sequestration and, therefore, more suitable for contributing to the goal of achieving net-zero carbon by 2050 (70). However, their higher structural and maintenance requirements limit their feasibility in many existing buildings (62). In contrast, extensive systems are more widely applicable but also provide lower environmental-benefit performance, illustrating a trade-off between practicality and effectiveness (62). This trade-off highlights an important gap in current research: the need to optimize hybrid systems that balance performance with feasibility. Nonetheless, those considering incorporating green roofs into their buildings must choose based on their building's structural conditions and commitment to maintaining it (62). Although these are two distinct categories of green roofs, researchers and practitioners can combine them or compromise on substrate depth to achieve the benefits of both (20).

Vegetation

Along with the substrate, the vegetation used in a green roof is essential to its overall performance (71). The range of vegetation suitable for a green roof, however, is dependent on the depth and conditions of the substrate (71). As explained previously, extensive green roofs are better suited to grasses, sedum plants, and other short plants (72). In contrast, intensive green roofs are better suited to taller plants, small shrubs, and even trees (73). In general, because larger plants have larger roots and shoots, they can store more carbon in their plant bodies. This allows them to sequester carbon more effectively than smaller plants (74).

Still, many other vegetation characteristics influence which vegetation types are best for optimal green roof performance (75, Table 3). The leaves on plants are significant in providing shade on green roofs, keeping buildings cool in hot summer months, thereby reducing the need to use HVAC systems, which waste energy (75). Similarly, a plant's leaf area index (LAI), the surface area of the leaf in relation to the total surface area, is a contributing factor in that it determines how much shade is provided as well as photosynthesis levels (76). A higher LAI would indicate greater carbon uptake via photosynthesis, increasing NPP in Eq. 1 (76).

To continue, leaf albedo and evapotranspiration are

Table 3. *Influence of key vegetation characteristics on carbon sequestration and energy performance in green roof systems. Higher leaf area index (LAI), albedo, evapotranspiration, and biodiversity enhance carbon absorption, thermal regulation, and long-term system stability by increasing photosynthetic activity, reflecting solar radiation, and promoting cooling effects (76–79). In contrast, lower values of these parameters reduce carbon sequestration efficiency and increase energy demand, particularly through greater reliance on HVAC systems (76–79). Created by Author (2025).*

	Higher	**Lower**
Leaf Area Index (LAI)	● Increased shade ● Increased carbon absorption from photosynthesis	● Reduced shade ● Reduced carbon absorption from photosynthesis
Albedo	● Higher light & heat reflection ● Reduced heat transfer ● Reduced energy consumption for HVAC	● Lower light & heat reflection ● Increased heat transfer ● Increased energy consumption for HVAC
Evapotranspiration	● Increased evaporation & transpiration of water ● Reduced energy consumption	● Reduced evaporation & transpiration of water ● Increased energy consumption
Biodiversity	● Increased stability in long-term performance	● Reduced stability in long-term performance

also essential to consider for vegetation (25). To achieve optimal cooling, green roofs should strive to maximize these benefits and strike an effective balance (25). When vegetation has a higher albedo, it essentially means that leaves can reflect more sunlight and, as a result, keep rooftop surfaces cooler (77). This ultimately helps to reduce heat transfer and increase insulation. The opposite is also true (77).

Additionally, plants with higher evapotranspiration rates can reduce the need for additional operational energy from HVAC systems (78). Higher evapotranspiration indicates evaporating and transpiring water at a faster rate (78). In terms of benefiting the surrounding environment, having a greater variety of vegetation is effective for increasing biodiversity and, in turn, ensuring the long-term stability of green roof performance (79). While these vegetation characteristics are widely recognized as important, there is limited consensus on the optimal combinations of these variables in order to maximize carbon reduction (76, 78). Most studies examine these factors in isolation, suggesting a need for more integrated research that evaluates their effects in tandem.

Concerns & Limitations

As discussed, there is incredible potential for green roofs in their application towards achieving net-zero carbon. However, to ensure the successful application of green roofs at a large scale, some concerns and limitations remain.

Economic Concerns

Regarding the cost of green roofs, they are typically between \$10 and \$30 per square foot, although this depends on the type and its materials (80). Although conventional cement roofs tend to cost less than green roofs do in terms of the initial down payment, green roofs can undoubtedly be a worthwhile investment if maintained in the long term (81). Since green roofs have excellent insulating properties and reduce energy usage, residents under green roofs can eventually realize economic benefits by spending less on energy and powering HVAC systems (81). However, much of the public remains reluctant to install green roofs due to the initial cost (81).

Structural Concerns

Most of today's buildings follow older construction styles and are less structurally sound than newer ones (62). Given the weight of green roofs, especially intensive ones, they may not be a realistic option for many existing structures (62). Additionally, the maintenance requirements of green roofs relative to regular rooftops can lead to a lack of commitment or an inability to provide the necessary level of maintenance, potentially harming the environment and, in some cases, even increasing carbon emissions (14).

Knowledge Gaps

The general public is largely unaware of green roofs, their potential environmental benefits, and proper installation and maintenance. There is still much research to be completed regarding the finer details of green roofs and their design.

CONCLUSION

Green roofs represent a practical and scalable strategy for reducing carbon emissions in the construction sector and supporting the transition toward net-zero carbon by 2050. Through both direct carbon sequestration and indirect energy reduction, green roofs can significantly mitigate embodied and operational emissions. However, their effectiveness depends heavily on design variables such as substrate depth and vegetation characteristics, which must be carefully optimized for different building contexts.

Beyond their environmental benefits, the findings of this review highlight important implications for building policy, sustainability standards, and urban design. Integrating green roofs into building codes and green certification systems could accelerate their adoption and incentivize their use in both new and existing structures. At an urban scale, widespread implementation of green roofs can contribute to climate resilience, energy efficiency, and more sustainable city planning.

Overall, advancing research, improving design optimization, and increasing policy support are critical to maximizing the role of green roofs in achieving net-zero carbon construction. With coordinated efforts across industry, government, and research, green roofs have the potential to become a standard component of sustainable building design in the coming decades.

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CONFLICT OF INTEREST

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