EUROPEAN CHAPTER
WORLD GREEN INFRASTRUCTURE NETWORK

Resilience by design? Future-proofing urban environments through green roofs

World Green Infrastructure Network
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Contents

1. Introduction

Our climate is changing. More so and in more severe steps every day. Severe heats, droughts or floods become more and more frequent every year. Last year in October, for instance, the Valencia region received a year's worth of rainfall in just 8 hours.[1] At the same time other regions in the country have record temperatures and announce a drought emergency. **Efforts to improve climate resilience and preparedness are increasing, but impacts are outpacing these efforts**. As the weather becomes more extreme, Europe needs to adapt to climate change. **This is of particular relevance to the urban environment.** As we adapt and future-proof our cities and our way of life, green infrastructure components can be a key to the solution to implement resilience by design. **The potential of nature-based solutions such as green roofs and walls often remains untapped, because their multitude of benefits that don't meet the eye go unnoticed.**

This paper aims to demonstrate to policymakers and national public authorities how green infrastructure elements, such as green roofs, have numerous benefits that can improve the way we live, e.g. by making our environment more resilient to extreme weather events, helping to absorb and reduce CO_2 emissions as well as increasing the energy efficiency of buildings. **It aims to shed light on the numerous technical advantages of green roofs**, providing national stakeholders with the necessary knowledge to make informed decisions as they implement and integrate EU legislation in their respective Member States.

This paper is based on desk research in conjunction with experience from World Green Infrastructure partners. The paper aims to outline the structural characteristics and advantages of green roofs by outlining specific technical benefits, before shedding light on the return of investment and other co-benefits and opportunities to improve urban environments. The third part of the paper presents the background of the legislative framework proposed at EU level.

2. Making urban environments future-proof and resilient: showcasing the benefits of Green Roofs

2.1 Stormwater Management

Green roofs act like sponges, soaking up rainwater. In case of extreme weather events, they significantly reduce and delay runoff, thus preventing large quantities of water from being released into the public sewer system. There is a large variety of empirical data on the capacity to capture rainwater on green roofs, which can be attributed to the specific roof system characteristics (Joshi 2021: 7ff.). **The more retention mechanisms are added together - like green roofs - the less water will run off during heavy rainstorms[2][3] into the city's sewer system.**

Thus, green roofs can significantly reduce the size of or even supersede traditional concrete stormwater management structures (such as combined and separate sewer systems), which are highly carbon-intensive to produce (Estokova 2013; Ali 2013).

Thanks to these benefits, green infrastructure effectively reduces CO_2 emissions at water treatment plants. **Moreover, studies have shown that runoff filtered by green roofs requires minimal treatment** since green roofs can serve as filters as well, reducing the content of pollutants in it (Akther

[1] https://wmo.int/media/news/devastating-rainfall-hits-spain-yet-another-flood-related-disaster
[2] Standard extensive green roofs reduce the stormwater volume on average by 58 % (mean of nearly 30 studies), intensive green roofs even by 79 % (mean of 3 studies) compared to unvegetated roofs (Manso et al., 2021).
[3] The green roofs delayed the start of runoff by average of 5.7 h (Berndtsson 2010). For some small storms, the time of peak flow rate was delayed by up to several hours. In general, the green roof delayed the start of runoff and extended the time period of low residual flows that existed at the end of a storm (Bliss et al. 2009).

et al. 2018: 1, 9). The first flush of rainwater after a long dry period, results in less pollutants when drained and filtered via a green roof (Zeng et al. 2019).

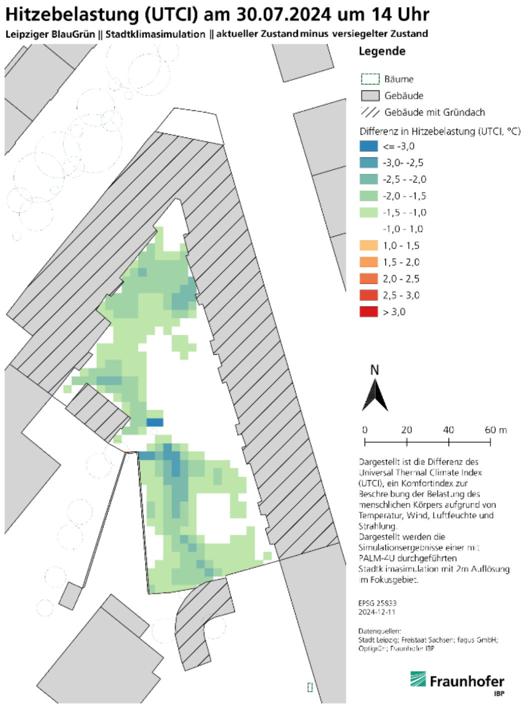
There are three measurement methods to calculate the water performance of a green roof: i) water storage capacity, ii) C-value and iii) yearly outflow rate. Today's practice is mostly focused on short-term performance measure of i) water storage capacity and ii) C-Value. Both performance measures can be easily increased through system height. However, the drawback of this practice is that it adds system weight and requires additional static performance of the building. Alternatively, iii) the yearly outflow rate indicates the percentage of rain which is not passed into the sewage system and the amount of retained water that is used for cooling and plant growth.

The use of smart retention roofs enables rainwater to be efficiently utilized as a resource. With the right technical systems, it can be used for irrigating green roofs or flushing toilets, for example. The smart system optimally manages the amount of water that can be stored on the roof. Looking toward the future, where periods of (drinking) water scarcity will become more frequent, this approach provides an opportunity to process rainwater as a resource rather than treating it as waste.

Green roofs have significant water retention capacity and thus play a key role in reducing the demand and costs of municipal water systems and improving the overall efficiency of water use in our buildings.

2.2 Cooling effect

2.2.1 Reduction of Urban Heat Island Effect



In cities, **green roofs can be very beneficial as they reduce the surface temperature of the rooftop leading to a decrease in the local air temperature.** This is especially important for cities facing a severe urban heat island effect.

Research states that green roofs can reduce roof surface temperatures by up to 22-28°C compared to traditional roofs and add to the summer comfort of inhabitants. This reduces ambient air temperatures by approximately 1-3°C in urban areas (Smalls Mantey et al. 2021; Santamouris 2014; N.Y. US EPA). Another study from Germany in Neubrandenburg showed, that the cooling effect of green roofs can reduce the temperature after rainfalls by 5°C (Jamei 2021: 8). The overall reduction of the urban temperature throughout different climate zones was found to be on average 1.34°C, with an average minimum of 1.00 °C and an average maximum of 2.30 °C (Manso et al. 2021).

A greened courtyard equipped with a green roof system can reduce the heat stress significantly compared to a fully sealed courtyard (Berger & Mohri 2025).

2.2.2 Combining green roofs with Solar PVs to boost electricity production

Green roofs can work in synergy with solar panels (so-called solar PVs[4]) by **creating a cooler environment that can improve the efficiency of photovoltaic cells.** The green roof has a natural way of cooling the solar panels with plants via evapotranspiration (Zheng et al. 2020: 1). Research conducted in Sydney, Australia, comparing a traditional roof with PV installation and bio-solar roof of a similar size[5] over an 8-month monitoring period, reveals that solar panels in combination with green roof increased the efficiency of PV installations by 3.6% - equivalent to 9.5 MWh of additional energy output (Irga, P. et al. 2021: 79). Numerous studies point to the potential of bio-solar roofs with an increased efficiency of the PV between 0.8% and 4%,[6] thereby increasing the production of renewable energy, and reducing reliance on fossil fuels and CO_2 emissions (Alonso-Marroquin & Qadir 2023: 2, Ogaili & Sailor 2016, Nagengast 2012).

The green roof can also be used as ballast for the solar panels, thus avoiding any perforations to the waterproofing membrane that would otherwise have been needed for the solar panel installation. Furthermore, bio-solar installations provide additional benefits, one of them being a positive impact on biodiversity. By providing shade to some parts of the roof, solar panels create a mosaic habitat, which allows a richer diversity on the roofs, for example, protecting certain species (plants and insects) from long sun exposure and bad weather conditions (Schindler et al. 2018). As mentioned by Bousselot et al. (2017), this way plants survive droughts easier and cover the area better, because shading helps conserve water in the soil and thus helps with stormwater capture.

The temperature reduction is not only crucial for cooling the building itself but also for enhancing the efficiency of rooftop devices such as coolers, generators, and photovoltaic systems, which perform more efficiently in lower temperatures. This becomes even more pertinent, as widespread/large-scale rooftop PV panel installations in urban environments can affect urban microclimates by increasing the temperature in cities during the day up to 1.9°, as observed in certain cities (Khan et al. 2024).

This impact becomes even more relevant if we consider that urban areas lack more and more available building land, which leads to storage demand being outsourced to rooftops, especially for those buildings housing technologies requiring cooling equipment to function. The rooftops of data centers have for instance a high density of coolers, fans, generators etc. Every equipment placed on the rooftop is exposed to the sun and higher temperatures, especially in hot periods of the year, which leads to a decrease of their efficiency. Green roofs create a cooler environment on the building and can thus protect and enhance the efficiency of building system equipment at the same time.

Not only does the combination with a green roof therefore help increase efficiency of PV panels, but it furthermore contributes to decreasing the urban heat island effect in cities due to its natural cooling effect on PV panels and other technologies e.g. coolers, generators, fans that emit heat during their operation.

2.3 Biodiversity

Particularly in urban areas, where there is increasing demand for housing and infrastructure, more and more ground area is being sealed. To cope with soil sealing and improve living conditions in urban environments, urban design tools integrating green infrastructure elements can have a positive impact. In terms of biodiversity, **green roofs and walls are the green stepping stones needed in cities to**

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[4] Photovoltaic systems are devices that convert sunlight directly into electricity, see the WGIN Solar Green Roofs Resource Guide.

[5] Both roofs, the green and conventional roofs were 1863 m2 with approx. 600 m2 PV panel coverage (Irga et.a. 2021: 10).

[6] Particularly vertical PV panels combined with a green roof bring optimal use of both solutions.

connect green spaces and increase habitat. Green roofs in urban environments help maintain and increase biodiversity and **play an important role in supporting pollinators**, which are essential for the persistence of plants in cities and beyond (European Environment Agency 2011; MacIvor et al. 2014: 1). Without pollinators, there would be significantly fewer plants and their multiplication in the urban context would be in danger. Certain green roof characteristics can also positively influence biodiversity: A study from the Netherlands showed that increased substrate depth on a green roof (up to 20 cm) and shading improve plant species richness and diversity (van der Kolk et. al: 2020). Higher diversity of plants brings higher variety of avian communities, insects, beetles or even nesting birds (Oberndofer et. al. 2007: 829). Overall, green roofs provide both a habitat and a food source for pollinators, fostering a sustainable urban ecosystem.

2.4 Carbon Sequestration

Green infrastructure elements furthermore help sequester carbon from the atmosphere. **Plants on green roofs absorb CO_2 from the atmosphere and use it for photosynthesis, converting it into oxygen and biomass**. This process directly removes CO_2 from the air (Cai et al. 2019: 2433). Research states that extensive green roofs with an optimal plant composition can absorb between 1.2 kg of CO_2 per square meter annually (Benz et al. 2018: 11) to 1.79 kg of CO_2 per m^2 per year and can release 1.3 kg of O_2 per m^2 per year (Cai 2019: 2443).

2.5 Fire Safety

Fire safety on rooftops, particularly those with PV installations, is a critical subject of research.

Incidents e.g. connected to overheating of PV panels can be avoided by the implementation of non-combustible (Broof) certified green roof systems. By opting for such certified green roofs, the need for traditional, heavy non-combustible roofing materials can be avoided (e.g., concrete tiles, gravel) that typically have a higher embodied carbon footprint (Estokova 2013). Broof certified green roof systems, for instance, provide an eco-friendly alternative that maintains fire resistance while promoting sustainability and reducing the overall carbon footprint of the building. This aspect will become more relevant as Member States are transposing the Energy Performance of Buildings Directive, more specifically, the obligations for life-cycle global warming potential for large, new buildings.

2.6 Extended Roof Lifespan

Traditional roofs suffer exposure to UV radiation, extreme temperature differences and weather events as well as mechanical damage through hailstorms, dropped tools, bird droppings and nesting (Rapid Roofing 2024). **Extreme temperatures and UV radiation impact the roofs and can lead to reduced thermal stress on the roofing materials**, which can cause expansion and contraction cycles that lead to cracks and deterioration of the roof. This reduces the overall lifespan and performance, such as the waterproofing over time, causing necessary earlier replacements and repairs (Blackhurst 2010: 136, Manso 2021: 5).

Traditional flat roof lifespan ranges approximately from 10 to 20 years, depending on the material used (Manso et al. 2018: 5; Ragan 2022). In contrast a green roof lifespan can reach even over 50 years (Manso et al. 2018: 5). The cost of flat roof repairs in Europe can vary depending on several factors, such as the type of repair needed, the materials used, the size of the roof and its location. A study conducted in Portugal by Cirreia Marrana et. al. (2017) examined all the costs associated with the lifecycle of flat roofs in economic and energetic terms. For instance, the net present value of a flat roof accessible to people ranges from 181.08 EUR/m2[7] to 256.95 EUR/m2[8]. The price includes acquisition, transportation, execution, energy, maintenance, and end-of-life processing costs of the roof (Correia Marrana et al. 2017: 6). **Green roofs protect the waterproofing from harmful events which results in fewer roof replacements and repairs over time**. Less frequent repairs and replacements lead to lower CO_2 emissions associated with manufacturing, transporting, and installing new roofing materials (Blackhurst 2010: 136).

Figure: Hailstorm damage on a roof. Source Rapid Roofing 2024 (https://rapidroofing.com/blog/identifying-and-repairing-hail-damage-to-roof-a-homeowners-guide/).

2.7 Return of Investment

Installing a green roof is a financial investment that offers numerous benefits. To calculate the return on investment (ROI), several costs and savings must be considered, including installation and maintenance expenses, as well as benefits such as energy savings, reduction of fees, increased property value and reduction of CO_2 emissions in stormwater management among others. However, not all benefits are easily quantifiable in monetary terms, as some, like enhanced biodiversity or urban cooling, are broad societal advantages. Amongst the most direct financial benefits is the saving of the stormwater fee. Local governments in countries such as Australia, Brazil, Canada, Ecuador, France, Germany, Poland, South Africa and the United States (USA) introduced a stormwater fee to enhance flood control and fund their stormwater management obligations (Tasca 2018: 287). In Poland, for instance, the "rain tax"[9] mandates a fee for water services when natural land retention is reduced. It applies to properties over 3500 m² where construction or permanent structures decrease retention by

[7] The price refers to following roof layers: "an inverted roof, made of lightweight concrete with EPS granules as shaping layer, thermoplastic PVC membrane for waterproofing, and external protection consisting of precast concrete tiles with XPS thermal insulation boards (6 cm thick)" (Correia Marrana et al. 2017: 6).
[8] The price refers to following roof layers: "expanded clay with a separating layer and traditional screed mortar as the shaping layer, ICB thermal insulation (8 cm thick), TPO thermoplastic waterproofing, and protection with ceramic tiles" (Correia Marrana et al. 2017: 6).

[9] Article 269, Section 1, Point 1 of the Water Law Act dated July 20, 2017.

covering more than 70% of the land with non-permeable surfaces, in areas not connected to open or closed sewage systems (Act Water Law 2017).

As described in paragraph 2.6, all costs associated with the lifecycle of flat roofs can range from 181 EUR/m2 to 257 EUR/m2 (Correia Marrana et al. 2017: 6). If a roof is to be exchanged every 20 years, it's a cost of 12.85 EUR per year per m2 (256 EUR/20 years). Assuming a roof is supposed to be replaced every 50 years, it will lead to a cost of 5.14 EUR annually per m2 (256 EUR/50 years). **Thus, this leads to a saving of 7,71 EUR per year per m2** (12.85 EUR - 5.14 EUR = 7.71 EUR). **The longer lifespan of a roof leads to a significant reduction in replacement material and associated costs to the owner, therefore realizing a quicker return on investment for a green roof.**

Municipalities investing in green roofing can take advantage of financial incentives, grants, subsidies, and tax credits to reduce initial investment costs. For example, Hamburg, Germany, implemented its Green Roof Strategy in 2015, allocating EUR 3 million to encourage green roof construction in the city (Hamburg 2024, Clar and Steurer 2021: 2).[10] Additionally, an experiment conducted in Wuxi, China, studied the thermal performance of extensive green roofs and found that a green roof can save 11.53 kWh of electricity, absorb 1.79 kg of CO_2, and release 1.3 kg of O2 per square meter per year (Cai 2019: 2443). The same study calculated the ROI within 10 years, assuming the quantitative ecological benefit of a green roof would be USD 3.37 per square meter annually (ibid.). Another study conducted by Kuronuma et al. concluded that the CO2 payback time of extensive green roofs in Japan was between 5.8 and 15.9 years (2018:1).

Table 1 below presents a calculation and a value of ecological benefits for green roofs in Germany. The price estimations are based on the prices of electricity and wastewater treatment in Germany (2024).

Table 1: Overview: Value of ecological benefits for green roof

Evaluation index		Quantity value per m2 per year	Benefit value per m2 per year (in EUR)1
Carbon sequestration and oxygen release	Absorb CO2 (kg/m2)1	1.20 kg/m2	**0.054 EUR/m2**
	Release O2 (kg/m2)2	0.9 kg/m2	**0.240 EUR/m²**
Cooling effect / Energy savings	Electricity savings (kWh/m2)3	42.29 kWh/m2	**4.876 EUR/m²**
	Reduced CO2 emissions (kg/m2)4	4.484 kg/m²	**0.292 EUR/m2**
Stormwater management	Water conservation (l/m2)5	50 l/m2 (0.05 m3/m2)	**0.090 EUR/m²**
	Reduced carbon emissions (kg/m2)6	0.04125 kg CO2/m²	**0.003 EUR/m2**
SUM Reduced CO2 emissions:		5.73 kg CO2/m2	
SUM Reduced costs (Value of benefits)			**5.555 EUR/m2**

1) Calculation based on following 2023 data: DE ETS 45.00 EUR/ton & 0.045 EUR/kg (Mendgen 2024).
2) Calculation based on following 2023 data: 2023 DE oxygen price: 0.267 EUR/m3 (IndexBox 2024).
3) Calculation based on following 2023 data: average DE electricity price for the average end user price 42.29 kWh/m2 (Destatis 2023).
4) Calculation based on following 2023 data: average DE electricity grid emissions: 0.380 kgCO2/kWh (UmweltBundgesamt 2024).
5) Calculation based on following data; DE surface water treatment price: 1.797 EUR/m2 (Berliner Wasserbetriebe 2023).
6) Calculation based on following data: CO2 emissions for wastewater treatment: 0.51 and 1.14 kg/CO2 /m3/ average: 0.825 kg/CO2/m3 (Gupta, Lee et al. 2024).

10 Numerous other cities/regions in Germany have funding schemes for green infrastructure in place. Additional information available here: BuGG_Listen_und_Grafiken_01-2024_Kommunale_Foerderprogramme_Dachbegruenung.pdf

2.8 Mental & physical health benefits

Green roofs have demonstrated notable health benefits, particularly in psychological well-being and cognitive performance. A study showed that viewing a green roof for just 40 seconds improved attention, with participants making fewer mistakes and responding faster compared to those who saw a bare rooftop—highlighting the restorative potential of even brief exposure (Lee et al. 2015). Another study found that people preferred green roofs with taller and more diverse vegetation, suggesting that aesthetic qualities also play a role in psychological benefits (Lee et al. 2014).

Further research supports the broader health value of green spaces. For example, participants who viewed a modular green roof during work breaks reported improved mood, lower stress, and better cognitive coherence, though no direct performance comparison was made (Lee et al. 2018).

Beyond rooftops, Mitchell and Popham (2008) found lower mortality rates in areas with more green space, and Ulrich (1984) showed that patients recovered better when viewing trees instead of walls. Similarly, De Vries et al. (2003) linked a higher percentage of nearby green space to fewer symptoms and better self-rated health, supported by findings from Maas (2009). **Together, these studies suggest that green roofs, especially when designed with visual appeal and accessibility in mind, can meaningfully support mental health and well-being in cities**, complementing the well-established benefits of general green space exposure and making cities more livable.

3. EU Legislative Framework

There are a number of EU legislations and political strategies that explicitly or implicitly advance the usages of green infrastructure solutions. Below listed are relevant legislative developments from the previous legislative cycle, along with relevant upcoming initiatives that could further the integration of nature-based solutions and thereby make urban environments more resilient.

3.1 Energy Performance of Buildings Directive[11]

The Energy Performance of Buildings Directive (EPBD) is the EU's key legislation for buildings, aiming to decarbonize the built environment and increasing the energy performance of our building stock in the EU. One key provision of the revised EPBD is its solar mandate, which promotes the deployment of solar technology on buildings all over the EU. Due to its energy efficiency performance and the cooling effect, green roofs can increase the performance of solar panels as compared to gravel rooftops – transforming them into so-called bio-solar roofs. (Shafique et al. p. 488). Although the solar mandate of the EPBD does not explicitly call for bio-solar roofs to be installed, it mentions green roofs for the first time as one of the factors to be considered when assessing the potential of solar energy installations (see Art. 10, para 4 below). According to this provision, EU Member States are to take green roofs and structural integrities in mind when fulfilling their new obligation to gradually install solar panels on public and private buildings across the EU. While it does not explicitly call for bio-solar roofs to be installed in every case, this requirement will drive awareness of the additional benefits they can provide.

Art. 10, paragraph 4:
"*Member states shall (…) in accordance with the assessed technical and economic potential of the* ***solar energy installations*** *and the characteristics of the buildings covered by this obligation. Member States shall also take into account structural integrity****, green roofs,*** *and attic and roof insulation, where appropriate*."
(Energy Performance of Buildings Directive 2024).

[11] Directive (EU) 2024/1275

3.2 Urban Wastewater Treatment Directive (UWWTD)[12]

The Urban Wastewater Treatment Directive aims to protect the environment from adverse effects of wastewater discharges from urban sources and specific industries and thus, supported by green and blue infrastructures, plays a vital role for sustainable urban development. The directive safeguards the environment from the negative impacts of the discharges from urban waste, leading to clean water for ecosystems and human use. The recast of the UWWTD aims to align the legislation with the EU's policy objectives on climate action, circular economy and pollution reduction and is one of the key initiatives under the EU's zero pollution action plan for air, water and soil. Especially for improved urban wastewater treatment, green and blue infrastructure, such as green roofs, green walls, and water bodies, can significantly improve the efficiency of wastewater treatment due to natural filtration, stormwater management, and restoration of urban biodiversity. Such infrastructures do not only target wastewater treatment but play a crucial role in increasing urban resilience, adapting to new climate conditions, and overall improve the urban living environment (WGIN EU chapter 2024). This directive is binding for all EU member states and will need to be transposed into national law.

3.3 Nature Restoration Law[13]

The Nature Restoration Law (NRL) aims to restore the EU's land and sea areas as well as overall biodiversity. To restore urban ecosystems, the NRL sets up specific targets, thereby also acknowledging the role of green infrastructure, green roofs and walls to adapt to climate change and make buildings and the urban environment more resilient overall. The NRL thus links biodiversity and improved urban ecosystems with green infrastructure. The NRL requires Member States to stop the loss of green spaces by 2030 and to achieve an increasing trend of green spaces, which also extends to greening buildings and infrastructure, from January 2031 onwards. The way Member States put this into practice is thus an important sphere to watch for the development of green infrastructures. Setting specific targets to bring nature back into cities is a unique element that the NRL introduces, which cannot be found in other EU regulations, turning the NRL into a breakthrough for restoring nature in cities.

> Article 5:
>
> "*Integrated urban wastewater management plans shall include at least the elements set out in Annex V **and prioritize green and blue infrastructure solutions wherever possible***."
>
> Annex V, 4 a)
>
> "When assessing which measures to be taken […] Member States shall ensure that their competent authorities consider at least the following:
>
> (a) firstly, preventive measures aiming at avoiding the entry of unpolluted rain waters into collecting systems, **including measures promoting natural water retention or rainwater harvesting, and measures increasing green and blue spaces in urban areas** in order to reduce storm water overflows […]"

[12] Directive (EU) 2024/3019
[13] Regulation (EU) 2024/1991

Art. 8 Restoration of urban ecosystems

1. By 31 December 2030, **Member States shall ensure that there is no net loss in the total national area of urban green space and of urban tree canopy cover in urban ecosystem areas**, determined in accordance with Article 14(4), compared to 2024.

….

2. From 1 January 2031, **Member States shall *achieve an increasing trend* in the total national area of urban green space, *including through integration of urban green space into buildings and infrastructure,*** *in urban ecosystem areas, determined in accordance with Article 14(4), measured every six years from 1 January 2031, until a satisfactory level identified in accordance with Article 14(5)[4] is reached*.

3.4 Biodiversity Strategy for 2030: Bringing Nature Back Into our Lives[14]

The Biodiversity Strategy for 2030 is the EU's long-term plan to protect nature and reverse the degradation of ecosystems. The strategy also specifically addresses the greening of urban and peri-urban areas. The strategy aims to bring nature back into cities and towns, to put people at the core of the process of dealing with nature emergencies. In this regard, the Commission invited European towns with a population of over 20,000 to develop comprehensive Urban Greening Plans over the course of 2021. These should include proposals for biodiverse, accessible urban forests, parks, and gardens; urban farms; green roofs; green walls; tree-lined streets; urban meadows; and hedges (WGIN EU chapter 2024). While a call for action to cities and towns is a good initiative and a targeted focus on green infrastructure is an important aspect, it needs to be noted that a strategy is a non-binding instrument. What is of relevance, however, is the output, i.e., the specific legislation stemming from the strategy, which for example can be seen in the Soil Monitoring Law or the Nature Restoration Law.

Paragraph 2.2.8.:
"*Green urban spaces, from parks and gardens to green roofs and urban farms, provide a wide range of benefits for people. They also provide opportunities for businesses and a refuge for nature. They reduce air, water and noise pollution, provide protection from flooding, droughts and heat waves, and maintain a connection between humans and nature.*" (European Commission 2020).

3.5 European Parliament's Resolution on the Revised Pollinators Initiative[15]

The European Parliament's resolution on the Revised Pollinators Initiative noted and emphasized that green roofs should be part of urban greening approaches. Green roofs are clearly an effective way to provide critical habitats for pollinators, while also enhancing urban biodiversity, and linking ecological

Paragraph 29:
"*Emphasizes the benefits of green roofs, vertical gardens and sustainable urban agriculture practices in providing habitats for pollinators and contributing to urban resilience and improved quality of life for city residents*;" (European Parliament 2023).

[14] COM/2020/380 final
[15] 2023/2720(RSP)

corridors across the city. In doing so, the town reverses the declining trend of pollinators, improves air quality, and mitigates heat islands in the towns while supporting biodiversity. These efforts also align with the broader objectives of increasing climate resilience and improving sustainability through nature-based solutions (WGIN EU chapter 2024). Of note is the fact that both the Resolution by the European Parliament on the topic and the initiative itself are non-binding. Yet they go hand in hand with the Biodiversity Strategy and the Nature Restoration Law and establish a link with green infrastructure. The more concrete the link between green solutions and the objectives of the pollinators initiative are, the more likely we will see binding legislation being proposed.

3.6 EU Strategy on Adaptation to Climate Change[16]

The EU Strategy on Adaptation to Climate Change sets out how the EU can adapt to the impacts of climate change and become climate resilient by 2050. The strategy clearly links green infrastructure as an effective solution to enhance climate resilience and achieve the goals of the Green Deal. These green infrastructures are promoted as 'no-regret' options, providing multiple benefits regardless of the severity of climate change impacts. Green roofs and walls help make urban infrastructure more climate-proof by reducing heat, managing stormwater, and supporting biodiversity. In short, green infrastructure should be playing a bigger role in infrastructure planning for the urban environment going forward. Of note is the fact that while a connection is crucial, the strategy itself remains a non-binding instrument, but could provide the groundwork for future binding initiatives (WGIN EU chapter 2024), such as the announced European Climate Adaptation Plan, planned for Q1 2026.

> Paragraph 11:
> "*Implementing nature-based solutions (NBS) on a larger scale would significantly enhance climate resilience and contribute to multiple objectives of the European Green Deal. Blue-green infrastructures, such as urban green spaces,* ***green roofs, and green walls****, offer multipurpose, "no regret" solutions.*" (European Commission 2021).

3.7 European Water Resilience Strategy[17]

The first strategy of the new European Commission's mandate (2024-2029) related to green infrastructures is the European Water Resilience Strategy, published on 4 June 2025. The strategy aims at ensuring European Commission will thus propose a European Water Resilience Strategy to water sources are properly managed, scarcity is addressed and improve the EU competitive edge of the water industry by boosting circular economy. Among others, the strategy stresses the importance of promoting the concept of "sponge cities" in urban areas with nature-based solutions, and, in that context announces that it will develop a "Sponge Facility". The strategy also puts forwards a new Water Programme by the European Investment Bank with over EUR 15 billion in planned financing during 2025-2027 for projects linked to water resilience, including nature-based solutions. Finally, the Water Resilience Strategy sets as a target for the EU to aim to enhance water efficiency by at least 10% by 2030, and, to support Member States in doing so, publishes a recommendation for a Water Efficiency First principle.

3.8 European Climate Adaptation Plan (Upcoming)

In the political guidelines for the new mandate, the European Commission identified the impact of climate change as one of the greatest risks to European security. Extreme weather events continue to

[16] COM/2021/82 final

[17] COM(2025) 280 final

ravage ever larger areas of Europe through floods, fires and droughts, throughout the year across the entire Union. As our climate warms faster, adaptation to new circumstances requires urgent action at EU level to ensure the best possible preparedness. This becomes especially urgent, as climate change impacts are outpacing our efforts of preparedness. Mapping the risks and preparedness needs for infrastructure, energy, water, food and land in cities and rural areas, as well as the need for data and early warning systems, will be key parts of the European Climate Adaptation Plan. This Plan is scheduled to be delivered in Q1 of 2026. Nature will be affected by climate risks, but nature also holds the keys to help fix the problem. Nature-based solutions, such as green roofs and walls in cities, can thus be a crucial element and part of the solution to help urban environments adapt to more extreme climate conditions.

4. Conclusion

As climates are getting hotter, cities more populous, and weather events more extreme, urban environments face more and more pressure points on various levels that require cities to look for adaptation strategies to cope with these changing circumstances. One way of adapting urban environments is by integrating resilience into the structure and design of cities. This can be done by integrating nature-based solutions such as green roofs and walls into cities, turning urban environments into safe havens and ensuring cities are future-proof and resilient to changing climate conditions.

Green infrastructure elements, such as green roofs and walls, can bring natural elements back into cities, serving as green lungs next to parks and local greenery and provide green oases to residents. But green roofs contain many more benefits than meet the eye: Green roofs are not just an innovative urban feature, they are an essential solution for sustainable cities, offering exceptional benefits in climate change adaptation, energy efficiency, stormwater management, biodiversity conservation and overall environmental well-being, while at the same time increasing the lifespan of roofs. Combining all these aspects together, green roofs are key to increase the **resilience of urban environments**.

Within the EU legislative framework, many directives and strategies are already considering green roofs as a solution. However, these legislations still need to be transposed by national governments and new ones need to be adopted to truly unlock the deployment of green infrastructures on the ground. As the World Green Infrastructure Network, we underscore the following recommendations to untap the full potential of green roofs and make our urban environments more resilient:

- **Real performance**: Green roofs need to be measured on all their performance indicators as they maximize the CO_2 absorption and increase the cooling effect of cities. Increasing height and weight of the green roofs is not equivalent to the actual performance of the green roof parameters (e.g. water storage; C-value). Therefore, a full and transparent green roof standard is needed, including consideration of a yearly water outflow percentage. This should have a positive influence towards CO_2 certificates trading system via the Voluntary Carbon Market.
- **Maximize building performance**: Increasing the life span of roofs, increasing the output of solar panels or cooling building equipment on roofs – green roofs support and protect infrastructure of buildings. It needs to be mandatory to include green roofs always as a solution to increase the overall building performance – rather than *an optional requirement.*
- **Making our cities more resilient:** Green infrastructure has the potential to reduce urban heat island effects, adapt to changing climate conditions and improve urban ecosystems. On top of that, green roofs allow cities to cope better with extreme heat and floods, by improving the stormwater management capacity. Member States should thus invest in greening urban spaces to allow for improved living conditions in cities – ambitious implementation of legislation such as the Nature Restoration Law, the Urban Wastewater Treatment Directive and the Energy Performance of Buildings Directive is key. At the same time, new initiatives must be proposed by the European Commission, namely in the European Climate Adaptation Plan, to accelerate the deployment of these solutions to increase the resilience of Europe's built environment.

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About Us

WGIN is a collaborative global network promoting the integration of green infrastructure in urban planning that unites 21 National Associations. In 2019, WGIN set up a European Chapter, supported by four corporate members, to raise awareness among EU policymakers about the multiple benefits of green infrastructure. The WGIN EU Chapter organises every year the European Green Infrastructure Day, which is an annual policy conference, gathering EU policymakers, green roof industry leaders, experts and NGOs, dedicated to exploring the state of affairs of urban green infrastructure in the European Union and how to foster their uptake.

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