GREENSCAPE CE

Climate-proof landscape through
renaturing urban areas in Central Europe

TECHNICAL HANDBOOK
FOR THE IMPLEMENTATION OF NBS/GI
IN THE URBAN ENVIRONMENT

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ABBREVIATIONS AND ACRONYMS

CE	Central Europe
ES	Ecosystem Services
EU	European Union
GI	Green Infrastructure
GIS	Geographic Information System
GVMP	GreenScape CE Visual Mapping Platform
KPI	Key Performance Indicator
LST	Land Surface Temperature
NbS	Nature-based Solutions
GI	Green Infrastructure
SME	Small and Medium-sized Enterprise
NbS	Nature-based Solutions
NGO	Non-Governmental Organization

1. INTRODUCTION

Urban areas across Central Europe are increasingly exposed to the consequences of rapid urbanisation, land-use intensification, and climate change. The expansion of grey infrastructure and loss of natural surfaces have exacerbated heat-island effects, increased surface-water flooding, and deteriorated air quality, while reducing biodiversity and overall liveability. Addressing these interconnected challenges requires integrated approaches that reconnect urban systems with nature.

The GreenScape CE project aims to respond to these challenges by promoting the adoption of Nature-based Solutions (NbS) and Green Infrastructure (GI) as essential components of sustainable urban development. By integrating ecological principles into spatial planning and infrastructure design, the project aims to support cities in adapting to climate change, restoring ecosystem functions, and enhancing the quality of life for their residents.

The project brings together 12 partners from six Central European countries (Austria, Croatia, Hungary, Italy, Poland, and Slovenia) to strengthen multi-level governance and promote transnational collaboration, capacity-building, and participatory decision-making for NbS and GI implementation. **GreenScapes' approach combines the development of five local NbS/GI Action Plans and pilot actions in the Metropolitan city of Milan, Ptuj, Szeged, Warsaw, and Zagreb**, each testing innovative and replicable solutions that merge technical feasibility with co-creation and long-term sustainability.

Key project objectives include:

- Enhancing citizen engagement and co-creation with key stakeholders;
- Developing technical and tendering solutions to facilitate NbS/GI implementation;
- Exploring public, private, and community-based financing models;
- Strengthening policy and planning frameworks for mainstreaming NbS/GI in urban environments.

About this handbook

This handbook aims to translate the collective experience of the GreenScape CE partnership and its pilot cities into practical guidance for the effective implementation of NbS and GI in urban areas. It provides municipalities, planners, and project developers with technical insights, planning requirements, and tendering approaches that strengthen local strategies and enable successful, replicable NbS/GI interventions.

Based on the results and lessons learned from pilot actions in the Metropolitan city of Milan, Ptuj, Szeged, Warsaw, and Zagreb, **the handbook shares evidence-based recommendations on design parameters, implementation processes, and expected impacts**, ensuring that guidance reflects real challenges and tested solutions across Central Europe.

Although this document focuses primarily on technical and operational aspects, it forms part of a broader and complementary set of outputs of the project:

- *Handbook for financing of NbS/GI for public project developers*, which explores financing models and investment mechanisms; and
- *How to co-create urban NbS/GI projects with citizens?* which provides guidance on participatory and co-creation models for community engagement.

Together, these handbooks create a comprehensive knowledge package supporting cities through all stages of NbS/GI development, from stakeholder engagement and financing to technical design, implementation, and long-term management.

Who is it for?

This handbook is designed to support especially municipalities, urban planners, engineers, utilities, Small and Medium-sized Enterprises (SMEs), and civil society actors involved in the planning, design, procurement, or maintenance of NbS/GI projects. It is particularly relevant for:

- **Local and regional authorities** responsible for urban development, spatial planning, and climate adaptation;
- **Technical professionals and contractors** implementing NbS/GI solutions on the ground;
- **Community organisations and NGOs** engaged in participatory or co-creation processes;
- **Decision-makers and public project developers** seeking practical guidance to integrate NbS/GI into long-term urban strategies.

The document combines technical guidance with practical experience from the GreenScape CE pilot cities and aims to be a reference tool for all stakeholders interested in implementing and replicating NbS in the urban scope.

2. PLANNING AND ENABLING CONDITIONS FOR NBS/GI

Planning a structured framework is an essential process for the effective implementation of NbS and GI, and should consider more than the technical design. Insights gathered from the GreenScape CE pilot cities through a gap analysis conducted via questionnaires to project partners, stakeholder interviews, and dedicated workshops[1] indicate that enabling conditions involve mainly allowing regulatory frameworks, coordinated governance, land ownership, alignment with planning instruments, meaningful stakeholder engagement, and a clear understanding of local vulnerabilities. Having these dimensions creates a foundation on which technically sound and socially accepted interventions can flourish.

2.1 Governance, regulations, and land ownership

The triad of governance, regulation, and land ownership comprises the backbone of NbS/GI feasibility. When these aspects are harmonised, they support smoother procurement processes and ensure that maintenance responsibilities are assigned realistically, an essential condition for the long-term performance of NbS.

Establishing the right governance conditions is a critical first step for any NbS/GI intervention. Urban green projects often intersect with other local competencies such as planning, environment, transport, water management, utilities, and heritage protection. Without an early coordination structure, administrations may face delays, overlapping approvals, and/or even conflicting requirements. For this reason, a clear governance model, i.e., one that defines roles during design, permitting, implementation, and maintenance, helps streamline procedures and ensures that all institutions influencing the project share a common understanding of its objectives.

In parallel, **regulatory constraints strongly influence design flexibility**. Heritage preservation rules, mobility standards, drainage regulations, or construction codes may limit the range of feasible NbS options. For example, among some of the pilot cities working in historic areas, there was a need to adjust their planting typologies or excavation depths to comply with preservation regimes. Others reported that strict water-management regulations guided the dimensioning of infiltration features, which aligns with more urban challenges outside the project scope. These situations demonstrate how NbS/GI must be planned within the legal frameworks that shape urban transformation, not as an exception to them.

Additionally, **land ownership proved to be one of the most frequent bottlenecks across pilot contexts, affecting site selection and long-term stewardship**. Unclear ownership, shared parcels, or overlapping public-private responsibilities often require additional cadastral checks or negotiations before interventions can proceed. In some cities, preferred sites had to be relocated due to unresolved ownership issues or incompatible land-use rights.

These observations are in line with project-wide analyses carried out across the pilot cities, which highlighted that **governance complexity, unclear responsibilities, and land-ownership constraints are recurrent barriers to the deployment of NbS/GI at the local level**. Verifying property conditions and governance responsibilities from the earliest planning stages, therefore, emerges as a critical enabling factor, as unresolved ownership issues can significantly delay tendering, implementation, and the definition of maintenance responsibilities.

[1] D.1.1.2 - Gap analysis of barriers and opportunities in deploying NbS/GI on the local level

2.2 Integration into spatial and urban planning frameworks

The implementation of NbS/GI is most effective when embedded within existing spatial and strategic planning frameworks. For this reason, aligning interventions with climate adaptation strategies, mobility plans, landscape frameworks, or municipal development plans ensures that they reinforce broader urban objectives and are recognised as part of long-term transformation processes[2]. Based on project outcomes, when local authorities embed NbS/GI projects within ongoing planning cycles, approvals tend to be faster, and cross-departmental collaboration improves substantially.

Planning integration also strengthens the systemic function of NbS. Rather than operating as isolated beautification projects, NbS/GI should become part of coherent networks that provide cumulative benefits at the city scale, such as reducing runoff across an entire catchment or improving connectivity between ecological corridors. In some pilot cities' experiences, for instance, redesigning a single street required linking the intervention with drainage basins, pedestrian flows, and neighborhood redevelopment priorities. This demonstrates that even small-scale NbS cannot be treated as stand-alone elements.

Several cities learned the importance of understanding NbS within a multiscale planning context. Metropolitan-level mapping and spatial analyses in Metropolitan city of Milan helped identify hotspots with insufficient green cover, gaps in accessibility and opportunities to connect fragmented green areas. Other municipalities integrated NbS data directly into their statutory planning documents, establishing the regulatory basis for future scaling-up. Following this approach ensures that individual interventions contribute to long-term ecological networks and urban resilience strategies.

Therefore, **integrating NbS/GI in planning frameworks is highly recommended as it promotes consistency, avoids conflicts between sectoral policies, and helps secure funding and political support**. When NbS are recognised as part of official planning instruments, they transition from experimental solutions to standard components of urban development.

2.3 Stakeholder and citizen engagement

As mentioned in the introduction, the handbook entitled *How to Co-create Urban NbS/GI Projects with Citizens?* complements this work focusing on stakeholder and citizen engagement; however, in this part, it is convenient to briefly include a few points only to avoid not touching such an important variable of the successful implementation of natural measures.

Engaging citizens and stakeholders throughout the planning and design process is fundamental for NbS/GI to respond to real needs and be better accepted by local communities. As these interventions modify public space and influence daily activities, transparent communication and participatory approaches help build trust and clarify expectations. In some pilot areas, involving residents as end-users helped early identify issues that were not captured by technical analyses alone. This process can be strengthened through stakeholder mapping and the development of a multi-level engagement roadmap, ensuring that engagement activities are targeted and aligned with project phases.

Co-creation approaches prove to be effective, allowing local actors to contribute to design decisions through workshops, site walks, surveys, or collaborative design exercises. In addition, stakeholder engagement also plays a crucial role in anticipating and planning for long-term maintenance. Engaging

[2] D.1.5.1 - Joint Strategy on Strengthening NbS Implementation in Central Europe

local institutions, like schools, sport clubs, or neighbourhood organisations, can further anchor NbS within local routines and strengthen their sustainability. This helps to build a long-term culture of shared responsibility and increases support for future NbS/GI initiatives. **When communities understand the purpose and value of the interventions, many benefits arise, including the likelihood of vandalism decreasing** as the sense of ownership rises.

2.4. Assessment of vulnerabilities and ecosystem service needs

Assessing urban vulnerabilities is essential to prioritise where NbS/GI can provide the most relevant benefits. Decision-makers should begin by identifying local climate and environmental challenges, such as urban heat islands, surface-limited water absorption, biodiversity loss, or lack of accessible green space, and mapping how these pressures vary across the territory. **A good practice is to conduct spatial analyses combining climate data, runoff simulations, and land-use characteristics to identify high-need areas**, which the cities within the project followed before making green choices.

Understanding the physical characteristics of each site is equally important. Soil permeability, hydrological patterns, available space, existing vegetation, sun exposure, and underground constraints all determine which NbS are technically feasible and likely to perform effectively. Some pilots working in compact or historic areas discovered that limited excavation depth or dense utility networks restricted the use of certain typologies, prompting a focus on modular or low-impact solutions. Others identified highly sealed areas where shading and evapotranspiration were essential to reduce extreme heat.

Apart from that, **having an ecosystem services (ES) lens helps translate vulnerabilities into functional objectives**. Cities used this perspective to determine whether the priority was stormwater retention, cooling, improved habitat, recreational quality, or multiple combined benefits. In many cases, **modelling tools supported decisions**, for example, calculating the storage capacity needed for runoff or estimating cooling potential based on vegetation density. This is recommended to adjust planning to realistic expectations in the project areas.

This assessment phase not only guides typology selection but can also strengthen strategic justification for investments and tendering. When authorities can clearly demonstrate how an NbS responds to a specific vulnerability and provides measurable ecosystem services, decision-making becomes more transparent and reliable. Ideally, it also establishes a baseline for monitoring future performance.

2.5 Criteria for NbS/GI selection

The selection of NbS and GI measures should respond to the specific environmental conditions of a site and the strategic objectives of the city[3]. **An effective choice usually balances ecological performance, technical feasibility, social acceptance, and long-term needs**. In other words, the natural solutions should not only be **environmentally adequate but also technically feasible, socially supported, and economically sustainable**.

First, planners should consider the physical and environmental context, meaning local climate, soil composition, hydrology, existing vegetation, and the degree of soil sealing, in order to best determine which interventions can really function and last. The practical objectives of the project then guide refinement according to the priority, whether it is, for instance, stormwater retention, urban cooling, biodiversity

[3] D.1.1.1 - Typology and criteria for planning CCI/GI/NbS on the local level

improvement, or increasing public space quality. As NbS can deliver several benefits simultaneously, the desired ES should be clearly defined from the outset, for example, prioritising stormwater retention and flood mitigation in sealed areas, urban cooling in heat-exposed neighbourhoods, or biodiversity enhancement along green and blue corridors, while recognising additional co-benefits as added value.

In parallel, **it is crucial to understand the urban and spatial environment and the respective rules**, including land use, ownership, heritage constraints, and links to existing green or blue corridors. These points can highly influence design flexibility, required permits, and maintenance responsibilities. Apart from that, technical and operational feasibility must also be considered early, as materials, construction methods, life-cycle costs, and integration with underground utilities often determine if a concept can be accomplished.

Finally, governance and social criteria complete the selection process for a NbS measure. In this context, considering expected long-term socio-economic effects, such as health and well-being benefits, avoided infrastructure costs, or increased use and attractiveness of public spaces, can further support informed decision-making when comparing NbS/GI options. Integrating participatory processes, opportunities for community co-creation, and alignment with regulatory frameworks can significantly affect acceptance, implementation, and general long-term success. Therefore, properly **choosing NbS/GI involves an intersection between environmental evidence, institutional capacity, and public values in the decision-making process**.

2.6 Decision-support tools

Decision-support tools help cities to analyse spatial conditions, evaluate alternatives and prioritise interventions. Within GreenScape CE, a set of digital and analytical tools supported the planning process, with the GreenScape CE Visual Mapping Platform **(GVMP)** serving as the central instrument. The GVMP is the project's primary Geographic Information System (GIS)-based decision-support tool, designed to integrate environmental, spatial, and socio-technical data to guide NbS/GI planning at local and metropolitan levels (Figure 1). It enabled GreenScape pilot cities to:

- Map existing and planned NbS/GI across urban areas.
- Analyse environmental risks, such as heat islands and soil sealing and connectivity.
- Assess accessibility and connectivity of green spaces, including public vs. private green areas.
- Identify priority zones for new NbS interventions based on vulnerability and lack of green coverage.
- Support participatory and bottom-up mapping, incorporating community feedback and local knowledge.

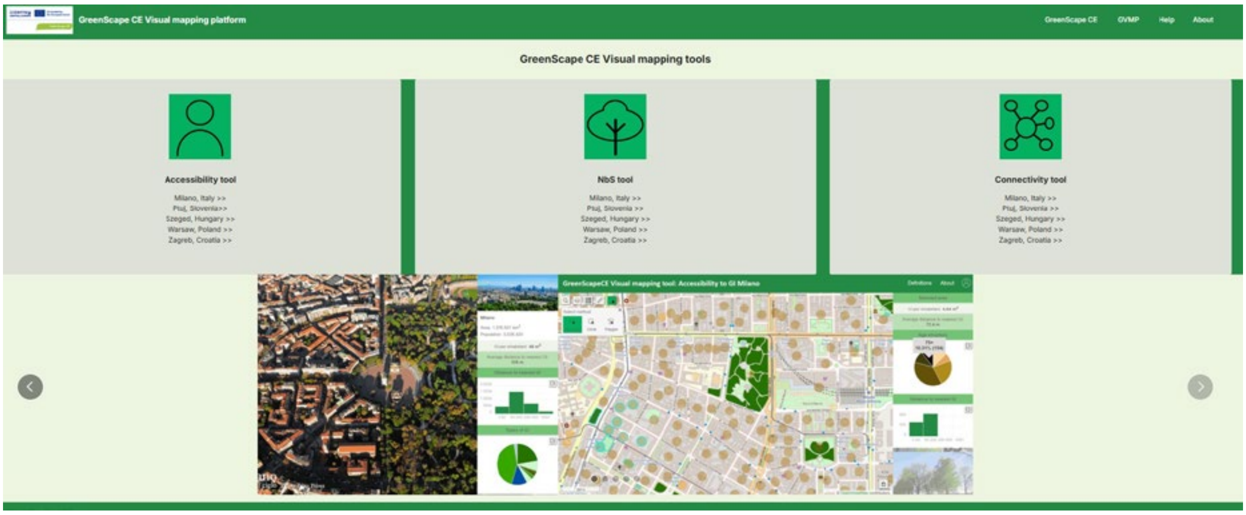

Figure 1: GreenScape CE Visual Mapping Platform homepage

Among the pilots, the Metropolitan city of Milan applied the GVMP most extensively, creating a metropolitan NbS inventory and using spatial overlays (e.g., land use, Land Surface Temperature - LST, population exposure) to identify strategic intervention sites. Other pilot cities, such as Zagreb, Ptuj, and Szeged, aligned their GIS-based suitability analyses with GVMP methodologies to ensure consistency and transferability. Apart from that, some additional decision-support tools were used in the pilot cities that are recommended for urban decision-making:

- **NbS/GI Typology and criteria:** the conceptual framework used to classify solutions and define environmental, economic, and social selection criteria.
- **Feasibility studies:** structured assessments of context, technical design options, and functional requirements.
- **Hydrological modelling:** used to size rain gardens and retention features to capture sufficient runoff and eliminate local flooding.
- **Utility and cadastral mapping:** essential for identifying underground constraints and avoiding conflicts with existing infrastructure.
- **Social and mobility analyses:** informed street redesign, stakeholder priorities, and the placement of NbS elements.

These tools played a decisive role in strengthening the evidence base for NbS/GI planning across the pilots. Through providing structured, comparable and spatially clear information, they can help enable local authorities to ground their decisions in consistent datasets (e.g., land use, environmental risks, population exposure), evaluate alternative design options transparently (e.g., different NbS typologies or locations), and align proposed interventions with broader strategic objectives (e.g., climate adaptation, health, biodiversity or spatial planning goals). At the same time, the analytical depth offered by these tools supports cities in assessing the technical and operational feasibility of NbS/GI within real-world constraints such as land ownership, underground utilities or regulatory requirements.

Among all instruments, the GVMP proved particularly valuable and can support other cities as it is a transferable and scalable resource that equips municipalities with a comprehensive framework to plan, prioritise and monitor NbS/GI interventions at both urban and metropolitan scales. For cities seeking to develop or enhance their own GIS-based decision-support systems, pilot experience suggests that key data layers include land use and soil sealing, ownership and cadastral information, environmental risk layers, green and blue infrastructure networks, population vulnerability indicators, and underground utility networks.

3. NBS/GI TYPOLOGIES AND PRACTICAL EXAMPLES FROM GREENSCAPE CE PILOT CITIES

The NbS and GI implemented across the GreenScape CE pilot cities illustrate how different typologies can respond to local vulnerabilities, planning constraints, and community needs. Although the interventions vary in scale and context, they collectively present how nature can address climate risks, improve ecological functions, and enhance urban liveability. In this sense, this section provides an overview of the typologies applied, summarises the main planning and design principles guiding their implementation, and presents a matrix linking ES to solution types.

3.1. Overview of typologies implemented

A diverse set of NbS/GI typologies was applied across the five pilot cities to address local environmental challenges. These typologies are described in detail in the document Typology and Criteria for Planning CCI/GI/NbS at the Local Level, to which readers are referred for further information. Each intervention was tailored to local environmental vulnerabilities, spatial constraints, and planning opportunities. While the measures differ in scale and form, they collectively illustrate the versatility that urban strategies can achieve when properly designed and can serve as inspiration for replication in other contexts. For this handbook, NbS/GI are presented through a functional grouping aligned with the project typology, including:

STORMWATER MANAGEMENT SOLUTIONS

As retention basins (Figure 2), rain gardens (Figure 3), bioswales, infiltration systems, widely applied in Warsaw, Ptuj, and Szeged, to mitigate surface-water flooding, increase on-site water retention, and support sponge-city approaches.

Figure 2: retention basin during the GreenScape CE study visit in Ptuj

Figure 3: rain garden during the GreenScape CE study visit in Vienna

PERMEABLE AND SEMI-PERMEABLE SURFACES

As permeable pavements (Figure 4), permeable turf, structural soils, implemented in Ptuj, Szeged, and Warsaw, to reduce soil sealing, improve stormwater infiltration, and support healthier tree growth in space-constrained urban environments.

Figure 4: permeable pavement during the GreenScape CE study visit in Vienna

URBAN GREENING

As street trees (Figure 5), native planting, green walls (Figure 6), vegetated pergolas (Figure 7) and community gardens, applied across all pilot cities, to enhance biodiversity, improve microclimate conditions, and increase the quality and usability of public spaces.

Figure 5: street trees during the GreenScape CE study visit in Warsaw

Figure 6: green walls during the GreenScape CE study visit in Vienna

Figure 7: vegetated pergola during the GreenScape CE study visit in Szeged

COOLING AND SHADING MEASURES

As shade-providing vegetation, redesigned green public spaces, green roofs (Figure 8), applied notably in Szeged, Warsaw, and Zagreb, combining vegetation, surface materials, and spatial reconfiguration to mitigate urban heat island effects.

Figure 8: green roof during the GreenScape CE study visit in Zagreb

STRATEGIC GREEN-NETWORK PLANNING

As metropolitan-scale mapping, connectivity analysis and NbS inventories, developed primarily in the Metropolitan city of Milan and informing planning approaches in Zagreb and Warsaw, to support the prioritisation and long-term integration of NbS/GI across municipalities.

Overall, **the typologies were selected based on feasibility studies, GIS-based suitability analyses, and stakeholder engagement**, ensuring that the chosen solutions respond directly to environmental needs while fitting within local physical, regulatory, and operational constraints.

3.2 Planning and design principles

Planning and designing natural solutions implementation requires an integrated and site-specific approach that aligns environmental objectives with spatial and regulatory realities. Across the cities, several principles emerged through the pilots' experience that municipalities can apply when developing similar interventions.

An important one is the need for context-sensitive analysis. For instance, understanding soil permeability, hydrology, sun exposure, vegetation potential, and underground conditions is essential to determine which typologies can function in a specific location. Compact urban areas or heritage-protected zones generally require shallow, modular, or surface-level solutions, while larger open spaces allow for more substantial infiltration and shading interventions. Therefore, technical assessments, such as runoff modelling or microclimate analysis, support more accurate design and positioning of NbS elements.

Another significant principle is multifunctionality. As mentioned before, NbS are most effective when they combine benefits like water management, cooling, biodiversity, and public-space quality. Integrating these ES within a single intervention strengthens its general performance, increases cost-effectiveness, and helps justify investment by delivering environmental and social co-benefits.

In addition, **the design choices are also shaped by regulatory and operational constraints**, including heritage protection rules, water legislation, mobility requirements, and long-term maintenance capacity. These factors influence what is technically feasible and should therefore be considered from the start. **Clarifying maintenance responsibilities early is particularly important** to ensure the durability and performance of NbS/GI.

Finally, **participatory processes can inform spatial layouts, planting schemes, and functional uses, enhancing acceptance, usability, and long-term stewardship.** To respond properly to local needs, stakeholder engagement is crucial. That being said, when environmental goals, technical feasibility, governance frameworks, and community expectations are integrated in the planning process, NbS tend to deliver meaningful outcomes.

3.3 Suitability matrix: linking vulnerabilities, ecosystem services, and NbS types

The following compact matrix in Table 1 links common climate/environmental challenges with NbS/GI types used in the pilot areas:

Table 1: urban challenges and respective suggested natural measures to counteract them

Urban challenge	Suggested NbS/GI measure	Main ecosystem service
Urban heat island	Trees, native planting, permeable surfaces	Cooling & shade
Surface flooding	Rain gardens, bioswales, retention basins, permeable surfaces	Runoff retention
Low biodiversity	Native planting, small green patches	Habitat provision
Poor public-space quality	Shaded seating, multifunctional green areas	Recreation & comfort
High soil sealing, exposure to droughts or heat	Permeable pavements, tree planting, infiltration trenches	Infiltration & cooling

Interpretation and practical relevance of the table - from pilot examples to useful recommendations

This matrix is not meant as a prescriptive list but as a decision-support logic that helps cities identify which NbS/GI types can realistically and effectively address the challenges present on a given site. Each link between challenge > service > NbS reflects lessons derived from the pilot cities and aligns with the principles of the GreenScape CE typology.

Urban heat island mitigation relies heavily on cooling and shading capacity, which is why urban trees and vegetated structures emerge as priority measures. In contexts such as Zagreb and Ptuj, tree planting had to be reconciled with underground constraints; where planting deep-rooted species was not feasible, alternatives such as pergolas, green walls, or permeable surfaces helped reduce surface temperatures while improving microclimatic comfort.

Flood-prone areas require NbS capable of retaining, storing, or filtering stormwater. Rain gardens, bioswales, and infiltration trenches were applied in cities like Warsaw, Zagreb, and Ptuj, where hydrological modelling informed the sizing of these measures. Warsaw's approach in Wileńska St. illustrates how NbS can be dimensioned to eliminate localised flooding when supported by runoff modelling.

In locations suffering from low ecological quality, NbS linked to habitat provision and connectivity become critical. Ptuj's use of native species, ecological hedgerows, and small planted patches shows how biodiversity gains can be achieved even in compact, historic, or densely built settings. These solutions help reconnect fragmented green elements into functional ecological networks.

Where the main issue is the lack of quality public space, NbS that enhance comfort, usability, and social value take priority. Zagreb's pilot demonstrates how multifunctional NbS, combining shading, permeable surfaces, and community-led design, can transform degraded areas into inclusive, climate-resilient recreational spaces.

Finally, **in highly sealed environments, NbS that promote infiltration and soil regeneration, such as permeable pavements or infiltration swales, are essential** to restore water cycles. This was also evident in Szeged, where the tram-stop redevelopment combined permeable surfaces with tree planting to address soil sealing and heat exposure in a transport-dominated setting.

4. TECHNICAL AND TENDERING SOLUTIONS FROM GREENSCAPE CE PILOT CITIES

4.1 Metropolitan city of Milan

Milan focused on the creation of a metropolitan-scale inventory and decision-support system for NbS/GI rather than physical implementation[4]. The intervention harmonised fragmented datasets, classified NbS types across 133 municipalities, distinguished publicly accessible versus private green areas, and identified priority zones exposed to heat stress or lacking green accessibility. Table 2 presents the city's measures in detail.

Table 2: Milan - Metropolitan mapping and strategic planning

KEY NBS TYPES	Urban forests, permeable surfaces, green roofs/walls, infiltration systems
CONTEXT	Metropolitan-scale integration across 133 municipalities
PURPOSE	Identify, classify, and prioritise NbS/GI at the regional scale
HIGHLIGHTS	Unified NbS inventory and accessibility/connectivity mapping

The city adopted a service-procurement model, contracting GIS, cartography, and environmental planning specialists. The process followed a modular structure, with sequential work packages for data harmonisation, GIS modelling, validation, and platform integration. It is significant to mention that the pilot introduced a unified data standard for NbS/GI across the metropolitan area and delivered a transferable GIS methodology integrated into the GVMP. In addition, the interoperability, open data, and replicability make this approach a technical foundation for future works and procurement of physical NbS across the region.

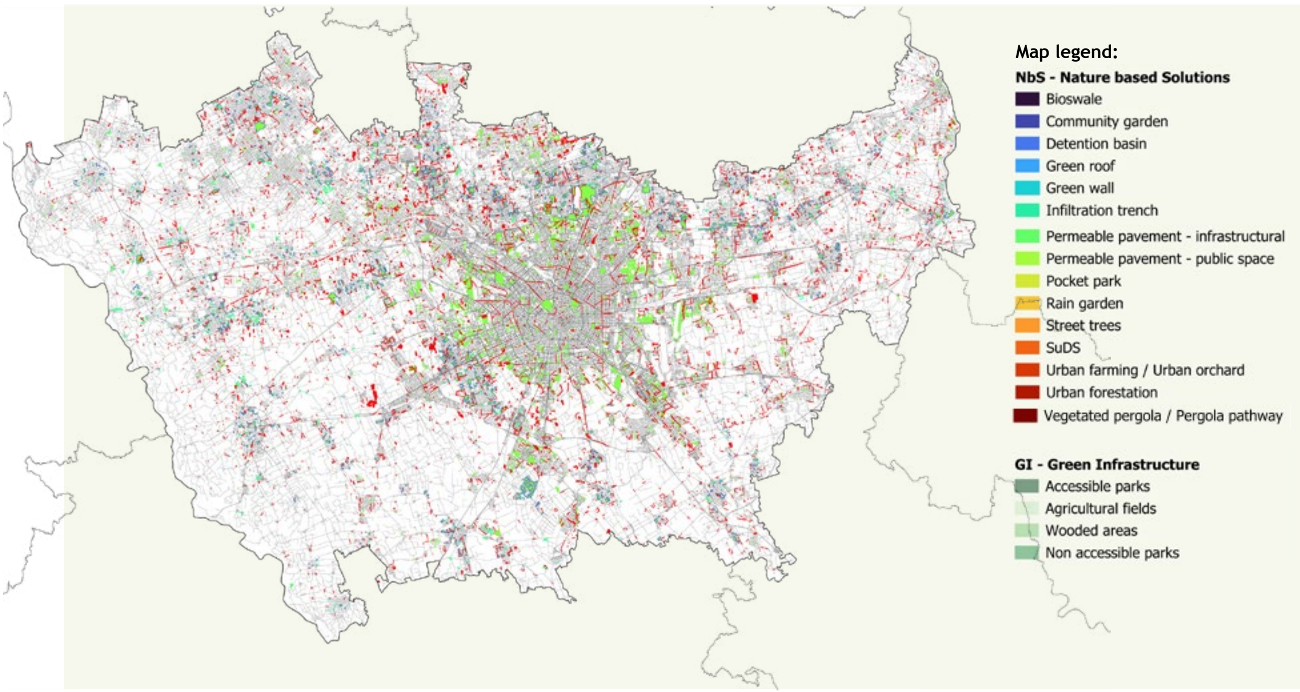

Figure 9: Milan technical solution

[4] D.2.4.4 - Report on Pilot Action – Technical and Tendering Solutions

4.2 Ptuj

Ptuj designed and aims to implement small-scale NbS in areas with severe spatial and regulatory constraints. Interventions included permeable pavements, rain gardens, improved tree-growing conditions and pocket greening solutions. These intend to address mainly water stagnation, urban heat, and the absence of vegetation both in the historic centre and surrounding residential streets. Table 3 indicates the municipality's main interventions.

Table 3: Ptuj - NbS in a dense historic environment

KEY NBS TYPES	Permeable pavements, rain gardens, urban trees, small-scale greening
CONTEXT	Constrained heritage area with dense underground utilities
PURPOSE	Reduce runoff, introduce greenery, and improve microclimate
HIGHLIGHTS	Modular NbS adapted to limited space and heritage rules

The city relied on standard public works procurement, but unusually detailed technical documentation was required due to heritage restrictions, narrow spaces, and dense utility infrastructure. Contractors needed precise drawings, soil specifications, and planting requirements to avoid delays and reworks. Then, Ptuj developed internal templates for NbS specifications, since national procurement frameworks lack standardised NbS clauses. The use of compact and modular NbS solutions allows effective implementation in restricted spaces and reduced risks of conflicts with underground infrastructure. Figure 10 illustrates this strategy.

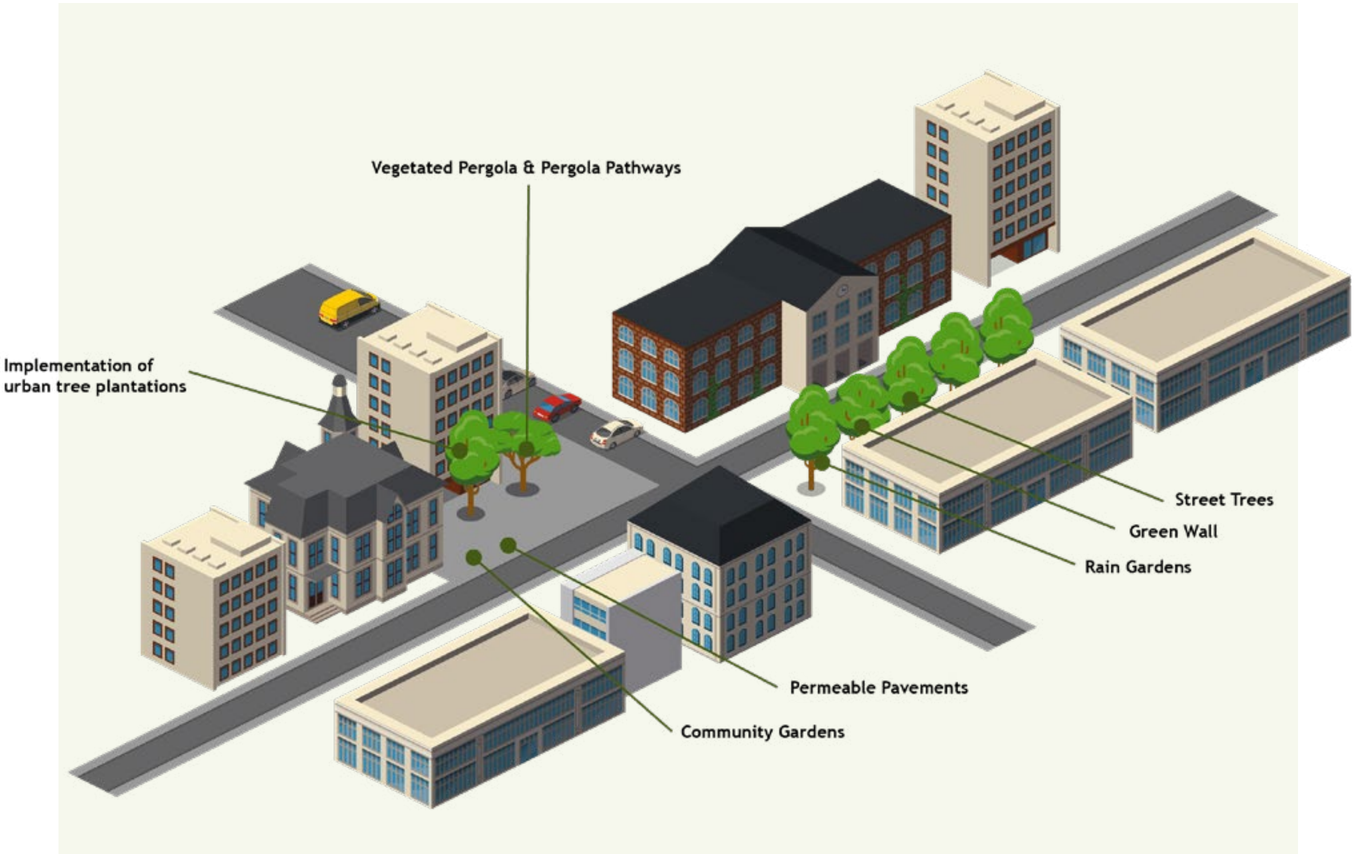

Figure 10: Ptuj technical solution

4.3 Szeged

Szeged is redesigning the Szivárvány tram stop to address heat, poor drainage, and poor pedestrian comfort. The pilot introduced permeable surfaces, shallow planted strips, and drainage improvements within a highly constrained transport environment. Further information is presented in Table 4.

Table 4: Szeged - Climate-resilient transport node

KEY NBS TYPES	Permeable surface, planted strip, improved drainage
CONTEXT	Tram stop environment exposed to heat and runoff issues
PURPOSE	Improve infiltration capacity and environmental comfort
HIGHLIGHTS	Shallow solutions designed around utility constraints

Due to the site intersecting tram infrastructure, procurement followed strict Hungarian and European Union (EU) rules for public works. Coordination with multiple municipal departments and the tram operator was necessary, and the works contract required detailed civil engineering specifications and safety conditions. In parallel, Szeged applied modular construction and emphasised early multi-stakeholder coordination to minimise redesign needs. The tender integrated both technical (infiltration, drainage, material performance) and accessibility standards, linking NbS functions with transport-system upgrades, as shown in Figure 11.

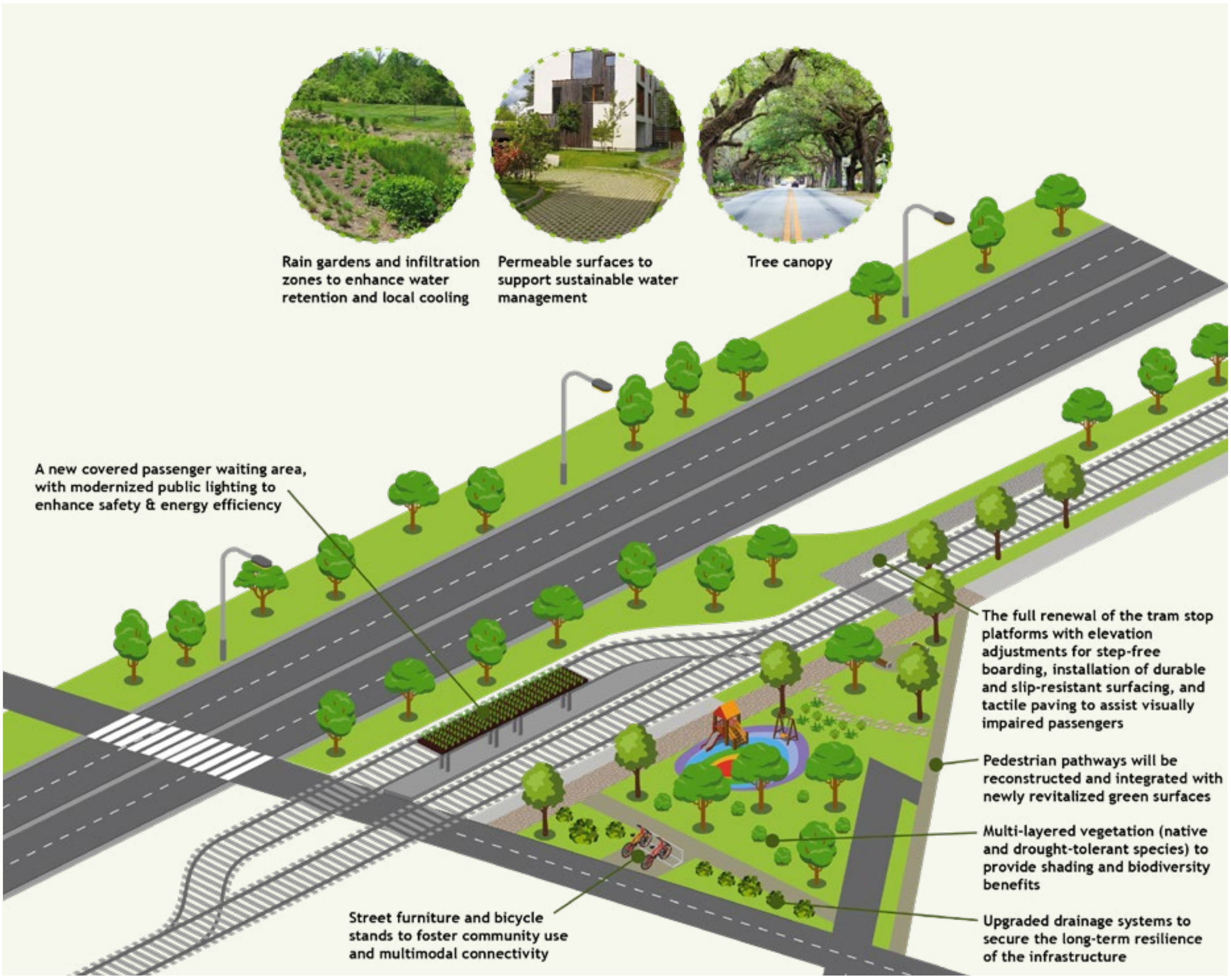

Figure 11: Szeged technical solution

4.4 Warsaw

Warsaw is transforming the Wileńska Street into a climate-resilient corridor using a sponge-city approach. Rain gardens, retention basins, permeable surfaces and shading elements were integrated to reduce runoff, improve microclimate, and enhance public-space quality while supporting active mobility. Table 5 provides more information on the local measures.

Table 5: Warsaw - Street-scale sponge-city approach

KEY NBS TYPES	Rain gardens, retention basins, native vegetation
CONTEXT	Mixed-use street with recurrent surface-water flooding
PURPOSE	Capture runoff and improve the pedestrian environment
HIGHLIGHTS	Hydrological modelling to size retention features

The city procured a design-and-documentation package through competitive tendering, combining hydrological studies, traffic analysis and social research. Price remained a mandatory criterion, which required careful balancing between cost-efficiency and technical quality. The innovative element was the incorporation of hydrological modelling directly into the tender requirements, ensuring that NbS elements were dimensioned to eliminate flooding under defined rainfall conditions. Figure 12 presents how Warsaw also created a unified documentation package combining mobility, drainage and NbS design, strengthening coherence across sectors.

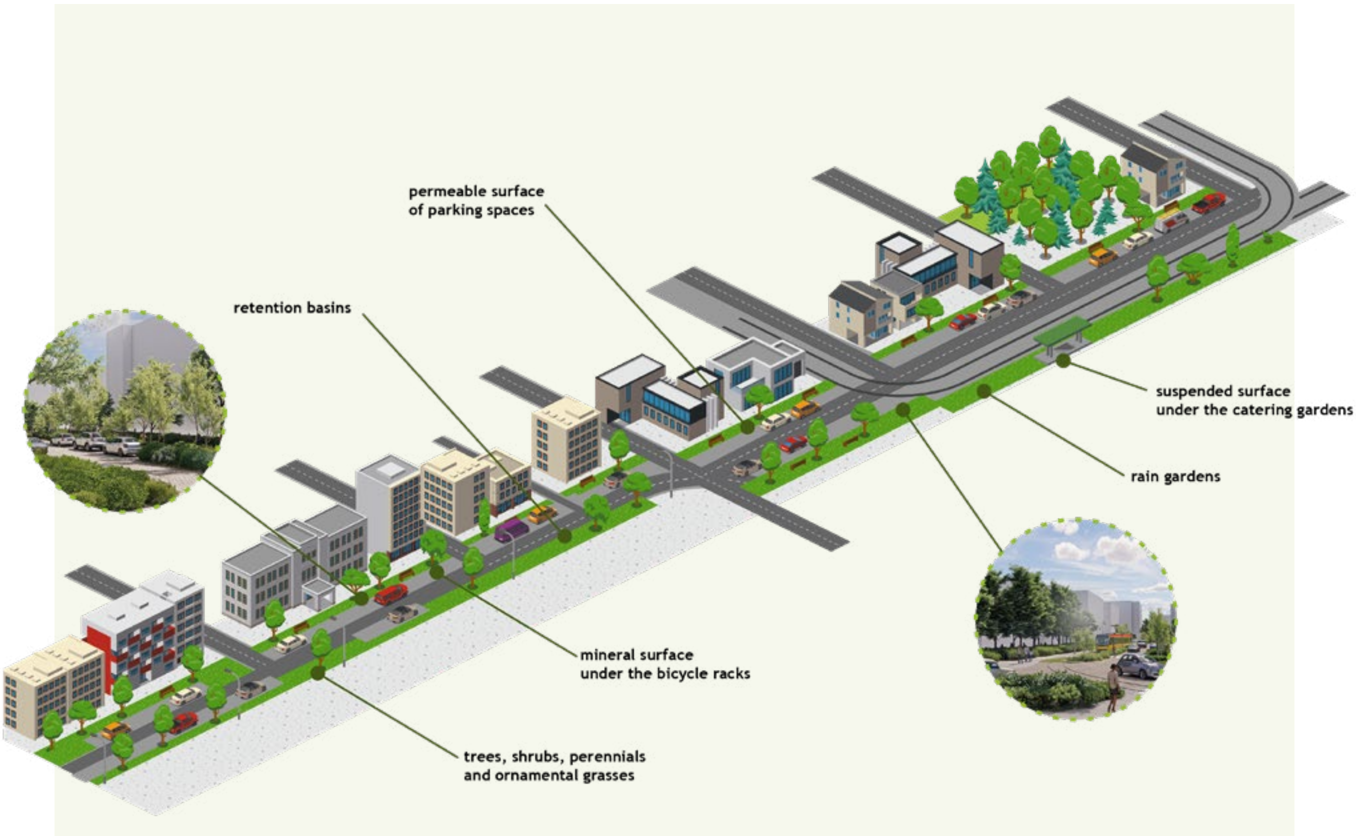

Figure 12: Warsaw technical solution

4.5 Zagreb

Zagreb is redesigning a degraded asphalt sports field in Novi Zagreb into a multifunctional, climate-resilient green area. Permeable synthetic turf, bioswales, infiltration strips, and rainwater harvesting were combined to mitigate heat, reduce runoff and create a more comfortable community space. Table 5 indicates Zagreb's measures in detail.

Table 6: Zagreb - Permeable sport and community area

KEY NBS TYPES	Permeable turf, bioswales, rainwater tanks, native planting
CONTEXT	Large, asphalted sports field under high heat stress
PURPOSE	Reduce heat and manage stormwater onsite
HIGHLIGHTS	Sports surface functions as a permeable retention system

The city implemented a multi-lot procurement structure to separate specialised components while meeting strict requirements under national water regulations and addressing unresolved land-ownership constraints. A key innovation was the integration of co-creation outputs (from community workshops and a design hackathon) directly into the technical documentation. The design also strategically selected a site with a separate stormwater system and adapted NbS elements to fit within restrictive water-management regulations, as shown in Figure 13.

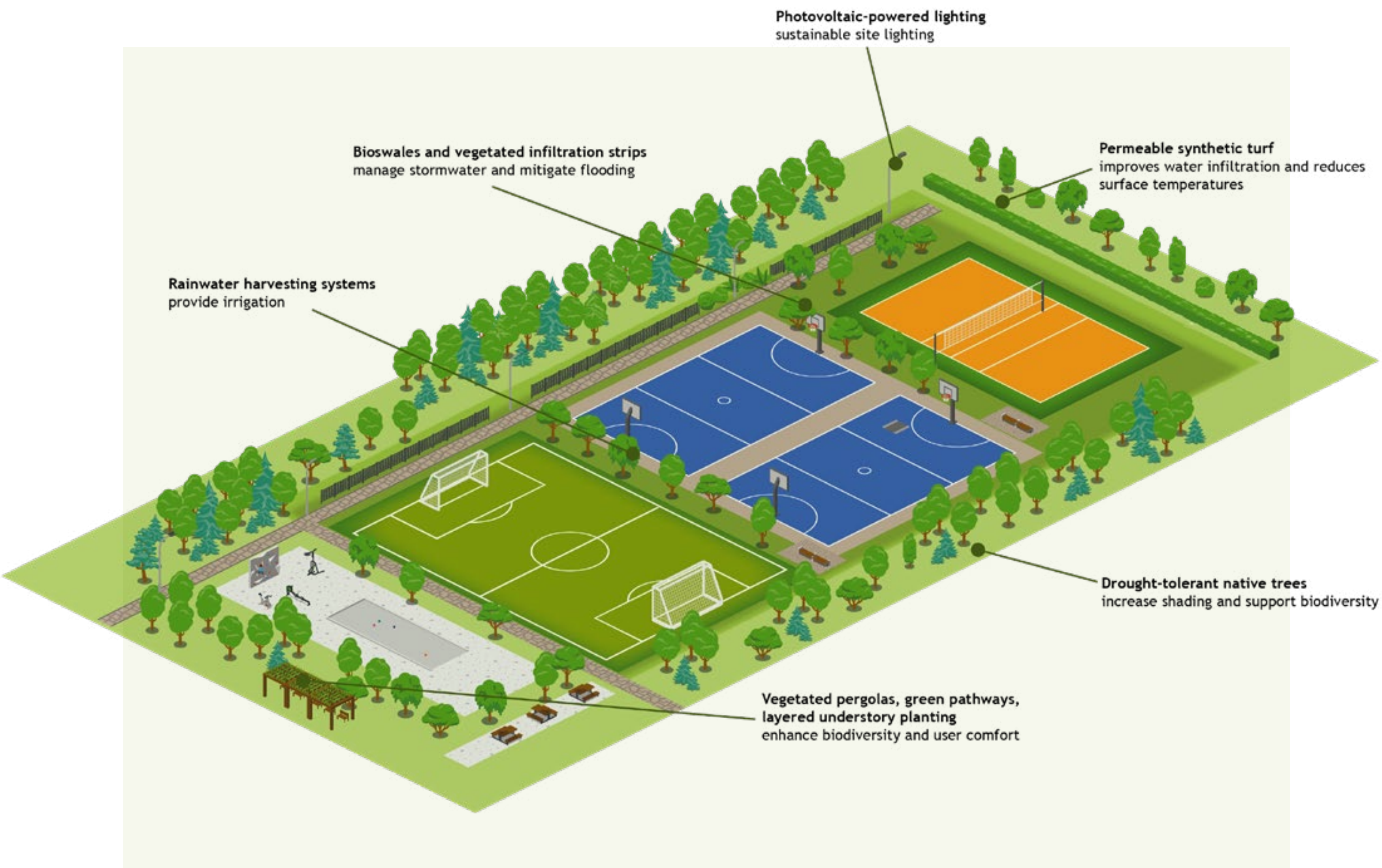

Figure 13: Zagreb technical solution

5. COMMON CHALLENGES AND HOW TO OVERCOME THEM

The implementation process of NbS across the pilot cities revealed a set of challenges that are likely to be encountered by other municipalities pursuing similar approaches. These challenges are not limited to technical design but also relate to procurement frameworks, institutional coordination, and long-term operational capacity. Addressing them early and systematically proved essential to ensure feasibility, avoid delays, and secure durable outcomes. This section summarises the main barriers identified and indicates practical steps adopted by the cities to overcome them, while aiming to inspire and support future similar developments.

5.1 Understanding technical barriers

One of the most common challenges identified in the pilots is the difficulty to integrate natural measures into dense urban environments characterised by limited space, high levels of soil sealing, and often complex underground infrastructure. These conditions usually constrain design options and require careful adaptation of standard NbS typologies, considering each context. Historic areas, transport corridors, and multifunctional public spaces tend to be particularly sensitive areas, where heritage protection, safety requirements, and accessibility standards further limit technical flexibility.

In order to respond to these challenges, **the pilot actions have relied so far mostly on site-specific and adaptive design approaches**. NbS/GI solutions have been adjusted in scale, depth, and composition to fit local conditions, for instance, through shallow infiltration systems, compact planting schemes, or permeable surfaces compatible with existing subsoil and utility layouts. Early technical surveys and iterative design processes have also helped identify constraints in advance and reduce the need for costly redesigns during implementation.

In parallel, long-term technical performance has emerged as a key consideration among cities. To address this, the pilots are prioritising reliable and solid construction methods, climate-resilient plant species, and materials suited to local maintenance capacities. Through the integration of operational and maintenance considerations into the design phase, cities trust that this approach is going to strengthen the durability and reliability of NbS/GI interventions over time.

5.2 Improving tendering and procurement procedures

In turn, based on the pilot experiences, **procurement frameworks seem designed mainly for conventional grey infrastructure**[5]. This often creates extra challenges as they are often insufficient to capture the multifunctional nature of NbS/GI. In many cases, rigid procedures, limited flexibility in tender specifications, and a strong emphasis on the lowest price can put interesting projects at risk, which also tends to lead to undermining design quality and environmental performance.

Aiming to respond to these issues, **the pilot cities are progressively adapting tendering approaches to better reflect NbS/GI characteristics**. Procurement documents now increasingly focus on functional and performance-based requirements, such as expected ecosystem services or environmental outcomes (e.g., stormwater retention capacity, shading performance, soil permeability, or vegetation survival rates), rather than narrowly defined technical solutions. This allowed greater design flexibility while

[5] D.2.2.3 - Overview of Best practices in the tendering processes for implementation of the NbS/GI

maintaining clear expectations regarding performance and quality.

The experience gained through pilot tenders has also contributed to improve internal capacity. Lessons learned informed clearer technical descriptions, more realistic cost estimates, and better alignment between design objectives and procurement criteria. These adjustments are reducing uncertainty for both contracting authorities and bidders, supporting smoother implementation and more consistent outcomes.

5.3 Strengthening institutional and governance coordination

NbS/GI projects often cross the interface of multiple policy domains, including, for instance, spatial planning, water management, green space maintenance, transport, and public works. Fragmented responsibilities and limited coordination between departments of the municipality or agencies can, and in the pilots' case, have been, a recurring challenge during planning and implementation.

For this reason, the cities have focused on early and continuous coordination among relevant institutional actors. In other words, regular exchanges between planning authorities, technical departments, utility providers, and regulatory bodies have helped clarify responsibilities, identify constraints at the beginning of any action, and align technical solutions with regulatory requirements. This proactive approach is effective in preventing delays related to land ownership, permits, or compliance with sectoral regulations.

Beyond administrative coordination, including NbS/GI projects (such as urban greening, stormwater management and cooling measures) within existing planning instruments and strategic frameworks seems to strengthen institutional ownership and long-term commitment. When this strategy is combined with stakeholder engagement and co-creation processes, these governance practices enhance acceptance, clarify maintenance responsibilities, and support the sustained integration of NbS/GI into local urban development processes.

6. KEY TAKEAWAYS AND RECOMMENDATIONS

The pilot actions implemented within the GreenScape CE project have generated an integrated body of knowledge on how NbS and GI implementation perform in real urban conditions. Beyond delivering site-specific improvements, the pilots have provided evidence on technical effectiveness, institutional readiness, and the coherence required between planning, design, and procurement processes. This section synthesises the main lessons learned and outlines the expected environmental, social, and economic impacts, with a view to supporting replication and upscaling in other urban contexts, including the European context and others.

6.1 Technical performance and Key Performance Indicators (KPIs)

The **pilot actions indicate that well-designed natural measures can deliver significant and measurable improvements** across varied performance dimensions when aligned with local conditions and supported by appropriate monitoring frameworks. The key performance areas identified across the pilots include stormwater retention and infiltration capacity, reduction of surface temperatures, enhancement of urban biodiversity, and improvement of environmental comfort in public spaces.

While monitoring periods differ and long-term data collection is ongoing, common indicators being used or defined by the cities include surface permeability rates, estimated runoff reduction, temperature moderation effects, vegetation survival rates, and accessibility of green spaces. The selection and interpretation of these indicators are consistent with the project's analysis of long-term environmental and socio-economic benefits of NbS/GI, as presented in one of the GreenScape CE outputs, Overview of socio-economic long term benefits of GI/NbS[6]. In addition, the project pilots evidence that NbS/GI performance is strongly influenced by site-specific factors such as soil conditions, maintenance regimes, and integration with existing infrastructure, emphasising the importance of early technical assessments and adaptive design when necessary.

A key lesson is that performance expectations need to be realistic and context-sensitive. Apart from that, **instead of maximising a single indicator, successful NbS/GI interventions should balance multiple objectives, thereby delivering moderate but cumulative benefits** that increase resilience at the neighbourhood or city scale.

For cities looking to replicate these approaches, the practical implication is to define KPIs before design finalisation — not after — so that monitoring frameworks are built into project specifications from the outset. Indicators such as surface permeability, estimated runoff reduction, temperature moderation, and vegetation survival rates should be selected based on the primary objectives of each intervention and verified against the site-specific conditions documented during early technical assessments.

6.2 Coherence between technical and tendering aspects

One of the most significant lessons learned concerns the need for strong alignment between technical design intentions and procurement procedures. Where tender documents clearly reflected the functional objectives of NbS/GI, for example, as water retention, cooling, or multifunctional use, implementation was smoother and outcomes more consistent with initial planning goals.

[6] D2.1.3 - Overview of socio-economic long-term benefits of GI/NbS

On the other hand, misalignment between design complexity and procurement frameworks led to delays, clarification requests, or reduced flexibility during construction. The pilots' work indicates that aligning collaboration from the beginning between technical teams and procurement units is essential to translate innovative NbS/GI concepts into feasible and legally reliable tender specifications.

The experience obtained through the implementations so far also highlights the value of **flexible procurement approaches that allow adaptive solutions while maintaining clear performance criteria**. Besides, embedding maintenance responsibilities, material quality requirements, and performance expectations into contracts has proved particularly important for safeguarding long-term effectiveness.

In practical terms, municipalities aiming to replicate these approaches should consider introducing a pre-tender alignment checkpoint: a structured review involving both technical and procurement teams to verify that functional objectives, site-specific conditions, and performance criteria are consistently reflected across all tender documents before publication. This step can significantly reduce clarification requests and reduce the risk of implementation diverging from original planning goals.

6.3 Environmental, social, and economic impacts

Considering the environmental positive impacts being pushed through the pilot actions, there is improvement of stormwater management, reduced heat stress, enhanced soil permeability, and increased urban biodiversity. When replacing or complementing grey infrastructure, **NbS/GI interventions contribute to more resilient urban ecosystems and improved climate adaptation capacity**.

In parallel, s**ocial impacts are equally significant, especially where NbS/GI are embedded in public spaces and shaped through participatory processes**. The pilots' design has the potential to improve the quality, usability, and attractiveness of urban environments, supporting recreation, social interaction, and a stronger sense of place, leading to healthier living (physically and mentally). In several cases, co-creation processes also increased awareness of climate adaptation and fostered shared responsibility for green spaces.

From an economic perspective, **while initial investment costs can be higher than conventional solutions, the pilots indicate potential long-term savings through reduced flood damage, lower cooling needs, and shared maintenance responsibilities**. Also, NbS/GI can generate indirect economic benefits by enhancing the attractiveness and liveability of urban areas, among other co-benefits[7].

6.4 Key takeaways

Even though pilots are still ongoing, several cross-cutting lessons have already emerged from the projects' experience. First, NbS/GI are most effective when treated as integral components of urban systems rather than isolated interventions. Second, early investment in planning, data collection, and institutional coordination significantly reduces implementation risks. Third, technical innovation must be matched by adaptive procurement and clear governance arrangements to ensure feasibility and durability. Finally, the pilots confirm that incremental and modular approaches can be particularly effective, allowing cities to test, learn, and refine NbS/GI solutions over time. Table 7 presents a summary of the takeaways mentioned.

[7] D.2.3.5 - Technical documentation with selected financing models

Table 7: Key takeaways from pilot actions and implications for replication

Key takeaway	Evidence from pilot actions	Implications for replication
NbS/GI perform best when integrated into wider urban systems	Pilots show stronger outcomes when NbS are linked to drainage, mobility, and public-space functions rather than implemented as stand-alone elements	NbS/GI should be embedded in integrated urban planning and infrastructure strategies
Early technical assessment reduces implementation risks	Soil conditions, underground utilities, and hydrology strongly influence feasibility and final design choices	Early site assessments and data collection are essential before design finalisation
Alignment between design and procurement is critical	Clear functional requirements in tender documents support smoother implementation and better outcomes	Technical objectives should be translated into performance-based procurement specifications
Multifunctionality strengthens impact and acceptance	Solutions delivering combined environmental and social/health benefits are more robust and better accepted	NbS/GI should be designed to address multiple objectives simultaneously
Maintenance planning is a determinant of long-term success	Unclear maintenance responsibilities create risks for long-term performance	Maintenance roles and requirements must be defined from the planning and tendering phases
Modular and scalable solutions support implementation	Smaller, modular interventions allow flexibility and adaptation to local constraints	Incremental and modular NbS/GI approaches facilitate replication and upscaling
Co-creation enhances usability and ownership	Participatory processes improve design relevance and user acceptance	Stakeholder engagement should be integrated throughout planning and implementation

These lessons can provide a solid foundation for replication and upscaling, informing the guidance presented in the following section.

6.5 Policy and governance recommendations

The successful replication and upscaling of NbS/GI do not depend only on technical solutions, but on enabling policy and governance conditions. Based on the lessons learned, the following recommendations can support municipalities and public authorities in mainstreaming NbS/GI across urban development processes:

1. Strengthen strategic integration

- Integrate NbS/GI objectives within spatial plans, climate adaptation strategies, and sectoral policies, ensuring coherence across scales.
- Align NbS/GI with existing urban priorities (e.g., flood risk management, heat mitigation, mobility, public space quality) to increase institutional ownership.

2. Improve governance and coordination

- Foster early and continuous coordination between planning, environmental, infrastructure, and procurement departments.
- Clarify the roles and responsibilities across institutions, especially for implementation and long-term maintenance.

3. Encourage cross-departmental working groups or focal points dedicated to NbS/GI

- Enable procurement frameworks adapted to NbS/GI characteristics.
- Promote performance-based and quality-oriented procurement criteria that reflect the multifunctional nature of the chosen measures.

4. Develop internal guidelines and/or standard technical references for NbS/GI to reduce uncertainty in tendering processes

- Allow sufficient flexibility in procurement to welcome site-specific design and adaptive solutions.
- Support scaling through data and evidence.

5. Institutionalise the use of decision-support tools, such as GIS-based mapping platforms, to guide prioritisation and investment

- Encourage monitoring and evaluation frameworks that link NbS/GI performance to environmental, social, and economic outcomes.
- Use pilot experiences (like the ones present in this handbook) and data to inform future policy revisions and investment decisions.

6. Invest in capacity-building and long-term sustainability

- Strengthen technical capacity within public administrations through training and knowledge exchange.
- Support continuous learning through transnational cooperation and peer-to-peer knowledge exchange.
- Ensure that financing and governance models consider the complete life cycle of NbS/GI, including operation and maintenance.

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