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Towards a Regenerative and Climate-Resilient Built Environment: Greening Lessons from European Cities

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Abstract: Nature-Based Solutions offer a concrete opportunity to integrate nature into cities and strengthen their resilience, in response to global challenges related to climate change, biodiversity loss, and water management, which are exacerbated by urban expansion and its impacts on the built environment. This study aims to analyze various European policies and urban greening practices, considering not only some European Union member states but also other cities geographically located in Europe. The main goal is to explore how these solutions are used in various European cities to address environmental challenges and improve urban quality of life. The study highlights the growing role of greening strategies in EU urban policies as key tools to tackle global challenges. It finds that green interventions—such as green roofs, façades, and green urban spaces—offer multifunctional benefits, but their effectiveness relies on integrated planning, strong public–private cooperation, and active community involvement. Key challenges include the limited scalability of these solutions in dense or economically constrained areas and the need for long-term financial and institutional support. Overall, the study highlights that greening is not merely aesthetic but central to building regenerative and climate-resilient cities.

Keywords: urban resilience; green infrastructure; nature-based solutions; best practices; regenerative design

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1. Introduction

In recent decades, urbanization has reached unprecedented levels. More than 70% of the world's population now lives in urban areas [1]. This phenomenon has determined an exponential growth in building density, accompanied by a progressive waterproofing of the soil and the reduction in natural surfaces [2]. These changes have a significant impact on the ecological balance and affect the ability of urban systems to adapt to the effects of climate change. Increasingly intense heat waves, extreme weather events, the loss of biodiversity, and an increase in hydrogeological risks are just some of the main challenges facing today's cities. This scenario highlights the need to rethink urban planning and management strategies to promote greater resilience of the built environment and support solutions that combine environmental sustainability and social well-being.

Despite the growing attention on the sustainable management of the built environment, there is still a lack of integrated approaches that consider the factors needed to make the sustainability of the built environment effective and concrete; policies and strategies often remain only theoretical approaches with few practical applications. To effectively implement and evaluate urban sustainability, for example, it is necessary to conduct a complex and integrated analysis of its morphology, paying particular attention to the various levels that compose it, since each of them exerts a specific and interconnected influence on the sustainability parameters [3]. An innovative response to these problems is represented by Nature-Based Solutions (NbSs), a set of strategies and interventions that are based on the use of natural processes and functions to address environmental and climate challenges [4]. According to the European Commission's definition, NbSs are "nature-inspired and nature-supported, economically sustainable solutions that deliver environmental, social and economic benefits and contribute to strengthening the resilience of ecosystems and communities" [5].

The effectiveness of NbSs strongly depends on the ability to integrate them with the existing urban morphology; therefore, the design and implementation of NbSs must take into account the physical and spatial characteristics of the city to promote urban well-being and health.

Implementing greening strategies in a compact and densely built urban fabric, such as that of a historic city center, presents very different challenges compared to applying the same solutions in neighborhoods with lower building density and fewer physical constraints. Key examples of NbSs include green and blue infrastructure such as urban parks, green roofs and walls, rain gardens, artificial wetlands, and sustainable drainage systems. These measures not only improve the adaptability of cities to the effects of climate change but also provide numerous co-benefits, including improving air quality, regulating the urban microclimate, and enhancing the aesthetic and recreational value of public spaces. The European Union (EU) has recognized the crucial role of NbSs in the green transition and is promoting their uptake through several strategic initiatives, including the European Green Deal and the Horizon Europe program. However, despite the growing evidence of its benefits, large-scale implementation of NbSs still faces several obstacles, including regulatory fragmentation, difficult access to funding and the need for greater coordination between different levels of government. The lack of common standards and effective evaluation methods is another obstacle to the dissemination and replicability of NbSs together with the lack or the reduced diffusion of reliable guidelines and implementation frameworks [6].

The aim of this study is to analyze current European policies to promote greening strategies in cities in order to strengthen their resilience and promote the transition to a more sustainable urban model. Through a detailed analysis of plans, urban strategies, and specific case studies, the solutions adopted to address key environmental challenges such as hydrogeological risks, heat waves, and biodiversity loss are examined. The research, carried out in different climatic contexts, aims to identify the most effective and replicable best practices and to highlight the degree of alignment with European goals, in particular the Sustainable Development Goals (SDGs) of Agenda 2030 [7].

Finally, from a regenerative design perspective, the work aims to propose a reflection on the opportunities that NbSs offer to rethink cities and promote urban development models that not only reduce environmental impact but are also capable of creating ecological and social benefits over time.

2. Materials and Methods

This study is based on a critical review approach [8], critically analyzing the main European policies, plans, initiatives, and measures to outline the current state of greening strategies implemented across Europe to address climate change and enhance urban resilience. The analysis is not limited to EU member states but also includes countries that are geographically part of Europe.

The analytical research framework is structured into 3 main areas (Figure 1):

i. European policy framework that provides an overview of the European Union's strategies and programs in the field of NbSs and climate adaptation.
ii. Urban–territorial plans and strategies focusing on key European cities to identify intervention models and emerging trends.
iii. Emblematic case studies selected based on their relevance to the plans analyzed in the previous phase, to further investigate the effectiveness and replicability of the solutions adopted.

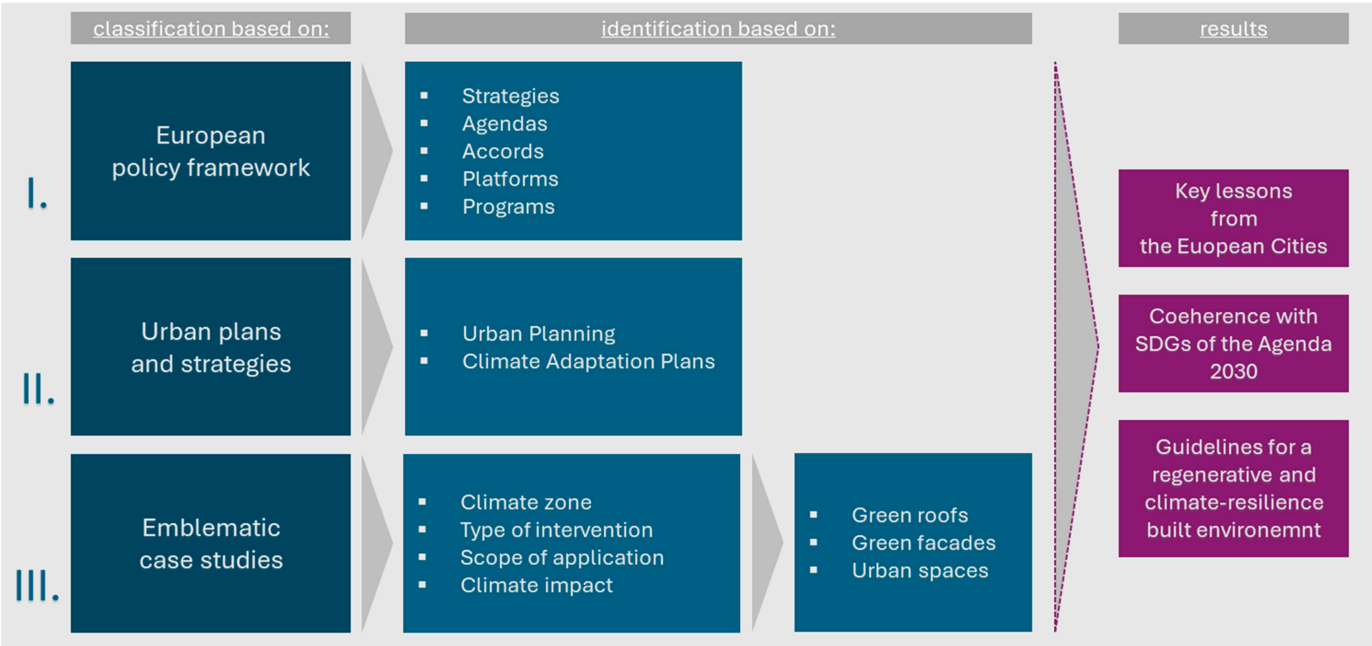

Figure 1. Research framework.

The data analyzed for each of the three research areas were gathered through an in-depth web-based investigation. Specifically, the official websites of the European Union were consulted to identify relevant policies and initiatives at the European level. Urban and territorial planning documents were examined through institutional websites of local governments. Finally, the case studies were selected through targeted online research, based on the planning frameworks discussed in the previous sections.

For the evaluation of cases from research areas II and III, a classification is proposed that takes several key factors into account:

- Climate zones, based on the official Köppen–Geiger classification [9], to determine the adaptability of solutions to different climate zones;
- Types of intervention or action, taking into account the main objective of the intervention in terms of climate impact (e.g., water management, mitigation of urban temperatures, protection of biodiversity);
- The scale of the intervention (building envelope, such as façades and green roofs, neighborhoods, parks, streets, etc.).

The classification of interventions (in terms of typology, topology and technology) and their fields of application follows the model proposed by Sommese [10] in his study on the taxonomy of Nature-Based Solutions. This methodological structure makes it possible to obtain a complete and multidimensional picture of greening strategies at the European level, which favors the identification of replicable models in line with the European objectives of climate neutrality.

3. Green Strategies in the Policy Framework of the European Union

NbSs are at the center of many European Union (EU) policies and initiatives aimed at promoting urban greening, climate change resilience, and biodiversity protection. These solutions, which utilize natural processes to address environmental, social, and economic challenges, are integrated into various EU policy instruments [11]. The EU Strategy on Adaptation to Climate Change [12] aims to strengthen the EU's capacity to respond to the impacts of climate change, with the objective of becoming a resilient society by 2050. In this context, NbSs are part of the adaptation strategies, which are divided into three categories: "gray" measures, which include traditional infrastructure such as dams and artificial drainage systems; "green" measures, which include interventions such as planting trees, creating wetlands, and restoring ecosystems to mitigate the effects of climate change; and "soft" measures, which involve non-structural measures such as awareness raising, governance, and sustainable urban planning [12]. The EU Biodiversity Strategy for 2030 [13], which is an integral part of the European Green Deal, also recognizes NbSs as tools to restore degraded ecosystems through measures such as the creation of ecological corridors, the renaturation of rivers, and the expansion of urban green spaces that improve habitat connectivity and promote ecosystem resilience. Another important instrument is the EU Green Infrastructure Strategy adopted in 2013 [14], which promotes the creation of natural infrastructure for local climate regulation, stormwater management, and the improvement of air quality in cities through green roofs, urban parks, and sustainable drainage systems. In parallel, the EU's New Urban Agenda [15] emphasizes the importance of integrating NbSs into urban planning policies in order to reduce greenhouse gas emissions and improve the quality of life in European cities. In the context of the European Green Deal [16], the EU has strengthened the role of NbSs as key instruments for the green transition and promoted them in the fight against climate change, the protection of biodiversity, and the promotion of the circular economy. The EU Forest Strategy [17] also recognizes the role of forests as NbSs in the fight against climate change and for biodiversity conservation through reforestation and sustainable management of forest heritage. At the urban level, the EU has introduced several initiatives to encourage the adoption of NbSs. The Green City Accord [18] is an agreement that invites European cities to engage in five key areas of environmental management: air quality, nature and biodiversity, circular economy and waste management, noise and water. NbSs play a central role in achieving the objectives of the Green City Accord, in particular in the promotion of green spaces and sustainable management of water resources. Furthermore, platforms such as the Urban Nature Platform [19] promote the sharing of best practices and knowledge among European cities, providing tools and resources to integrate NbSs into urban policies. The Horizon Europe Programme [20] also fits into this scenario, funding research and innovation projects on NbSs to address issues related to climate change, biodiversity loss, and pollution. In conclusion, the European Union has developed a set of policies, strategies, and instruments to foster the adoption of NbSs and urban greening strategies, contributing to the creation of greener, more resilient and sustainable cities. The integration of NbSs into urban and territorial policies not only addresses the main environmental challenges but also offers economic and social benefits, contributing to the creation of more livable urban spaces in harmony with natural ecosystems. This approach, in line with the European Green Deal and the SDGs of Agenda 2030, represents a strategic direction for the future of urban and environmental planning in Europe.

Table 1 presents a list of the most recent EU initiatives cited above. As evident, there has been a noticeable increase in the number of initiatives in recent years, reflecting a heightened political awareness of environmental issues, particularly in the aftermath of the COVID-19 pandemic.

Table 1. The European Union's latest initiatives in the field of Nature-Based Solutions.

Year	Name	Aim
2013	**EU Green Infrastructure Strategy**	Promotes the use of green infrastructure such as green roofs, urban parks, and sustainable drainage systems to improve the environmental quality and resilience of cities.
2016	**New EU Urban Agenda**	Emphasizes the importance of NbSs for reducing greenhouse gas emissions and improving the quality of life in cities by incorporating them into urban planning policy.
2019	**European Green Deal**	Key EU initiative for the ecological transition, which considers NbSs as key for decarbonisation, biodiversity protection, and circular economy.
2020	**EU Biodiversity Strategy 2030**	Aims to restore biodiversity through NbSs such as ecological corridors, the renaturalization of rivers, and the expansion of urban green spaces.
2020	**Green City Accord**	Voluntary agreement calling on European cities to improve environmental management in five key areas: air quality, nature and biodiversity, circular economy and waste, noise pollution and water management, through the use of NbSs.
2020	**Urban Nature Platform**	Facilitates the exchange of best practices between European cities to integrate NbSs into urban policy.
2021	**EU Forest Strategy**	Promotes reforestation and sustainable forest management as NbSs to combat climate change and protect biodiversity.
2021 (2013)	**EU Strategy Adaptation to Climate Change**	Promotes actions to adapt to climate change, divided into gray, green and soft actions.
2021	**Horizon Europe Program**	Research and innovation program that funds NbS projects to address climate change, biodiversity loss, and pollution.

4. European Territorial Plans and Strategies

European cities are gradually adopting innovative strategies to contrast climate change and integrating NbSs into their adaptation plans (Table 2). From a methodological perspective, the shortlist of territorial plans and strategies selected in this section refers to case studies that are considered exemplary, well-known, and paradigmatic in terms of practical applicability and, often, linked to the political sensitivity toward environmental issues. The selected plans and, even more, the specific interventions detailed in Section 5 differ according to the climatic zone and the specific climatic challenges they are designed to address.

Barcelona, for example, has updated its "Plan Clima" and introduced the "Plan Calor", which includes targeted measures such as the air-conditioning of schools and the creation of widespread climate houses, emphasizing the urgency of responding to the rise in urban temperatures [21]. Similarly, Copenhagen has developed an advanced stormwater management system through the integration of green spaces that absorb stormwater runoff and thus reduce the risk of flooding [22]. Rotterdam is taking a similar approach with its "Rotterdam Climate Proof" plan, which promotes the use of green roofs and floating infrastructure to improve urban resilience [23].

Hamburg has also structured its "Klimaplan" around NbSs, emphasizing the creation of green corridors and the planting of trees to reduce air pollution and counteract the heat island effect [24]. With the "ForestaMi" project, Milan has set itself the ambitious goal of planting three million trees by 2030, not only to reduce carbon emissions but also to regenerate the city ecologically [25]. In parallel, Paris has included a strong greening component in its "Plan Climat Air Energie 2024–2030" and is promoting green roofs and walls to increase natural cooling capacity [26].

Other cities have developed targeted strategies for specific climate issues. Berlin has introduced the "StEP Klima KONKRET" [27], a plan that addresses the heat island effect and the sustainable use of water resources, while Vienna "has placed a special focus on reducing urban overheating through large-scale NbS measures with its "Urban Heat Island Strategy Plan" [28]. Stockholm and Oslo have developed climate action plans that include sustainable stormwater management and increased urban greening, while Helsinki and Zurich focus on reducing emissions through integrated strategies that combine tree planting with efficient natural resource management.

Finally, cities such as Brussels and Lisbon have adopted regional climate plans that incorporate green corridors and green infrastructure to improve territorial resilience and water management. In general, the European approach to NbSs is not limited to individual measures, but tends towards systemic planning that takes into account the climatic and urban specificities of each context.

Table 2. The most important adaptation plans that include greening strategies. Climate [9]: hot-summer Mediterranean (Csa); humid subtropical (Cfa); temperate oceanic (Cfb); cold semi-arid (BSk); warm-summer humid–continental (Dfb).

Year	City	Country	Climate	Plan	Aim
2011	Copenhagen	Denmark	Cfb	Climate Adaptation Plan	Green spaces to absorb and manage water runoff
2011	Hamburg	Germany	Cfb	Klimaplan	Green corridors and tree planting to improve air quality and climate resilience
2012	Stockholm	Sweden	Dfb	Stockholm Action Plan for Climate and Energy	Sustainable stormwater management and expansion of green spaces
2014	Helsinki	Finland	Dfb	Helsinki City Strategy	Integration of NbSs such as tree planting and creation of green spaces for improving climate resilience
2014	Zurich	Switzerland	Cfb	Masterplan Energie	Sustainable stormwater management and green space expansion to improve urban resilience
2015	Rotterdam	The Netherlands	Cfb	Rotterdam Climate Proof	Integrating green roofs and floating parks to manage stormwater and reduce the heat island effect
2015	Oslo	Norway	Dfb	Climate and Energy Strategy	Creation of urban parks and sustainable management of water resources
2015	Bruxelles	Belgium	Cfb	Brussels Regional Climate Plan	Use of NbSs as green corridors and water management to improve climate resilience
2016	Berlin	Germany	Cfb	StEP Klima KONKRET	Using NbSs to reduce the heat island effect and manage water resources
2017	Lisbon	Portugal	Csa	Lisbon Climate Change Adaptation Strategy	Tree planting and creation of green spaces to address climate challenges and improve the quality of urban life
2018	Paris	France	Cfb	Plan Climat Ènergie	Urban greening with green roofs and walls to improve urban resilience to climate change
2018	Vienna	Austria	Cfb	Urban Heat Island Strategy Plan	Reducing urban overheating through NbSs such as tree planting and creating green spaces
2019	Milan	Italy	Cfa	ForestaMi	Planting 3 million trees by 2030 to improve air quality and climate resilience
2020	Barcelona	Spain	Csa	Plan Clima Plan Calor	Urban heat adaptation strategies, school climate control, climate shelters, and cooling spaces

5. Green Roofs

After outlining European policies, exemplary territorial plans and urban strategies, Section 5, Section 6, and Section 7 present a selection of case studies featuring interventions recognized as best practices for green roofs, green facades, and urban spaces, respectively. Green roofs have become a key solution for urban sustainability and offer numerous environmental, social, and economic benefits. This paragraph presents the most significant case studies from various European cities (Table 3). The case studies have been classified according to climatic zones, building use, typology, topology, technology, and climatic impact. In this regard, the city of Basel is a leader in the implementation of green roofs with numerous projects that have improved the urban environment and contributed to environmental sustainability. In 1999, the city of Basel introduced a cantonal law requiring the construction of green roofs on new and renovated buildings with a roof pitch of less than 10 degrees [29]. In this way, it became the first city in the world to make the greening of new buildings a legal requirement. Currently, around 50% of Basel's flat roofs are green, which also serve as ecological compensation areas [29]. The regulations stipulate the use of native plants in order to promote urban biodiversity.

Table 3. Identification of some green roofs in the European context. **Climate** [9]: hot-summer Mediterranean (Csa); humid subtropical (Cfa); temperate oceanic (Cfb); cold semi-arid (BSk); warm-summer humid–continental (Dfb). **Typology:** green roof (GR), blue roof (BR), blue-green roof (BGR). **Topology:** extensive (E), intensive (I), semi-intensive (SI). **Technology** [30]: no-tech (NT), high-tech (HT), low-tech (LT). **Climate impact:** extreme temperature (T); water management (W); pollutant (P); biodiversity loss (B).

Building Name	City	Country	Climate	Building Use	Typology	Topology	Technology	Climate Impact
Opus	Dublin	Ireland	Cfb	Residential	BGR	I	HT	T; W
Basecamp	Copenhagen	Denmark	Cfb	Social housing	BGR	E	HT	W; B
Vierhanstrip	Rotterdam	The Netherlands	Cfb	Social park	BGR	I	HT	W
Max Planck Institute	Hamburg	Germany	Cfb	Educational	BGR	I; E	HT	T; W; B
Escape Bievenue	Paris	France	Cfb	Educational	BGR	E	HT	T; W; B
Axel Springer Haus	Berlin	Germany	Cfb	Editorial office	BGR	E	HT	T; P
Mcer	Lods	Poland	Dfb	Multifunctional	BGR	E	LT	W; B
St. Jakobshalle	Basel	Sweden	Cfb	Sport	BGR	E	HT	T; W; P

A prime example is the St. Jakobshalle (1976), a sports facility that has transformed its roof into a habitat for urban biodiversity. This project utilized local seeds from the Reinacher Heide nature reserve, encouraging the growth of native plants and the presence of various animal species, including wild bees and butterflies. The initiative has improved the environmental quality of the area and is a good example of how green roofs can promote biodiversity in the city. The implementation of the green roof on St Jakobeshalle has led to a number of environmental benefits, including a reduction in the urban heat island effect, improved air quality, and more efficient rainwater management.

The city of Copenhagen has introduced a policy that encourages the installation of green roofs to manage rainwater and reduce urban temperatures [22]. Indeed, city policies encourage the use of green roofs on new and existing buildings to improve climate resilience. In particular, new buildings must be equipped with green roofs that can absorb at least 50–80% of precipitation, have an insulating effect on the building, contribute to lowering temperatures in the city, double the lifespan of the roof itself by protecting it from UV rays, and help to beautify Copenhagen architecturally and aesthetically to improve the quality of life of citizens. Green roofs in Copenhagen must also be installed on existing buildings with flat roofs or a slope of less than 30°.

A prime example for the city of Copenhagen is Basecamp Lyngby (Figure 2), an expression of the integration of housing and environmental sustainability. One of the characteristic features of the project is the extensive green roof, which extends over 20,000 square meters [31]. The green space not only helps to enhance the aesthetic appearance of the building but also performs significant social and ecological functions, including the management of stormwater and the enhancement of urban biodiversity. The project has received awards such as the Green Cities Europe Award 2023, underlining its focus on environmental sustainability and social cohesion [32].

Hamburg is one of the greenest cities in Europe and the first in Germany to develop a green roof strategy. The city has made the installation of green roofs mandatory and offers financial incentives that cover 30 to 60 per cent of the costs for voluntary installations. The aim is to green 70 per cent of new buildings and renovated roofs. This corresponds to a total area of 100 hectares of green roofs, 20 per cent of which are earmarked for recreational areas.

Figure 2. BaseCamp. (**a**) Front view of the complex. Credits: KraghBerglund. (**b**) Roof paths seen from above. Credits: SayskyRace -KraghBerglund. (**c**) Integrated vegetation on the roof. Credits: SofieCold-Ravnkilde—KraghBerglund. (**d**) General view of the architectural complex. Credits: KraghBerglund.

One of the most remarkable examples is the Max Planck Institute for the Structure and Dynamics of Matter, designed by Landschaftsarchitektur+. The 3870 m^2 roof is largely green, with a combination of an extensive, multi-layered roof and a roof garden on the terraces and in the dining area. It includes perennials, herbs, and trees, offers relaxation areas and paths with ramps and stairs [33]. This project was awarded the "Green Roof of the Year 2021" prize by the German Green Building Association (BUUG). The green roof of the Max Planck Institute for the Structure and Dynamics of Matter is an innovative project that combines environmental sustainability, human well-being, and social cohesion. Thanks to extensive planting with perennials, trees, and shrubs, it improves biodiversity and helps regulate the microclimate, thereby reducing the building's energy consumption [31]. Furthermore, the rainwater collection system optimizes the use of water resources and reduces disposal and irrigation costs [34]. In addition to the ecological aspects, the roof was designed as a social space for researchers and visitors, offering walking paths, relaxation areas, and an outdoor café. The design, inspired by the natural landscapes of northern Germany, makes the roof a point of reference for the campus and encourages interaction between the various scientific institutions.

Rotterdam has taken several measures to promote the introduction of green roofs, as they are recognized as effective tools for adapting to climate change. In 2014, the city installed over 185,000 m^2 of green roofs, demonstrating its strong commitment to sustainable solutions [35]. In addition, the "RoofScape" project has mapped the city's rooftops and identified 130 potential uses, including rainwater harvesting and energy generation, to improve urban resilience.

A prime example of these initiatives is the Roofpark Vierhavenstrip in Rotterdam's Delfshaven neighborhood. Opened in summer 2013, this roof park is the largest in Europe with a length of 1 km, a width of 80 m, and a total area of 80,000 m^2. Built on the site of a former marshalling yard, the park rises above a number of commercial activities and combines green spaces with urban functions. Designed by Buro Sant en Co, the park offers an attractive and well-maintained environment that is easily accessible from the surrounding neighborhood, with themed areas, children's playgrounds, and refreshment facilities [36].

Dublin, the capital of Ireland, is a city that combines a rich cultural history with a growing commitment to environmental sustainability. In recent years, the city has seen an increasing number of initiatives to promote sustainable architecture, although there is little specific information on green roofs. Of note, however, is the OPUS building project (by MDO Architects), which includes extensive rooftop gardens and communal areas on the roof that contribute to biodiversity. The planting includes over 20 species of herbs, shrubs, and trees such as lavender and rosemary, which attract pollinators and birds [37]. This green design not only improves the quality of life for residents but also promotes a healthier environment by reducing the heat island effect and contributing to rainwater management.

The Berlin Climate Plan envisages the introduction of green roofs as a measure to improve the urban microclimate and water management, and to promote the thermal insulation of buildings. The integration of plant elements into urban architecture helps to reduce the heat island effect and improve the energy efficiency of buildings, thereby promoting the ecological sustainability of the city.

The green roof of the Axel Springer publishing house in Berlin, designed by Rem Koolhaas' OMA, is an innovative example of sustainable architecture. It combines nature and design and provides green spaces that improve thermal insulation and reduce environmental pollution. It not only serves as a recreational space but also promotes rainwater management and urban biodiversity. The roof helps reduce the heat island effect and improves air quality. The project integrates the building into the urban context and creates a symbolic and functional landmark. The selection of different plants promotes an ecological and regenerative environment.

Paris' urban planning instruments include incentives for the installation of green roofs and green walls as well as subsidies for urban greening projects to improve air quality and energy efficiency. One notable example is the undulating green roof of the Espace Bienvenüe, designed by Jean-Philippe Pargade, which combines aesthetics and sustainability. It is accessible to visitors and consists of layers of drainage, waterproofing and plant substrate that contribute to thermal insulation, reduce energy consumption and absorb rainwater. The native vegetation promotes biodiversity and counteracts the heat island effect. The design, which blends perfectly into the landscape, creates a natural terrace that is accessible to all.

In recent years, Poland has also begun to pay more attention to green roofs, although this practice is not yet as widespread as in other parts of Europe. Some municipalities are utilizing the concept of green roofs in urban redevelopment. A notable example is the MCER building (Młodsze Centrum Ekologiczne i Rewitalizacji), in Lods, which is the only environmentally friendly public building in Poland to have a green roof, which is one of the distinguishing features of this complex and was designed to improve the building's thermal and acoustic insulation and reduce energy consumption. It also contributes to rainwater management, reducing the risk of flooding in the surrounding areas. The green roof improves biodiversity by providing shelter for insects and birds.

Vienna promotes the use of green roofs to mitigate the urban heat island effect and offers financial incentives for their installation on residential and commercial buildings. The integration of plant elements into architecture helps to improve air quality and reduce pollution thanks to the absorption of carbon dioxide and the release of oxygen by plants. In addition, green roofs provide natural insulation that improves the energy efficiency and environmental comfort of buildings.

In Oslo, Norway, incentives are planned for the introduction of green roofs on public and private buildings to reduce CO_2 emissions and improve water management. The city is even considered the eco-capital of Norway.

These examples represent only a small selection within the broader European context. The collection presented here is not intended to be exhaustive and numerous additional examples can be identified.

6. Green Facades

Among various greening strategies, green facades are one possible solution and an effective approach to improving the quality of urban life. These interventions not only improve the quality of public and private spaces, but also offer numerous environmental and social benefits: improvement of air quality, due to the purifying action of plants [38–40]; thermal and acoustic insulation [41–45]; and protection of urban biodiversity. In addition, they do not require the occupation of land and make available a greater surface area of the building envelope, which goes beyond the exploitation of the roof alone. Several European cities have successfully implemented green façade projects (Table 4).

Table 4. Identification of some Vertical Greenery Systems in the European context. **Climate** [9]: hot-summer Mediterranean (Csa); humid subtropical (Cfa); temperate oceanic (Cfb); cold semi-arid (BSk); warm-summer humid–continental (Dfb). **Typology:** green façade (GF), living wall (LW), plants in pots (PP). **Function:** insulation (I), screening (S). **Technology** [30]: no-tech (NT), high-tech (HT), low-tech (LT). **Climate impact:** extreme temperature (T); water storage (W); pollutant (P); biodiversity loss (B).

Building Name	City	Country	Climate	Building Use	Typology	Function	Technology	Climate Impact
Fiordaliso shopping center	Rozzano, Milan	Italy	Cfa	Commercial	LW	I	HT	T, W
VIU Hotel	Milan	Italy	Cfa	Hotel	GF, PP	I, S	HT	T
Tower Flower	Paris	France	Cfb	Residential	PP	I	HT	T, P
Oasis d'Aboukir	Paris	France	Cfb	Residential	LW	I	HT	T, P, B
Edgware Road tube station	London	England	Cfb	Infrastructure	LW	I	HT	T, P
Regal House	London	England	Cfb	Residential	LW	I	HT	T, W, P, B
Hill House—Shoe Lane Library	London	England	Cfb	Residential, Office	PP	S	NT	T, P, B
Citicape House	London	England	Cfb	Hotel	LW	I	HT	T, W, P
Intermediate Contemporary Archive	Barcelona	Spain	Csa	Office	GW	I	HT	T, B
Sportplaza Mercator	Amsterdam	The Netherlands	Cfb	Social	LW	I	HT	T
Ravel Plaza Complex	Amsterdam	The Netherlands	Cfb	Residential, Office, Commercial	PP	S	NT	T, P, B
Ducati Business Center	Rimini	Italy	Cfa	Office	GW	S	HT	T
Ricola Company Office Building	Laufen	Swiden	Cfb	Office	GW	S	HT	T
CaixaForum	Madrid	Spain	Cfa	Museum	LW	I	HT	T, W, B

Among the best practices, we find the immense green wall covering 1250 square meters of area at the Fiordaliso shopping center in Rozzano, near Milan, designed by Architect Francesco Bollani. To create it, 44,000 plants were used, belonging to more than 200 different species of succulents such as Sedums and many hardy, almost weedy ornamental grasses capable of withstanding difficult environmental conditions. A total of 11,000 metal boxes were used, which are lightweight, water-resistant and able to facilitate maintenance. Chilean sphagnum moss, a fiber that does not rot even when in continuous contact with water, was used as "soil" to best grow the plants in a vertical position. Plants live on this type of moss by growing roots without contact with soil. The wall has a drip system that, thanks to thin channels that reach each box, brings water directly near the roots, without wasting it. Under the building, two 800-cubic-meter cisterns have been buried for rainwater, which is filtered and also used for irrigation of the surrounding greenery.

Another interesting example is the two large green walls of about 500 square meters each at Hotel VIU in Milan, designed by AG&P greenscape [46]. The main objective was to make the intervention sustainable from a maintenance point of view to ensure quality and durable vegetation. Taking advantage of the location of the two stairs located at the ends of the building behind the blind walls, easily accessible external steel walkways were built at each stringer. Metal pots were placed on each walkway so that they could take advantage of the correct amount of soil for their growth. By connecting the walkways to each other on the outer side with steel cables every 20 cm, it was possible to create a mix of vegetation: drooping from the same metal tubs, climbing thanks to the presence of the steel cables placed between each floor, and shrubby to ensure a thicker cover, always taking into account the different sun exposures of the two walls (northeast and southwest). The green wall spaced from the wall of the building also allowed for natural insulation of the building resulting in effective energy savings, as well as protection from the weather.

The "Paris Green" project, which promotes the installation of vertical gardens on public and private buildings, has been approved in Paris. The French capital's sensitivity to ecological and naturalistic issues is evidenced by the presence of numerous emblematic examples of the creation of vegetated walls by botanist Patrick Blanc, who pioneered the integration of "vertical gardens" in buildings. Some of his works worth mentioning are as follows:

The Quai Branly Museum was built in 2004; it has an area of 800 square meters and consists of about 15,000 plants of 150 different types; in 2017, it was enriched with 350 different species from all over the world. It integrates a water collection and runoff system near the façade openings and a drip system that provides nutrients and irrigation.

The BHV Homme, in the 4th arrondissement, built in 2007, features a large living wall above the entrance to the store. The "Mur végétal" at Rue d'Alsace, in the 10th arrondissement, planted in 2008, has an area of 1400 square meters and a height of 27 m; it contains 40,000 plants of more than 110 different species. The Green Hotel 13 at 90 rue de Patay was built in 2016, in which the green wall occupies all six floors of the facade.

An example of integration between vegetation and construction is the Tower Flower, a residential building constructed between 1999 and 2004, designed by architect Edouard François, in the Porte d'Asnière urban expansion area [47]. It can be seen as a true vertical extension of the neighboring park, with its 400 large pots arranged at the ends of the terraces that surround the building along its entire perimeter, within which bamboo plants are placed. The large pots also serve the function of protection, partially replacing the parapets. The shrubs and foliage of the bamboo act as a vegetal filter, shielding the view of the city.

An interesting intervention of creating a living wall in an existing building is the redevelopment of the façade of Oasis d'Aboukir, a residential building with five floors above ground, carried out in 2013 [48]. A vertical garden consisting of about 7600 plants of 273 different species placed on a felt-based technological support applied to the existing wall was created on the side facade. The plant layer thus created promotes urban biodiversity, improves the thermal insulation of the wall in both winter and summer, helps reduce air pollution (pollutant particles are slowly decomposed and mineralized on the felt, transforming into fertilizer for the plants), and improves the microclimate through the phenomenon of evapotranspiration.

In recent years, London has shown increasing interest in implementing green facades as part of a strategy to improve urban sustainability. The City of London has adopted the "Living Roofs and Walls" program, with guidelines and policies to encourage the development of green roofs and walls by integrating them into urban planning projects. Tax incentives and funding were provided to encourage owners and planners to invest in green solutions.

One of London's most interesting living walls is located on the side elevation of Edgware Road tube station, at the corner of Marylebone Road [49]. In 2011, the City of London commissioned the company Biotecture to design and install this green wall in an effort to combat air pollution in the city. This living wall was built by adopting a modular hydroponic system and occupies an area of about 200 square meters. It contains 14,000 plants of 15 different species with smaller leaves and a variety of textures, which were specially chosen because they are better air filters for PM10, the harmful particulate matter produced by car exhaust. The planting design of the Living Wall at Edgware Road was set on intersecting wavy vertical lines to create as natural an effect as possible, which has the effect of softening the shape of the building. In addition to reducing the building's heat load, mitigating the heat island phenomenon and limiting CO_2 emissions, this green wall also contributes to improving air quality by reducing environmental pollution. In this regard, the benefits of the aforementioned living wall on air quality have been monitored by Imperial College London, which has analyzed leaf samples at regular intervals to determine the amount of particulate matter absorbed by them.

An emblematic example of a vertical park is the living wall on the facade of Regal House, at the entrance to the Covent Garden area, created in 2017 by the company Biotecture, commissioned by Capital and Counties [50]. The living wall consists of more than 8000 plants of 21 different varieties. The main objective when designing the wall was to include as many colors as possible, taking into account the orientation of the facade and local conditions. The choice of plants had to ensure both biodiversity and improved air quality. In particular, efforts were made to encourage the presence of native birds and invertebrates and flowering plants that would provide nectar. Irrigation of the living wall is partly provided by a rainwater harvesting system, with a storage tank placed in the basement of the building. A custom solution had to be developed for the installation of the greening system on the facade of the existing building; a steel frame was attached to the brickwork of the building, adapting to the morphological characteristics of the facade and the presence of the windows.

A recent example of urban regeneration that includes a green envelope is the proposed 2024 redevelopment of the Hill House complex and Shoe Lane Library in the City of London by APT Architects [51]. The office building will feature a façade with cascading green roof terraces, with the goal of creating a sustainable and healthy workplace. Each floor will have an outdoor space designed to accommodate plants of various sizes that will envelop the building and make a major contribution to improving indoor air quality, reducing the heat island effect, and protecting biodiversity. The building-scale intervention will be part of a larger redevelopment plan to green the roadway and add new public green spaces.

Another interesting example of a green envelope in a new building is the Citicape House project, designed in 2019 by architecture firm Sheppard Robson and currently under construction [52]. It is a concrete example of the urban greening policy introduced by the New London Plan. It is a luxury hotel on whose shell is placed a green wall of the total development of about 3700 square meters, the largest in Europe, with 400,000 plants capable of capturing 8 tons of air pollution each year, producing 6 tons of oxygen, lowering the surrounding temperature by 3 to 5 degrees and significantly improving the local air quality by trapping about 500 kg of particulate matter (PM2.5 and PM10) per year. There is also a rainwater harvesting system in the building, which is functional for irrigating the green wall.

Also in London, a negative example that underscores how green walls need constant and careful maintenance, without which the intervention can even be detrimental to the building and its surroundings, is the Paradise Park Children's Centre. The building was designed by DSDHA Studio with a green façade designed by landscape architect Marie Clarke and made with a modular steel cage inside which rock wool is placed to allow hydroponic plant cultivation. Constructed in 2006, the vegetation on the wall died completely after 3 years, probably due to the irrigation system fed by recycled water, leaving the facade bare and with the supporting substructure exposed.

In Barcelona, with both the Superilles project for the city and the Metropolitan Urban Master Plan (in Spanish, Piano Direttore Urbano—PDU) for the entire metropolitan area, the goal is pursued of creating a more livable and healthy city with a harmonious relationship with its environment by protecting the system of open spaces, defined as ecosystems that benefit humans. In particular, the PDU adopts the notion of green infrastructure referring to the planned system of natural elements that are capable of conserving and enhancing metropolitan biodiversity.

An example of the adoption of vertical greening systems for the improvement of environmental quality is the wall of the Barcelona Intermediate Contemporary Archive in the Laguna del Poblenou neighborhood. Photovoltaic panels and climbing plants of 12 different species coexist on the wall over a total area of 560 square meters. An 8000 L reservoir collects rainwater from the roof of the building, which will be used to water the plants through a drip irrigation system. The intervention was carried out by the Municipal Institute of Urban Landscape and Quality of Life, with the collaboration of the Parks and Gardens Department and the Sant Martí District.

In the city of Amsterdam, attention to environmental issues has led planners to integrate greening systems into buildings.

An early emblematic example of the integration of green walls is the Sportplaza Mercator, built in 2006 and designed by Venhoeven Architecture Studio [53]. It is a building dedicated to leisure and socialization in a multicultural and multiethnic neighborhood. It includes bars, restaurants and a swimming pool. Because it stands in a park, to integrate it more into the context and to preserve the environment and biodiversity, it was entirely covered with vegetation. On the vertical envelope, a living wall with a pocket system and grassed panels was created, which characterizes the entire building. Through its green envelope, the Sportplaza Mercator ideally marks the beginning of the Rembrandtpark.

A relatively recent project by the studio MVRDV that integrates trees and other vegetation into the building's various floors is the Ravel Plaza Complex in Amsterdam's financial district [54]. The project, which promotes sustainable development and biodiversity, involves three tower buildings of varying heights joined together. The complex will contain apartments, offices and businesses and will feature visually striking green elements. The various floors are staggered so as to allow for the creation of large balconies full of plants and vegetation, which will help improve the area's microclimate and clean the air of the entire neighborhood.

Other significant interventions do not fit into specific urban greening programs.

The Ex Ducati Business Center in Rimini, Italy, was built between 2003 and 2006, designed by Mario Cucinella Architects [55]. In this building, a double vegetal skin, made of a 60 $\times$ 60 cm stainless steel grid on which Trachelospermum Jasminoides grows, covers the curved volume to the south. The green wall functions to screen and protect the building's distribution walkways. The plants are placed inside reinforced concrete planters arranged on each floor.

The Dutch Pavillion IGA in Rostock, Germany, was designed by Atelier Kempe Thill in 2003. The plant screen that forms the closure of the Dutch Pavilion at the International Garden Exhibition (IGA 2003), consisting of Dutch ivy, is able to modulate light and limit introspection.

The Ricola Company Office Building in Laufen, Switzerland, was designed by Jacques Herzog and Pierre De Meuron and built from 1997 to 1999 [56]. Wire mesh is attached to the intrados of the projecting roof to allow the growth of evergreen creepers and deciduous essences that act as sunscreens on the facades.

The CaixaForum Museum, located in the heart of Madrid's cultural district, features a green wall designed by Patrick Blanc [57]. It includes more than 15,000 plants of nearly

300 different species, all chosen by Patrick Blanc to take into account the extreme climate that characterizes the city: very hot in summer and cold in winter. The plants are housed in special pockets of a non-biodegradable felt mat in which the plants' roots grow. The total weight of the vertical garden is estimated at 30 kg per square meter. An irrigation and fertilization system, divided into zones at different heights, ensures adequate sustenance for the plants. In addition, there is a system at the base of the green wall for the recovery and subsequent recirculation of water from runoff that occurs along the leaves and stems.

Despite the specificities related to the design and implementation of VGSs, two integrated regeneration examples, although related to small cities, testify to how it is possible to plan urban greening works that effectively combine urban-scale interventions (reforestation, increase in permeable and/or reflective surfaces, regeneration of public areas) with those at the building scale (green roofs and walls).

This is the case of social housing projects by Stefano Boeri Architetti, still under construction, in several cities such as Monza and Prato (Italy), where energy upgrading and social inclusion are the two pillars of a regeneration of social housing that implements different scales of urban forestation interventions.

In Monza, the intervention for Aler social housing covers a total area of 8270 square meters and involves the reconnection between two buildings, which are currently divided. In both buildings, a climbing green system with support in metal cables anchored to the ground has been integrated into the facades, in which vegetation is planted directly in the areas adjacent to the building, so as to promote its growth and reduce its maintenance. Both solutions aim to create green walls by increasing the outdoor spaces pertaining to the apartments, with two different approaches: the first punctual, with prefabricated aluminum structures to create balconies, and the second continuous longitudinal, creating a prefabricated aluminum balcony. In both cases, the new prefabricated structures become the support for climbing plants that modify and enliven the facade. The resulting effect is that of a vertical extension along the facades of horizontal greenery.

The Municipality of Prato has developed the Urban Jungle project, with which it aims to improve the social and environmental quality of the urban context through urban forestation interventions, increased permeable surfaces, and the implementation of innovative and sustainable Nature-Based Solutions specifically designed and applied on facades and green roofs. As part of this project, the firm Stefano Boeri Architetti developed the design for the redevelopment of an office building and public housing complex [58]. The project brings forward a new conception of open spaces and green areas in the city, where nature is an active tool for safeguarding the health of citizens.

7. Urban Spaces

Nature embedded in urban design functions not only as a strategy for environmental adaptation, but also as a catalyst for inclusion, social regeneration and collective identity. When NbSs are integrated coherently into the urban fabric, they produce effects that exceed the mitigation of climate impacts, creating spaces for gathering, informal education, food production and participatory management. In both European and extra-European contexts, the widespread implementation of NbSs has led to the development of shared green areas that act as urban commons—spaces co-managed by communities that reinforce cohesion, activate local knowledge and renew the relationship between citizens and place [59].

These spaces work as hybrid socio-ecological infrastructures, particularly effective in neighborhoods exposed to physical or social vulnerability (Table 5). Examples such as the community gardens in Thessaloniki, the participatory reforestation experiences in Potenza, or the rain gardens in Rotterdam show how the success of these interventions often lies in the inclusion of local actors throughout the design and management phases. From this perspective, the most effective NbSs are those that emerge from a combination of ecological performance, social demand and cultural specificity. Their implementation is reinforced when embedded in collaborative governance systems that facilitate active participation by citizens, institutions, and third-sector organizations, fostering a form of environmental democracy in which shared management replaces traditional top-down planning [60].

Table 5. Identification of some green urban spaces in European cities. **Climate** [9]: hot-summer Mediterranean (Csa); humid subtropical (Cfa); temperate oceanic (Cfb); cold semi-arid (BSk); warm-summer humid–continental (Dfb). **Typology:** green corridor (GC), green infrastructure (GI), urban park (UP), edible garden (EG). **Technology** [30]: no-tech (NT), high-tech (HT), low-tech (LT).

Project Name	City	Country	Climate	Intervention Type	Typology	Technology
Green Corridors	Barcelona	Spain	Csa	Pollinators, Corridors, Meadow streets	GC	HT
Victoria BID	London	UK	Cfb	Green corridors, Rain gardens	GC	HT
Biblioteca degli alberi	Milan	Italy	Cfa	Multifunctional Urban park	UP	LT
Toyenparken	Oslo	Norway	Dfb	Community urban park	UP	LT
Stadtgarten	Leipzig	Germany	Cfb	Urban gardens	EG	NT

However, while some cities have consolidated institutional frameworks and urban living labs capable of sustaining these models over time, the replicability of such systems remains a major challenge. In contexts with lower administrative capacity or fewer financial resources, the diffusion of NbSs is often slowed by fragmented policies or limited access to evidence-based design. Initiatives such as the Urban Nature Platform or the Green City Accord play a key role in supporting the mainstreaming of NbSs, offering transferable typologies and common evaluation metrics that can guide urban decision-makers in tailoring NbSs to their specific socio-spatial context [59,60].

In recent years, there has been growing attention on equity-oriented planning strategies and the role of food systems in shaping inclusive urban spaces. Within this framework, the paradigm of the edible city has gained momentum as an approach that aligns nature-based urbanism with social justice and food security. Urban agriculture, community gardening and edible landscaping are increasingly seen not only as climate-resilient infrastructures, but also as platforms for social innovation and cultural expression [61]. Projects such as Incredible Edible in Todmorden or the Essbare Stadt initiatives in Leipzig and Berlin show how urban food production can activate dormant spaces, support economic regeneration and foster intergenerational dialogue [60].

These edible strategies contribute to the regeneration of peri-urban and inner-city areas by reconnecting citizens with natural cycles and enhancing access to healthy food, particularly for marginalized communities. Moreover, rooftop gardens, balcony farms and other zero-acreage farming systems are proving to be effective even in high-density urban environments, providing benefits in terms of thermal regulation, biodiversity, and microclimate resilience. Their multifunctionality allows them to contribute simultaneously to ecosystem services, civic engagement and education, making them highly adaptable to diverse socio-ecological settings.

These dynamics are not limited to cities at large. Increasingly, they are being tested and refined in more controlled environments such as university campuses, which function as microcosms of urban systems. The concept of the campus as a “living lab” fosters a dynamic interplay between theoretical knowledge and applied sustainability, enabling students and staff to co-design and monitor NbSs in real time. Through the integration of lifecycle-based approaches and participatory practices, institutions like the University of Copenhagen and the University of Oxford are demonstrating how campuses can reduce their carbon footprint, enhance biodiversity, and build resilience to climate risks, while simultaneously educating future generations in environmental stewardship.

Moreover, national initiatives such as the EU Green Campus Life and locally grounded strategies—as seen in the University of Parma's commitment to shared governance and the development of climate-resilient open spaces—highlight how higher education institutions are not only contributing to the green transition but also shaping new cultural paradigms around sustainability, care, and community involvement. This positioning of campuses as both symbolic and operational actors in the ecological transition reinforces the systemic nature of NbSs, bridging urban planning, institutional responsibility, and transformative education. In parallel, the paradigm of edible cities, although still fragmented in urban strategies, offers a complementary perspective to Nature-Based Solutions by introducing productive green spaces that reinforce food resilience and social inclusion. The convergence between green campuses and edible cities suggests a systemic evolution in urban design, where the urban metabolism is reconnected with natural and food cycles through shared educational and productive environments. Several real-world implementations confirm the transformative potential of Nature-Based Solutions. Cities such as Barcelona, London, Milan, Oslo, and Leipzig are now widely referenced as exemplary cases for integrating ecological thinking with social infrastructure through both top-down and community-led interventions. In Barcelona, the city's Green Infrastructure and Biodiversity Plan promotes the renaturalization of public space by turning overbuilt streets into green corridors and introducing meadows and pollinator-friendly species in formerly impervious zones. The projects by the architecture office 08014 Arquitectura stand out for their tactical approach: through the gradual removal of asphalt and the reintroduction of native soil and vegetation, they enable spontaneous biodiversity while reclaiming street space for pedestrians and local communities (Figure 3a,b).

Figure 3. (**a**) Plaça de les Glòries, Barcelona: park view. Green urban regeneration project integrating vegetation and recreational space within a dense urban context. Photo by Marco Bellomo, 2024. (Project completion year: 2025.) (**b**) San Martí district, Barcelona: street view. Example of nature-based urban regeneration focused on pedestrian comfort, vegetation recovery and climate adaptation in a high-density residential context. Photo by Marco Bellomo, 2024.

In London, the Victoria Business Improvement District (Victoria BID) has implemented green corridors and urban rain gardens to enhance biodiversity, improve pedestrian comfort, and mitigate flooding risks in a densely urbanized area. In Milan, the Biblioteca degli

Alberi offers a multifunctional urban park that integrates ecological connectivity, recreational spaces, and climate mitigation features in one of the most densely built parts of the city. In Oslo, the transformation of Tøyenparken highlights the role of community engagement in the creation and management of multifunctional green spaces that promote both social inclusion and biodiversity. Similarly, Leipzig's Stadtgärten initiative demonstrates how urban gardens and edible city strategies can revitalize vacant lots, foster community cohesion, and contribute to urban food sovereignty [62]. Together, these interventions illustrate how integrating ecological functionality with social accessibility can generate multifunctional spaces that respond to both planetary and human needs. Moreover, the geographical distribution of these case studies across different climate zones—ranging from the hot-summer Mediterranean climate of Barcelona, through the temperate oceanic climates of London and Leipzig, to the humid subtropical environment of Milan and the cold continental conditions of Oslo—demonstrates the remarkable adaptability of Nature-Based Solutions. Their success across such diverse contexts highlights that, when properly tailored, NbSs can act as effective socio-ecological infrastructures capable of enhancing urban resilience, fostering social inclusion, and supporting ecosystem services independently of climatic constraints.

8. Discussions

8.1. European Policies and Urban Management

The temporal analysis of European initiatives on urban greening, or more broadly on NbSs, reveals a significant intensification of actions starting from 2010 (Figure 4): a phenomenon attributable to various dynamics. First, the adoption of the EU Strategy on adaptation to climate change in 2013 provided a framework for action at local, regional and national levels, encouraging cities to develop their own adaptation strategies. Furthermore, initiatives such as the Covenant of Mayors for Climate and Energy promoted the adoption of concrete measures by local governments.

Figure 4. Timeline of the key milestones in EU NbS policy development.

European cities that have adopted climate adaptation plans are distributed across different climate zones. Cities with an oceanic climate (Cfb), such as London, Paris, Brussels, Hamburg, Rotterdam and Copenhagen, characterized by moderate temperatures, year-round rainfall and non-extreme winters, have focused their strategies on stormwater management, as in the case of Rotterdam and Hamburg, on the creation of green corridors, as in Paris, and on the mitigation of the urban heat island effect, as in the policies adopted by London. Cities with a Mediterranean climate (Csa, Csb), including Barcelona, Milan and Lisbon, instead face high summer temperatures and long periods of drought, which is why their strategies focus on urban shading measures, such as the "Plan Clima" in Barcelona, reforestation, as in the "ForestaMi" project in Milan, and heat wave management. Cities with a humid continental climate (Dfb), such as Vienna, Berlin, Stockholm and Oslo, characterized by harsh winters and well-distributed precipitation, have developed plans that focus in particular on water management and thermal insulation through Nature-Based Solutions. Helsinki, which falls within the subarctic climate (Dfc), has adopted strategies aimed at balancing the need for heating with sustainability, implementing multifunctional green spaces and green roofs. Zurich, with its transitional alpine climate (Cfb/Dfb depending on the altitude), has instead focused on NbSs to mitigate hydrogeological risk and stabilize the territory. The geographical and temporal distribution of these plans highlights a greater adoption in cities with oceanic and Mediterranean climates, where the increase in summer temperatures and the risk of extreme weather events have prompted a more timely response. The post-2010 acceleration in the adoption of these plans can be traced back to the European Union's commitment to providing a reference regulatory and strategic framework, with key documents such as the 2013 European Strategy for Adaptation to Climate Change and the 2020 Biodiversity Strategy, as well as initiatives such as the 2020 Green City Accord, which has strengthened the promotion of Nature-Based Solutions. However, a critical analysis shows that cities with harsh winters, such as Oslo and Helsinki, have adopted strategies later than Mediterranean or oceanic ones, probably because the climate challenges in these contexts require different solutions. Furthermore, although most cities have developed strategies based on soft and green actions, gray infrastructures are less integrated into the plans, limiting in some cases the effectiveness of the measures adopted. In particular, cities with high vulnerabilities, such as Mediterranean ones, exposed to droughts and heat waves, or Nordic ones, where cold management is a central challenge, may require even more incisive interventions to ensure effective and long-lasting resilience over time. It should be noted, as already mentioned in the introduction, that despite the numerous benefits of NbSs, their large-scale implementation is hindered by several factors, including regulatory fragmentation, limited access to funding, weak coordination among different levels of government, and the lack of shared standards and effective evaluation tools. However, these challenges can be overcome through careful and integrated planning and design, capable of harmonizing regulations, facilitating the definition of investment priorities, strengthening institutional coordination, and promoting the development of common guidelines and operational frameworks, thereby making NbSs more accessible, replicable, and scalable.

8.2. Green Roofs

The comparative analysis of the European case studies (Table 3) highlights the growing strategic importance of green roofs in urban planning and climate change policies. What emerges as particularly significant is not only the diversity of solutions adopted but also their adaptability to specific local conditions, signaling a shift from isolated technical installations to integrated, multifunctional systems that contribute meaningfully to urban regeneration. This design flexibility is an important factor for the large-scale adoption of green roofs; however, it is crucial to emphasize the need for a careful analysis of structural characteristics along with a set of parameters and variables, especially when working on existing buildings [6].

Among these factors, climate plays a fundamental role, exerting a direct influence on the design of green roofs, particularly in the selection of plant species and the management of rainwater. The examples analyzed in paragraph 5 focus on green roofs implemented in cities with predominantly temperate oceanic (Cfb) and humid continental (Dfb) climates. Basel and Berlin, for instance, characterized by moderate precipitation and cold winters, favor the use of native and resilient plant species, whereas Copenhagen and Rotterdam, experiencing higher levels of rainfall, primarily emphasize strategies for water retention. Particularly noteworthy is the systemic approach adopted by some cities, which have not limited themselves to promoting individual projects, but have instead embedded green roofs within broader urban strategies. These cities distinguish themselves not only through their quantitative ambitions (in terms of green surface area created) but also through the quality of their policies and implementation mechanisms. These include regulatory frameworks, financial incentives, technical guidelines, and monitoring systems. From this perspective, the models developed in Basel, Hamburg, and Copenhagen represent exemplary practices that can serve as references for other contexts, provided they are critically analyzed and adapted to local specificities.

A particularly relevant aspect is the capacity of some projects to transcend purely environmental goals, incorporating social, cultural, and even symbolic functions. In fact, green roofs become spaces for community engagement, educational tools, and identity-forming elements within the urban landscape. This holistic approach enhances the public value of such interventions and supports their stable integration into long-term urban planning policies. However, not all cities have reached solid maturity in this regard and, in some cases, the green roof is reduced to a simple technical or aesthetic intervention, not connected to a broader discussion aimed at increasing the climate resilience of the built environment. Promoting this type of broader approach, aimed at climate resilience, is not easy due to several aspects. The most advanced cases have developed within contexts equipped with strong economic resources, administrative capacities, and a mature planning culture. The gap with emerging contexts—where green roofs are still fragmented or experimental—underscores the need for coordinated political and technical support at supralocal levels to ensure equitable and structured diffusion. Furthermore, despite their proven effectiveness, many of the projects lack systematic long-term impact assessments. The evaluation of effects on microclimate, biodiversity, energy efficiency, or social well-being is often absent or limited to qualitative indicators. To consolidate green roofs as essential urban infrastructure rather than supplementary features, it is crucial to implement more rigorous monitoring and evaluation systems capable of generating objective, comparable data.

Thus, the examples analyzed provide an overview, though not yet exhaustive, of the achievements to date, but more importantly, they indicate a clear direction for the future. The most resilient cities will be those capable not only of adopting effective technical solutions and integrating them into their urban systems in an inclusive, measurable, and strategic manner. In this regard, green roofs should not be seen merely as additional features, but as fundamental components of green infrastructure essential for promoting the ecological transition.

8.3. Green Facades

Although the greening measures and plans adopted by several European cities mainly focus on urban-scale interventions in public spaces and areas adjacent to buildings, in some cities, such as Copenhagen and Berlin (Green Roof and Wall Program), planning tools for building interventions actively promote the creation of green roofs and facades. Often, these projects are specific and punctual initiatives driven by private developers.

Even the Metro Adapt project, prepared by the City of Milan, defines the implementation of VGSs as a punctual intervention at the building scale. This could be ascribable to the peculiarities specific to vertical greening interventions, for which buildings, whether new or existing, must possess certain specific characteristics in terms of orientation, morphology, geometry and the ratio of opaque to transparent surfaces.

In relation to façade orientation, the application of VGSs is very useful on east- or west-facing elevations, where they can validly contribute to both shading of opaque walls and shielding of incoming solar radiation from glazed surfaces, with significant benefits in the summer period in terms of reducing surface temperatures and improving indoor comfort. On south-facing elevations, the presence of VGSs is advisable when facades are devoid of overhangs or balconies that, in summer, may already be sufficient to provide shading and screening for vertical closures, both opaque and transparent.

The application of VGSs is strongly conditioned by the morphology of the building. The presence of projections such as cornices, stringcourses, or balconies means that VGSs must be advanced relative to the façade. The presence of porches, commercial activities, or garages on the ground floor greatly limits the construction of VGSs, not allowing the placement of plants on the ground.

In relation to the presence of glazed surfaces in the elevations, it will be necessary to carefully consider which greening system to use also depending on the required performance (shading of opaque surfaces or screening of glazed ones).

8.4. Urban Spaces

The growing integration of NbSs into the design and transformation of urban spaces marks a paradigmatic shift in how cities address environmental and social challenges. Beyond their ecological functions, these interventions generate hybrid spaces that promote inclusion, health, and cultural expression, aligning with regenerative and systemic design approaches. Recent European experiences, such as the green corridors and pollinator-friendly streets in Barcelona, demonstrate how NbSs can reconcile environmental performance with the enhancement of everyday urban life through low-tech, community-centered, and spatially inclusive interventions [63,64].

Increasingly, university campuses are emerging as strategic testing grounds for the real-world implementation of NbSs. Institutions such as the University of Copenhagen and the University of Oxford are promoting integrated approaches that combine lifecycle assessment, biodiversity enhancement, and participatory research, transforming campuses into microcosms of urban resilience [65]. Initiatives like EU Green Campus Life and actions by universities such as Parma further demonstrate how higher education environments can foster climate adaptation strategies while embedding environmental values in daily academic practices.

These developments reinforce the broader need to reframe urban spaces—whether public streets, community gardens, or academic campuses—as multifunctional systems capable of delivering ecosystem services, social cohesion, and health co-benefits simultaneously. The Millennium Ecosystem Assessment already recognized the intertwined nature of ecological and human well-being [66], while more recent research has clarified how urban green infrastructure can address complex socio-environmental risks in dense urban contexts [67]. Conceptual frameworks such as regenerative cities [68] and planetary boundaries stress the urgency of integrating nature into built environments to avoid ecological tipping points and enhance urban resilience. In this context, Nature-Based Solutions emerge as critical policy tools for systemic transformation [69] calling for innovative governance models and cross-scalar collaborations to embed sustainable practices into everyday urban and academic life.

Nevertheless, the long-term effectiveness of NbSs within urban settings is not guaranteed by design quality alone. Their success also hinges on the governance and maintenance strategies that support them over time. As these spaces are increasingly recognized as shared commons, their durability requires a balance between institutional responsibility and civic engagement. Public entities must provide adequate resources and adaptive management frameworks, while communities are called upon to nurture a collective sense of stewardship. Without this shared care, even well-designed interventions risk degradation or disengagement. Embedding NbSs into urban life therefore means integrating not only ecological performance, but also intelligent and inclusive models of long-term maintenance. This perspective also highlights the need for greater coordination among different dimensions of Nature-Based Solutions. For instance, integrating green campus strategies with edible city initiatives could foster hybrid urban models that combine environmental education, food sovereignty, and social equity. From this viewpoint, future urban policies should explicitly consider the synergistic potential of these practices, emphasizing their environmental, cultural, and community-driven value.

9. Towards a Regenerative Design

The integration of green roofs, green façades, and the revitalization of urban spaces through greening interventions represents a concrete response to the challenges outlined in the 2030 Agenda, as shown in Figure 5. Urban greening supports SDG 11 by enhancing the livability and resilience of cities, helping to mitigate the urban heat island effect and reducing energy demand for cooling. The creation of ecological corridors promotes urban biodiversity (SDG 15) by connecting natural habitats. At the same time, the greening of the built environment acts as a "green lung", absorbing carbon dioxide and combating climate change (SDG 13), with a direct impact on reducing greenhouse gas emissions. The widespread presence of green areas improves air quality, fosters physical and mental well-being among citizens (SDG 3), and encourages healthier lifestyles. Moreover, through natural drainage solutions and the purification of stormwater, greening strategies contribute to more efficient and sustainable water resource management, aligning with SDG 6. Ultimately, urban green infrastructure emerges as an essential element for building more sustainable, resilient, and inclusive cities.

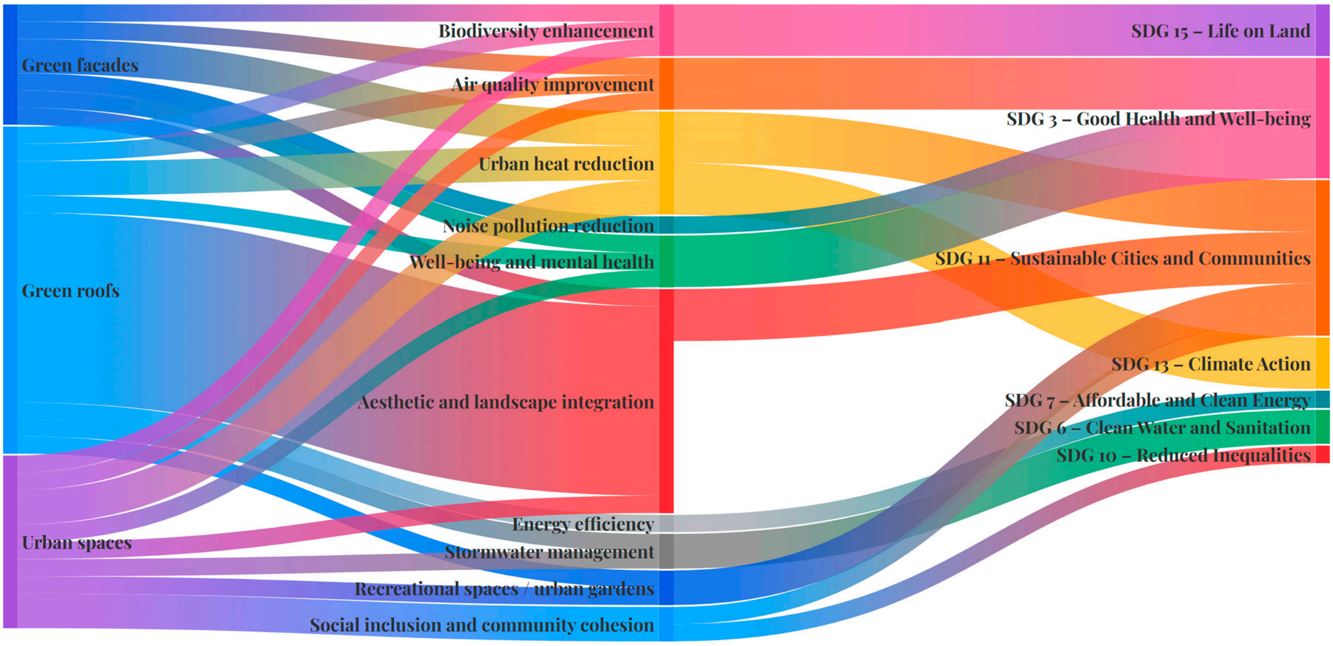

Figure 5. Connections between greening strategies, resulting benefits, and SDGs of the 2030 Agenda.

However, it is important to emphasize that greening strategies do not merely aim to preserve the existing urban environment in a sustainable way. On the contrary, they introduce transformative dynamics that enrich the quality of the built space, turning the urban environment into a more complex, interconnected, and productive ecosystem. The creation of new urban habitats, the increase in biodiversity, and the reduction in air and noise pollution, as well as urban heat island effects, are just some of the positive impacts that go beyond simple environmental compensation, generating tangible added value for both local contexts and the entire planet. In this regard, the greening of the built environment aligns perfectly with the principles of regenerative design, which, moving beyond mere sustainability, seeks to regenerate, restore, and enhance natural systems [70,71]. It can thus be considered as a progression beyond simple mitigation and adaptation strategies in response to climate change. According to this approach, indeed, the built environment is no longer considered as an external or opposing element to nature, but rather as an integral part of an evolving ecosystem, capable of producing resources, hosting life, and improving over time. Greening solutions, such as Nature-Based Solutions, undoubtedly represent a fundamental pillar of regenerative design due to their ability to restore ecosystems, enhance urban resilience, and provide environmental, social, and economic benefits. However, they are not the only tools available. To achieve a truly regenerative approach, these solutions must be complemented by other strategies and instruments, including the use of bio-based, renewable, and low-impact materials. It is also essential to assess and quantify environmental impacts through lifecycle assessment. Moreover, the support of smart technologies can be a promising avenue for evaluating the effectiveness of specific interventions in regenerative design. Therefore, to strengthen the methodological framework of regenerative design, future research should develop measurable indicators aligned with the SDGs, create simulation models to assess ecological and social performance, and analyze real-world case studies where the integration of greening, innovative materials, and intelligent technologies yields tangible results.

10. Conclusions

This study offers a comprehensive overview of the strategies and initiatives implemented at the European level, providing a valuable reference for policymakers, urban planners, and built environment practitioners committed to promoting a regenerative transition.

Since 2010, the European Union has increasingly prioritized greening policies as critical tools to address challenges such as rising temperatures, hydrogeological risks, and biodiversity loss. However, issues remain regarding the scalability and replicability of greening solutions, particularly in densely built or economically constrained urban contexts. The long-term effectiveness of these strategies will largely depend on their integration with broader urban policies and the availability of sustained financial support to ensure meaningful impacts on urban resilience.

The principal lessons derived from this study can be synthesized as follows:

- Greening the built environment must be understood not merely as an aesthetic intervention, but as a multifunctional strategy that delivers environmental, social, and economic benefits;
- The incorporation of green roofs, green façades, and the ecological regeneration of urban spaces requires a holistic approach and integrated planning across multiple governance levels;
- The success of such initiatives is strongly contingent upon public–private collaboration and active community engagement;
- Economic incentives, clear regulatory frameworks, and robust awareness-raising campaigns are essential to foster the widespread adoption of greening practices;
- Systematic monitoring and evaluation of impacts are crucial to validate the effectiveness of these strategies and to refine future policies aimed at enhancing urban climate resilience.

It strongly emerges that these strategies go beyond the pursuit of sustainability, aiming instead at the regeneration of the built environment. Their tangible impact fosters the creation of spaces that enhance biodiversity and ecosystem health, thereby contributing to the development of a climate-resilient urban fabric that harmoniously integrates with the natural environment. Finally, it is worth noting that the long-term success of nature-based strategies depends not only on their design and policy alignment, but also on how they are maintained and cared for over time. Ensuring continuity and effectiveness requires shared responsibility between public institutions and local communities, fostering a culture of co-management and stewardship of green urban assets. Despite the progress made in implementing green strategies for the built environment, several issues still require further investigation and represent promising directions for future research. Among these is the need to develop more accurate indicators and dynamic monitoring systems capable of assessing the real impacts of greening strategies over time on climate resilience, urban well-being, and biodiversity. At the same time, to keep pace with emerging challenges, it is essential to explore the potential of digital tools—such as GIS, digital twins, and artificial intelligence—in supporting the planning, management, and simulation of resilient green urban scenarios.

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