



Nature-based Infrastructure Whitepaper

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Table of Contents

Management Summary	5
1 Introduction	6
1.1 Background and Context	6
1.2 Vision	7
1.3 Purpose and Objectives	7
1.4 Scope and Limitations of the Document	7
2 Conceptual Foundations	8
2.1 Service Demand and Resource Consumption	8
2.2 Principles of the Circular Economy for Open Space Design	8
2.3 Definition of Nature-Based Infrastructure	9
2.4 Distinction from Related Concepts	10
2.4.1 Ecological Infrastructure	10
2.4.2 Nature-based Solutions (NbS)	10
2.4.3 Green, Blue, Brown, Grey and Yellow Infrastructure	10
2.4.4 Porous Infrastructure	11
2.5 Contribution to Critical Infrastructure	11
3 Ecosystem Services in the Built Environment	11
3.1 Categories of Ecosystem Services	12
3.2 Ecosystem Cycles	12
3.2.1 Water Cycle	12
3.2.2 Carbon Cycle	13
3.2.3 Nutrient Cycle	13
3.3 Boundary Conditions and Resources	13
3.3.1 Microclimate Regulation	13
3.3.2 Ecological Factors and Habitat Creation	14
3.3.3 Noise	14
3.3.4 Pollutants	14
3.3.5 Light	15
3.4 Social and Cultural Processes	15
3.5 Intersections and Related Fields	15
4 Performance Dimensions of Nature-Based Infrastructure	16
4.1 Impact-Oriented Framework for NBI	16
4.2 Overarching Objectives	18
4.3 Design Relevant Objective Categories	18
4.4 Interactions and Planning Implications	18
5 Levels of Analysis and Intervention	18
5.1 Overview of the Levels	19



5.2	Levels of Analysis	19
5.2.1	Regional Level	19
5.2.2	Neighbourhood Level	19
5.3	Levels of Intervention	19
5.3.1	Plot Level	20
5.3.2	Element Level	20
5.4	Connectivity and Connectedness	20
5.5	Impacts of Use	21
6	Elements Influencing Ecosystem Services	21
6.1	Element Categories	21
6.2	Open Spaces	21
6.3	Surfaces	21
6.4	Vegetation	21
6.5	Underground	22
6.6	Connections and Transitions	22
6.7	Furnishings	22
6.8	Interplay of Elements	22
7	Key Performance Indicators (KPIs)	23
7.1	Indicators by Level	23
7.2	Requirements for Key Performance Indicators (KPIs) for Nature-Based Infrastructure	24
8	Collaboration Processes	24
8.1	Common Understanding	24
8.2	Involved Disciplines and Collaborative Culture	25
8.3	Building the Case for Nature-Based Infrastructure	26
8.4	Information Requirements by Level	26
9	Current Opportunities and Barriers for Nature-Based Infrastructure	27
9.1	From Measures to Impact Objectives	27
9.2	Multifunctionality and Quality of Nature-Based Infrastructure Building Blocks	27
9.3	Integrated Systems, Operations and Maintenance	28
9.4	Data, Digitisation and Transformation	28
10	Fields of Action	29
10.1	A Shift in Perspective	29
10.2	Strategic Levers	29
10.3	Organisational and Procedural Levers	30
10.4	Priorities for Further Development	30
11	Outlook: Potential Tools and Next Development Steps	32
11.1	Web Based Awareness Raising Tool (Proof of Concept)	33
11.2	Assessment Methodology for Ecosystem Service Performance	33
11.3	Life Cycle Assessment Methodology for Open Space Design	34



11.4	Pathway from Whitepaper to Standardisation	35
12	References	36
13	Imprint	38
14	Appendix A – Key Performance Indicators (KPIs)	39
15	Appendix B – Element and Attribute List	39
16	Appendix C – Process Matrix	40
17	Appendix D – Gap Analysis	41
18	Appendix E – Further Reading	41
19	Appendix F – Examples	42
20	Appendix G – Glossary	50



Management Summary

Climate change, biodiversity loss, demographic change and population growth are increasing heat stress, health risks and damage risks in urban areas. At the same time, statutory requirements call for urban densification, climate protection and resource conservation. Conventional technical infrastructure is increasingly reaching its capacity limits while generating substantial greenhouse gas emissions and resource consumption.

Solution Approach

Circular and regenerative systems provide an approach to addressing these challenges. They keep resources in circulation, strengthen natural regeneration processes and simultaneously support ecological performance, economic viability, public health and infrastructure capacity. Nature-based infrastructure (NBI) plays a key role in this context. It provides essential infrastructure services including microclimate regulation, water retention and purification, pollutant regulation, oxygen production, biodiversity enhancement, support for human health and protection against environmental hazards. Due to these critical functions, nature-based infrastructure should be recognised as critical infrastructure and treated, planned, developed and maintained on an equal footing with built and technical infrastructure systems.

Objectives of the Whitepaper

This whitepaper establishes nature-based infrastructure as an integral component of circular and regenerative urban development. It provides a performance-oriented framework that starts from societal objectives and translates them into clear requirements for planning, construction, operation and maintenance. The framework serves as a common reference for policymakers, public authorities and practitioners.

Conceptual Framework

The framework is based on a shared understanding of ecosystem services. Natural resources such as soil, water and energy form the foundation. Spatial structure, vegetation, construction, materialisation and maintenance influence ecosystem processes and determine their performance. Within circular systems, planning and operational management deliberately align these factors with local regeneration processes, thereby reducing dependence on external resources and inputs.

Implementation and Action Needs

Nature-based infrastructure requires consideration across multiple spatial scales, including regions, neighbourhoods, plots and individual infrastructure elements. The plot or development area represents the most important scale of intervention because strategic objectives are translated into concrete actions at this level. The whitepaper demonstrates that many relevant foundations already exist, but they remain insufficiently connected across planning, construction and operational processes. The integration and scaling of nature-based infrastructure are hindered by the absence of consistent performance indicators, limited availability and accessibility of data, missing digital standards, insufficient interdisciplinary collaboration, and gaps in maintenance and operational practices focused on the delivery of ecosystem services.

Positioning

This whitepaper serves as both a common reference framework and a strategic guide for action. It provides the professional foundation required to systematically and effectively integrate nature-based infrastructure into planning, construction, operation and maintenance processes as an equal component of infrastructure systems. In doing so, it contributes to the creation of more climate resilient, healthy and future-ready built environments.



1 Introduction

1.1 Background and Context

Population growth, demographic change, climate change and biodiversity loss are intensifying the risks associated with heat, drought and extreme weather events. The resulting impacts on public health, safety and the security of essential services affect urban areas particularly strongly. Natural water storage systems in glaciers, ice and snow are shrinking dramatically as a result of rising temperatures and increasingly dry winters [1]. Heat related mortality is now almost twice as high as the number of traffic fatalities [2]. Labour productivity on hot days declines by approximately one quarter [3], while temperatures exceeding 30°C are associated with a significant increase in workplace accidents [4]. At the same time, damage caused by extreme weather events is increasing substantially [5].

Approximately 85 per cent of Switzerland's population already lives in urbanised and densely populated areas, and this proportion continues to grow. These areas are already heavily affected by heat, drought and extreme weather events. At the same time, the Swiss Spatial Planning Act limits further urban expansion, while net zero targets and objectives related to security of supply require resource efficient and climate resilient urban development based on inward densification. New legal foundations supporting this transition have been established through the Climate and Innovation Act (KIG) and the Environmental Protection Act (USG, Articles 10h and 35j).

Conventional technical infrastructure systems, such as wastewater networks and mechanical cooling systems, are increasingly reaching their limits. Nature-based solutions offer simple, decentralised and ecologically effective alternatives. They mitigate urban heat, store and regulate water, improve air quality, enhance biodiversity and create healthy open spaces. When connected into a coherent nature-based infrastructure network across the built environment, their performance, multifunctionality and resilience increase significantly. In practice, however, they are often considered too late in project development processes and implemented only in isolated fragments because clear requirements for planning, implementation, operation and maintenance are lacking.

Particularly within building construction projects, considerable potential remains for performance improvement. Limited understanding of the functioning of nature-based solutions and their performance relevant components, unclear responsibilities, a lack of standardisation, and consequently insufficient integration into digital planning processes hinder early communication, efficient project development and integrated monitoring. As a result, nature-based infrastructure is often not incorporated at an early stage and its long-term development, maintenance and capacity to deliver ecosystem services are compromised. This leads to higher costs, unnecessarily redundant technical solutions and missed opportunities to enhance infrastructure performance and resilience while reducing greenhouse gas emissions and resource consumption.

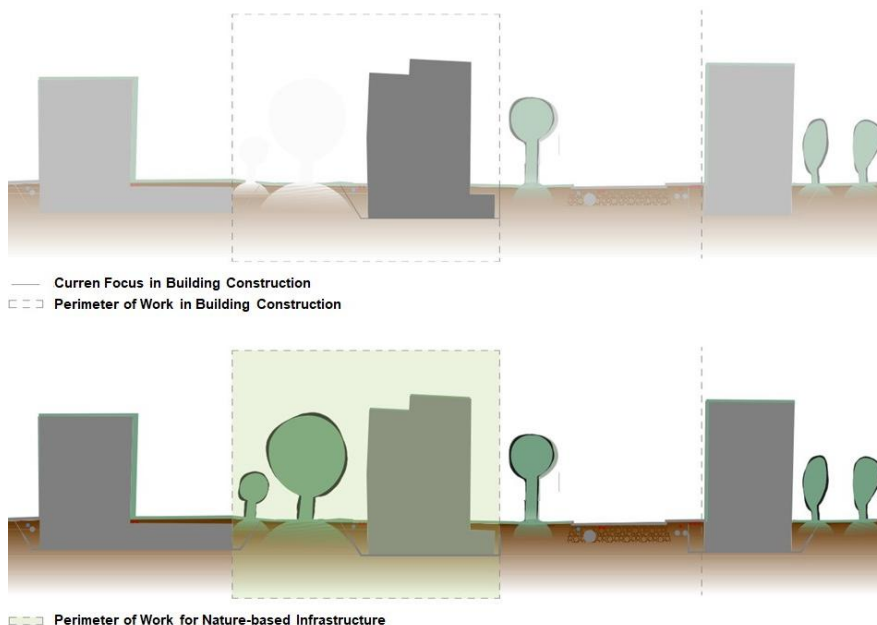


Figure 1: Current and Desired Focus in Building Construction / Source: sysTEAMatik GmbH



1.2 Vision

Built environments are planned and developed to be safe, healthy, climate resilient, biodiverse and liveable, while minimising environmental impacts and resource consumption and maximising local regeneration. Open spaces, buildings and infrastructure form an integrated system designed to deliver the ecosystem services required to support human well-being and ecological functioning. The plot or development area constitutes the smallest unit for planning, coordination and optimisation. Boundaries between plot are deliberately designed as connectivity zones, to create a continuous, coherent and high performing nature-based infrastructure network. These objectives are formally defined and systematically embedded throughout planning, construction, operation and maintenance processes.

1.3 Purpose and Objectives

The objective is to establish open space design with high performing nature-based elements as an integral component of resilient and future oriented development of the built environment. Connected nature-based elements should be understood as providers of ecosystem services and as core components of critical infrastructure [6], rather than as decorative additions. Climate resilient, biodiverse and socially inclusive built environments emerge through the integration of nature-based and technical infrastructure systems, both underground and within open space defining surfaces such as pavements, façades and roofs. The result is a multifunctional environment with a high quality of place that strengthens ecology, local identity and building culture while simultaneously delivering effective ecosystem services. nature-based solutions complement or substitute technical infrastructure and provide safety, health and quality of life through resource efficient low technology systems. Biodiversity represents a fundamental performance and resilience factor within these systems.

This whitepaper presents an impact-oriented framework and a practice-based methodology. It demonstrates how nature-based infrastructure (NBI) can be planned, implemented, operated and maintained throughout the project lifecycle.

The document provides a common interdisciplinary basis for understanding and collaboration among real estate development, planning, construction and operations teams. It establishes a foundation for consistent communication across all lifecycle phases of open spaces and real estate assets, supports the integration of digital methods and facilitates the incorporation of nature-based infrastructure (NBI) into existing processes. Furthermore, it identifies current gaps and potential fields of action and promotes efficient, impact-oriented implementation at the interface between risk management and high-quality open space development focused on the delivery of ecosystem services.

1.4 Scope and Limitations of the Document

This document addresses nature-based infrastructure as an overarching topic. It serves as an overview and orientation for use case topics that are intended to be developed in greater detail at a later stage.



2 Conceptual Foundations

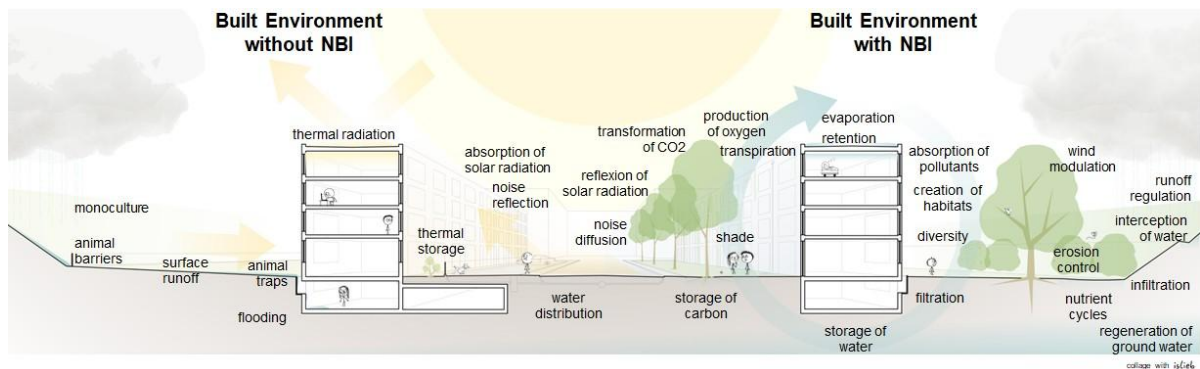


Figure 2: Interactions Between Open Spaces and Enclosed Built Spaces / Source: Anne Nyffeler Master's Thesis [29]

2.1 Service Demand and Resource Consumption

People depend on protected and well serviced built environments in order to live healthy and safe lives. Infrastructure systems secure these basic needs and therefore form the backbone of societal prosperity. In Switzerland, critical infrastructure sectors include energy, health, safety, food supply, water supply, wastewater management and waste management [6].

Buildings and open spaces interact directly with one another (see Figure 2: Interactions Between Open Spaces and Enclosed Built Spaces / Source: Anne Nyffeler Master's Thesis). The microclimate and quality of open spaces influence both the spatial requirements and the technical requirements of buildings, for example regarding cooling, shading, water supply and wastewater management (see also 11.1). Climate change, population growth and demographic change are increasing the demand for high performing systems capable of providing these services.

Nature-based solutions make an important contribution by delivering ecosystem services when open spaces are designed accordingly. In doing so, they also reduce the need for technical building systems, lower material requirements, decrease maintenance efforts and minimise environmental impacts.

2.2 Principles of the Circular Economy for Open Space Design

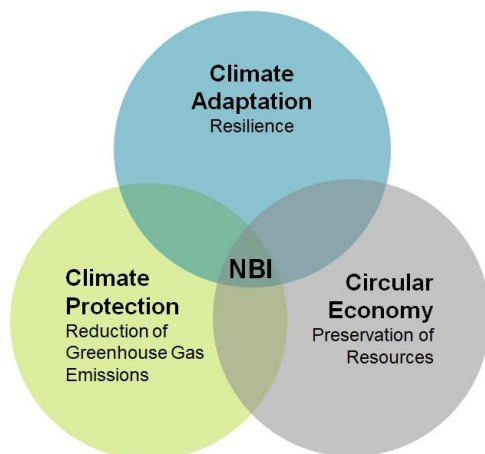


Figure 3: Intersection of Themes Related to Nature-based Infrastructure (NBI) / Source: Based on TAZ Zurich

Linear consumption models follow the principle of take, use and dispose. Materials are replaced rather than preserved, water is discharged rather than utilised, and vegetation is renewed rather than developed and maintained. This results in high resource consumption, high emissions and high lifecycle costs for the overall system, while delivering limited performance.

For future-ready development of the built environment, the circular economy is therefore equally important in open space design. The objective is to reduce material and energy flows, extend their service life, retain them within closed loops and manage them as regenerative systems.

Nature-based infrastructure applies these principles by planning, implementing and operating open spaces as interconnected regenerative systems with closed loops wherever possible. Its nature-based and near natural elements provide specific services. For example, trees provide cooling, soils store water, vegetation filters pollutants, and permeable surfaces enable water infiltration.



The R strategies represent a central organising principle of the circular economy. They describe how resources can be used effectively, value can be retained and environmental impacts can be minimised throughout the entire lifecycle of materials, products and systems.

The following list presents the R strategies adapted for open space design [7]:

R0	Refuse	Unnecessary interventions are avoided by minimising land consumption, surface sealing and built elements. Required functions are addressed first through existing assets, particularly existing trees, through intelligent spatial organisation or through natural processes.
R1	Rethink	Use and design are adapted so that open spaces provide several ecological and social services simultaneously and replace or minimise isolated technical solutions.
R2	Reduce	Material, energy and maintenance requirements are reduced through simple constructions, site appropriate vegetation and the promotion of natural cycles instead of technical solutions.
R3	Reuse	Materials, construction components and excavated material are reused directly wherever they are suitable and can be applied without extensive processing.
R4	Repair	The function of open spaces is maintained and, wherever possible, extended throughout their lifecycle through targeted vegetation management and the repair of built open space elements.
R5	Refurbish	Existing open spaces are adapted, enhanced or renewed to improve their functional and ecological performance without requiring complete replacement.
R6	Remanufacture	Components or materials are refurbished and upgraded before being used in new open spaces for the same purpose.
R7	Repurpose	Existing materials or structures are repurposed for new functions, for example as ecological features or landscape design elements.
R8	Recycle	Materials are processed into new raw materials when they cannot be reused or repurposed.
R9	Recover	Materials are composted or used for energy recovery only when no higher value circular use remains possible. Wherever feasible, this should be achieved through pyrolysis to produce biochar, which can be used to improve soil quality.

2.3 Definition of Nature-Based Infrastructure

Nature-based Infrastructure (NBI) [8] refers to an interconnected system of near natural spaces and elements within the built environment. Through natural processes, it delivers essential ecosystem services such as cooling, groundwater regeneration, health promotion, habitat creation and protection from hazards. In doing so, NBI makes a significant contribution to safe, healthy and resilient built environments. It builds upon the concepts of ecological infrastructure (EI) [9], [10] and nature-based solutions (NbS) [11], while focusing on the targeted delivery of ecosystem services within densely populated environments.

Within human dominated environments, NBI includes large scale ecological spaces as well as individual elements such as trees, water bodies, green spaces, parks, stepping stones, and green roofs and façades. However, it is the connectivity between these elements that creates a resilient and high performing infrastructure system, although individual nature-based elements can already provide important services. Soil and the underground constitute the fundamental resource on which these systems depend [12].

Not every green space qualifies as nature-based Infrastructure. Intensively managed monocultures and/or vegetated areas requiring high levels of water, fertilisers or pesticides are not considered part of NBI. The same applies to solutions that are predominantly technical in nature, for example those consisting mainly of pipes and shafts, and that are associated with significant environmental impacts. Accordingly, green and blue infrastructure can only be regarded as nature-based infrastructure when they are designed and maintained in a near natural manner and thereby provide multiple ecosystem services.



2.4 Distinction from Related Concepts

2.4.1 Ecological Infrastructure

It consists of well distributed and interconnected habitats. It provides sufficient space for animals and plants and enables their movement, including under changing climatic conditions. In doing so, it connects ecologically valuable environments across both natural and built environments, extending through undeveloped as well as human dominated areas [9], [10].

2.4.2 Nature-based Solutions (NbS)

These are actions that protect, restore, sustainably manage and regenerate natural or human modified ecosystems while delivering essential ecosystem services. They help address societal challenges effectively and simultaneously enhance human well-being and biodiversity.

2.4.3 Green, Blue, Brown, Grey and Yellow Infrastructure

These terms describe different and complementary infrastructure systems within the built environment that need to be planned and coordinated in an integrated manner. Various definitions of these terms exist and may differ from those presented here. For this reason, each project should establish a shared understanding of the project specific terminology and definitions at an early stage (see also Chapter 8.1).

- **Green Infrastructure:** vegetation-based spaces and structures such as trees, hedges, planting areas, green façades and green roofs
- **Blue Infrastructure:** natural and technical water related systems such as water supply and wastewater networks, water utilisation elements, evapotranspiration elements, retention areas and water bodies
- **Brown Infrastructure:** natural and constructed soils (technical substrates, such as roof substrates and root zone substrates) within the built environment that form the ecological and physical foundation upon which all other infrastructure types depend
- **Grey Infrastructure:** technical infrastructure such as utility supply and disposal networks as well as predominantly sealed mobility infrastructure
- **Yellow Infrastructure:** technical infrastructure for the generation, storage and distribution of renewable energy, such as photovoltaic and solar thermal systems, district heating networks, areas for heat pumps and energy storage systems

Nature-based infrastructure focuses on the targeted provision, coordination and enhancement of ecosystem services within the built environment. As part of an integrated, resilient and future-ready built environment, it supports, complements and, where feasible, substitutes elements of other infrastructure types.

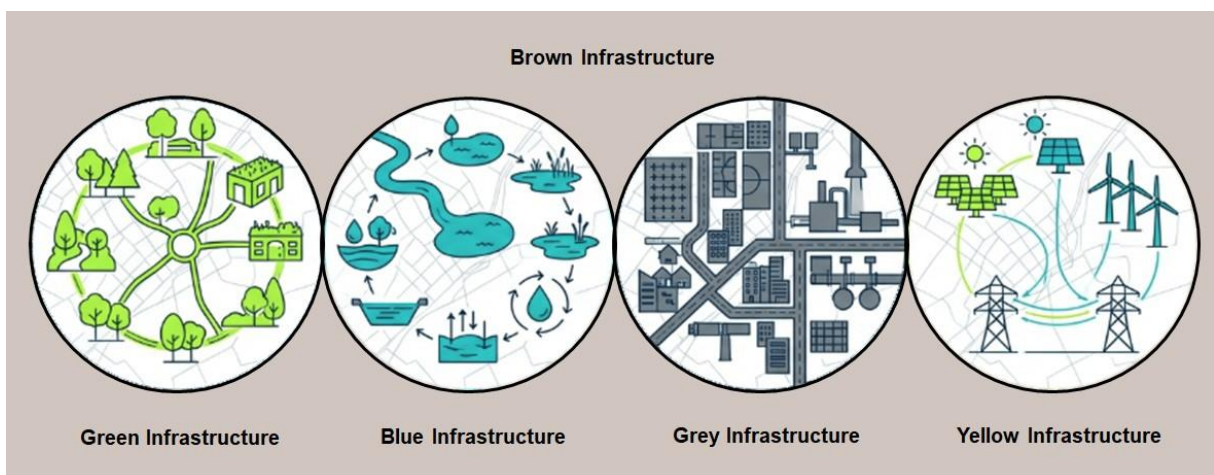


Figure 4: Types of Related Infrastructures in the Built Environment / Source: based on Canton of Berne [14]



2.4.4 Porous Infrastructure

Refers to settlement morphology (urban form and development structure) as well as the integration of existing local resources and processes such as cold air flows and water bodies. In the following, this aspect [14] is incorporated through an emphasis on the importance of designing connectivity, connectedness, linkages and deliberate transitions (see also Chapters 5.4 and 6.6).

2.5 Contribution to Critical Infrastructure

The services (ecosystem services) provided by nature-based infrastructure contribute to several critical infrastructure sectors as defined by the Swiss Confederation:

- **Energy:** reduction of energy demand through cooling, shading and microclimatic regulation
- **Public Health:** heat mitigation, air purification, stress reduction and the provision of restorative spaces
- **Public Safety:** water retention, soil stabilisation and reduction of surface runoff, as well as damage prevention during heavy rainfall events
- **Food and Water Supply:** water filtration, infiltration and groundwater recharge, reduced surface runoff, pest regulation, pollination services and local food production
- **Wastewater Management:** reduced pressure on technical drainage systems through natural stormwater management, as well as filtration and pollutant removal functions (see Chapter 3.3.4)

Due to its system relevant functions, nature-based infrastructure should therefore be regarded as critical infrastructure and considered on an equal footing with technical infrastructure systems during planning processes. Integrated and professionally informed open space planning, including the coordination of interfaces with buildings and structures and their comprehensive integration into the overall ecosystem of the built environment, is therefore essential for creating future-ready living environments.

3 Ecosystem Services in the Built Environment

The performance of nature-based infrastructure is based on ecosystem services [13] and emerges from natural processes. Its functioning can be described using a simple systems model (Figure 5): resources and boundary conditions (inputs) influence processes within open spaces. These processes, shaped by factors such as tree water relations and the associated transpiration, generate services (e.g. evaporative cooling and habitat provision), which cumulatively produce measurable outputs such as microclimate regulation and biodiversity enhancement.

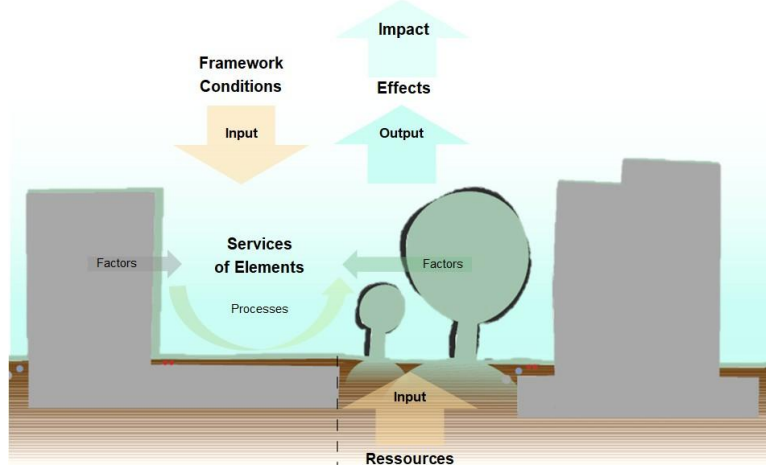


Figure 5: Impact Model for Nature-Based Infrastructure in Open Spaces (see also Chapter 3.3) / Source: NBI Working Group

Resources include, for example, water, energy and anthropogenic pressures such as noise, pollutants and spatial fragmentation. Boundary conditions are determined both by climatic, hydrogeological and topographical characteristics and by the design of the built environment, including spatial structure, soil composition, vegetation, materials and patterns of human use. Together, resources and boundary conditions determine which processes occur and whether the resulting services generate positive or negative effects. A fundamental understanding of this impact model provides the basis for the planning, implementation and long-term maintenance of buildings and open spaces that effectively deliver ecosystem services.



3.1 Categories of Ecosystem Services

Ecosystem services [13] refer to the contributions of ecosystems to human well-being. They form the foundation of the functions provided by nature-based infrastructure and can be grouped into four categories [13]:

- **Regulating Services:** for example, microclimate regulation, water infiltration and water purification
- **Provisioning Services:** for example, urban gardening, edible gardens and food forests
- **Cultural Services:** for example, identity formation and aesthetic value
- **Supporting Services:** for example, pollination and nutrient and water cycling

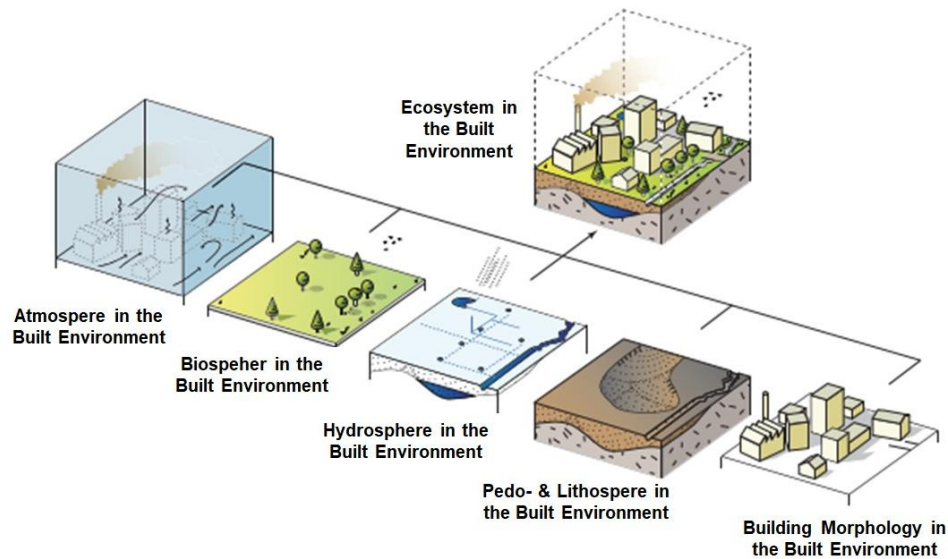


Figure 6: Biophysical Components of Ecosystems in the Built Environment / Source: Oke et al. (2017) [15]

For resilient, safe and healthy built environments, regulating and supporting ecosystem services are of primary importance. However, other ecosystem services also play a crucial role. Provisioning services such as food production, habitats for animals and plants, and opportunities for physical activity, as well as cultural services such as identity formation, contribute to user acceptance and engagement. In doing so, they support the development and long-term effectiveness of nature-based infrastructure and help ensure the quality and sustainability of open space design.

3.2 Ecosystem Cycles

Ecosystem services are based on ecosystem cycles. These cycles, in turn, are driven by physical, chemical, biological and geological processes within the built environment and can be deliberately influenced through the design, materialisation, use and maintenance of open spaces.

3.2.1 Water Cycle

Rainwater is retained on green roofs, vegetated areas and in swales. It evaporates, infiltrates into the ground and is purified as it passes through biologically active topsoil layers. At the same time, it remains available to vegetation and contributes to groundwater recharge.

Processes	Retention, Infiltration, Filtration, Irrigation, Groundwater Recharge, Evaporation, Transpiration, Precipitation
Factors	Vegetated Areas, Green Roofs, Trees, Retention Swales, Plant Species Selection, Vegetation Diversity, Soil Quality and Permeability, Open Water Bodies, Nature-Based Watercourses, Surface Water Conveyance



Services | Microclimate Regulation, Cooling through Evaporation, Water Retention, Water Infiltration and Purification, Reduction of Surface Runoff

3.2.2 Carbon Cycle

Plants absorb CO₂ from the atmosphere and incorporate carbon into their trunks, leaves and roots. A portion of this carbon is transferred into the soil, where microorganisms convert it into humus. Growing trees store large amounts of carbon in their wood over several decades and thereby provide long-term stabilisation of the carbon cycle. Through decomposition and exposed bare soil, CO₂ is released back into the atmosphere.

Processes | Photosynthesis, Carbon Sequestration in Biomass and Soil, Decomposition, Humus Formation, Long-Term Carbon Storage in Wood and Humus

Factors | Plant Species Selection, Vegetation Structure, Soil Quality, Site Conditions, Maintenance Practices, Tree Maturity and Tree Health

Services | Carbon Storage, Biomass Accumulation, Soil Formation, Emission Reduction through Nature-Based Elements, Long-Term Climate Change Mitigation

3.2.3 Nutrient Cycle

Plants absorb nutrients such as nitrogen, phosphorus and potassium from the soil and incorporate them into their biomass. When leaves or other organic material fall to the ground, they are decomposed and mineralised by soil organisms. As a result, nutrients are released and become available for uptake once again.

Processes | Nutrient Uptake by Plants, Decomposition of Organic Biomass by Fungi and Bacteria, Mineralisation, Humus Formation

Factors | Vegetation Diversity, Diversity of Soil Organisms, Proportion of Living Biomass in the Soil, Unsealed Soils, Soil Chemistry, Structurally Diverse Plant Communities, Diversity of Vegetation, Fungi and Animals

Services | Improved Soil Fertility, Increased Humus Content, Stable Soil Structure, Reduced Dependence on External Fertiliser Inputs

3.3 Boundary Conditions and Resources

Site-specific boundary conditions and resources provide the foundation for ecological processes. They determine the extent, quality and resulting effects, whether positive or negative, of ecosystem services generated within the built environment.

3.3.1 Microclimate Regulation

Plants release water through their leaves. Similar to the evaporation of water from open water bodies, this water evaporates under solar radiation and cools the surrounding air. Tree canopies provide extensive shading and thereby reduce the heating of surfaces. In addition, through transpiration and evaporation, they create local cool air zones. Structurally diverse vegetation reduces wind speeds and creates comfortable airflow conditions.

Processes | Evaporation, Transpiration, Shading, Deflection of Airflows, Reflection of Solar Radiation

Factors | Existing Tree Stock, Canopy Cover, Leaf Area, Tree Species Selection and Site-Suitability, Soil Moisture, Water Availability, Unsealed and Permeable Surfaces, Arrangement and Connectivity of Green Structures, Surface Materials with Low Heat Storage Capacity

Services | Reduction of the Urban Heat Island Effect, Temperature Moderation, Improved Thermal Comfort



3.3.2 Ecological Factors and Habitat Creation

Plants provide food, shelter and breeding habitats for many animal species. Pollinating insects enable plant reproduction and, in turn, support food resources for other animals. Connected stepping stones and green corridors allow animals to move between habitats. A diverse, biodiverse and well-connected community of plants and animals with a continuous food supply is largely self-regulating. This makes ecosystems more resilient to disturbances such as drought and functions as a natural immune system for nature-based infrastructure. As a result, ecosystem services remain effective over the long term and continue to benefit the built environment and its inhabitants.

Processes	Habitat Creation, Food Webs, Ecological Connectivity, Pollination, Reproduction, Genetic Exchange
Factors	Species Diversity, Site Appropriate Plant Selection, Structural Diversity of Vegetation, Temporal Continuity of Flowering and Fruiting Resources, Ground Level Habitat Structures, Unsealed and Low Disturbance Areas, Habitat Connectivity, Reduced Artificial Light and Noise Pollution, Extensive Maintenance
Services	Promotion of Biodiversity, Stabilisation of Ecological Processes, Natural Pest Regulation, Pollination and, through these functions, Food Security

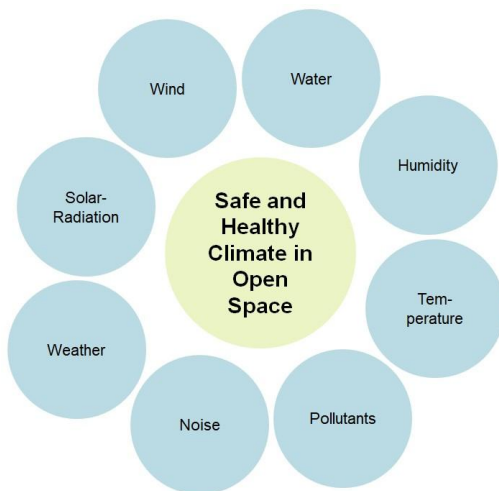


Figure 7: Factors Influencing a Safe and Healthy Open Space Microclimate (Open Space Comfort) / Source: Based on DWD (2023) [16] & ecobau, n.d.

3.3.3 Noise

Vegetation influences how sound propagates within the built environment. Plants, shrubs and green façades can attenuate noise, redirect sound waves and reduce the reflection of unwanted noise. Nature-based infrastructure therefore contributes to improving the acoustic environment. Dense and strategically positioned vegetation structures are particularly effective in reducing traffic noise and enhancing tranquillity in open spaces. This contributes to stress reduction, improved well-being and a restorative acoustic environment.

Processes	Sound Absorption, Sound Deflection, Reduction of Sound Reflections, Alternative Background Sound Levels
Factors	Size and Density of Vegetation Structures, Green Façades, Hedges, Dense Rows of Trees
Services	Reduced Noise Exposure, Enhanced Quality of Tranquillity, Stress Reduction

3.3.4 Pollutants

Plants and soils can absorb, retain and break down certain pollutants from air and water. Leaf surfaces, root zones and soil organisms act as natural filters and pollutant degrading systems within the built environment (phytoremediation). Nature-based infrastructure can therefore significantly reduce environmental pollution. However, some pollutants, such as microplastics, PFAS and high concentrations of heavy metals, cannot be degraded and may accumulate over time, making soil remediation necessary.



Processes	Deposition, Filtration through Leaf Surfaces, Sorption in Soils and Plant Tissues, Microbial Degradation
Factors	Leaf and Needle Structures, Soil Microorganisms, Porous Surfaces, Leaf Area (Trees and Vegetation in General)
Services	Reduction of Particulate Matter and Air Pollutants, Reduction of Soil Contamination, Improved Water Quality

3.3.5 Light

Vegetation influences lighting conditions within the built environment. It provides shade and diffuses sunlight, thereby protecting against direct solar radiation and reducing unwanted reflections from surfaces. Nature-based infrastructure therefore improves visual comfort and contributes to microclimate regulation. However, artificial lighting can impair these functions. Excessive artificial lighting at night leads to light pollution, which reduces the performance and resilience of nature-based systems. Lighting considerations should therefore be integrated into both the planning and operation of nature-based infrastructure.

Processes	Shading, Light Diffusion, Regulation of Reflection and Glare
Factors	Tree Canopies, Vegetation Density, Material Dependent Reflectance Properties, Artificial Lighting
Services	Reduction of Glare and Light Pollution, Reduced Thermal Stress

3.4 Social and Cultural Processes

Well-designed open spaces provide opportunities for recreation, physical activity and social interaction. They reduce stress, promote physical, mental and social health and offer an important counterbalance to everyday life, particularly in densely developed areas (see in particular SIA Factsheet 2066 [17]).

Through repeated use, open spaces become familiar places. They strengthen a sense of belonging and identity and create opportunities for informal learning. In doing so, they also increase awareness of the environment and nature [17].

Open spaces deliberately designed with nature-based infrastructure make a significant social and cultural contribution. They enhance safety, health (including physical and cognitive development [18]), quality of life, economic productivity and resilience within the built environment. These benefits arise both from regulating and supporting ecosystem services and from the everyday use of appropriately designed open spaces and direct contact with natural elements, for example through recreation in green spaces and access to clean drinking water [8].

Processes	Recreation and Use, Sense of Identity, Learning through Experience, Social Interaction, Gardening, Stewardship and Maintenance Activities
Factors	Accessibility, Connectivity and Availability of Open Spaces such as Green Spaces for Play and Sports, Gardens, Tree-Lined Avenues and Parks with Near Natural Structures, Sensory Experiences Including Fragrance, Tactile Qualities and Essential Oils, Access to Regulating and Provisioning Ecosystem Services, Awareness Raising Measures such as Information Boards, Guided Tours and Educational Courses
Services	Physical Activity Promotion, Health Promotion, Health Protection, Stress Reduction, Social Cohesion, Education and Connection to Nature

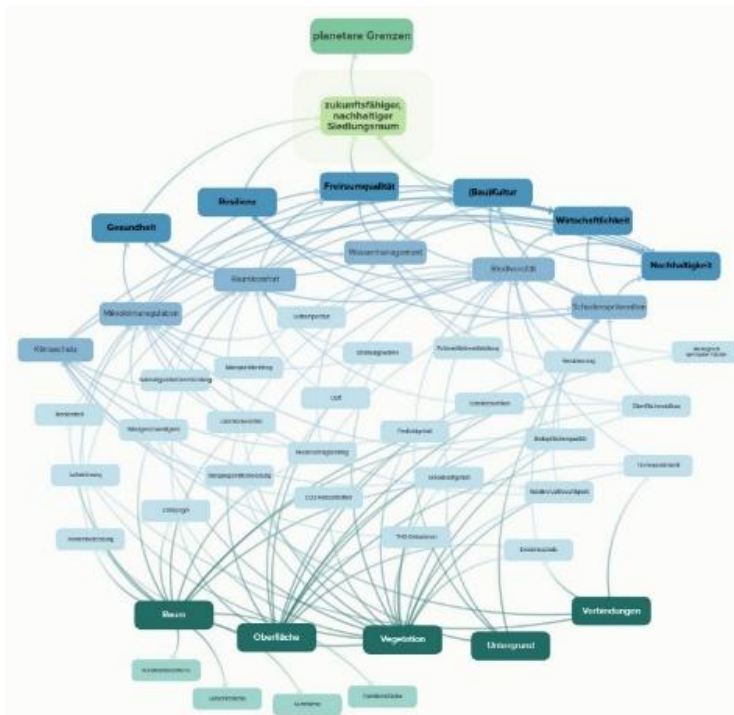
3.5 Intersections and Related Fields

Nature-based infrastructure interacts with, among others, the following strategic and professional fields of practice (see also SIA Factsheet 2066 [17]):

- **Sustainable Development [20]:** climate related objectives such as resource conservation, net zero targets and biodiversity strategies
- **Urban Ecology:** interactions between built structures and biological systems



- **Heat Mitigation:** reduction of urban heat island effects and improvement of thermal comfort
- **Sponge City:** nature-based water management as an adaptation strategy to climate change
- **Urban Forestry:** the systematic planning and management of trees within the built environment
- **Biomimicry:** an approach that applies natural functional principles to achieve resource efficient and resilient outcomes. It represents a fundamental principle of nature-based infrastructure
- **Permaculture:** a planning approach for long-term self-regulating systems that utilises ecological cycles and arranges elements to create multiple benefits



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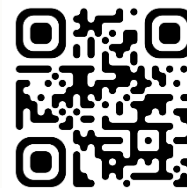


Figure 8: Thematic Map / Source: NBI Working Group

4 Performance Dimensions of Nature-Based Infrastructure

Nature-based infrastructure can provide a wide range of ecological, social and economic benefits, referred to as ecosystem services. To ensure that these services can be effectively planned, implemented and maintained over the long term, clear objectives are required to guide the selection of appropriate measures and enable their optimal coordination [21], [22].

This whitepaper therefore proposes overarching objectives and derived impact objectives. These objectives are aligned with the principles of resilient development of the built environment and high-quality urban densification. They serve as a translation framework for developing project specific measures that achieve the desired outcomes through ecosystem services [29].

Their purpose is to ensure that available resources are used as efficiently, effectively and equitably as possible. This enables ecosystem services to be maximised according to specific local needs while reducing the overall resource consumption associated with building and open space development projects.

4.1 Impact-Oriented Framework for NBI

Clear, project specific objectives help to position nature-based infrastructure appropriately within a project context. This enables its integration into societal, institutional and individual interests.

Nature-based infrastructure delivers functions within open spaces that are comparable to the functions provided by architectural and technical measures for health and comfort within buildings, for example thermal insulation, room acoustics and building services systems.



To support sustainable development within the construction sector, the performance dimensions of nature-based infrastructure can be used as concrete objective categories and prioritised according to project specific requirements. These dimensions are interdependent and together provide the foundation for designing open spaces that are functional, resilient and sustainable.

The starting point is the spatial requirements of a project. These requirements arise from the local boundary conditions and the intended societal benefits within the project perimeter, namely the plot or development area. Important prerequisites for acceptance and appreciation include quality of place, safety, health and social inclusion. At the same time, these factors strengthen economic performance and the long-term value of a project [24]. In addition to visual, functional and ecological quality [17], the microclimate and resource supply of open spaces, for example water and nutrient availability, must therefore be deliberately planned and coordinated.

To avoid further exacerbating current climate and environmental risks, climate change mitigation and resource conservation should be considered as priority objective categories. This includes the preservation of existing resources, the responsible use of natural resources, the reduction of greenhouse gas emissions, carbon sequestration and storage, and therefore the removal of CO₂ from the atmosphere, as well as the targeted substitution or reduction of technical systems through nature-based systems.

Biodiversity forms the ecological foundation of system performance because it determines the resilience, functionality and stability of nature-based processes [25].

Water management functions as the regulatory backbone by ensuring water use, retention, infiltration, evaporation and purification, thereby strengthening both ecological and technical resilience [26].

Microclimate regulation, resulting directly from vegetation structures, material properties and settlement morphology, is essential for thermal comfort [7].

Damage prevention [23] is achieved through the reduction of surface runoff, the mitigation of overloads on technical infrastructure, the reduction of heat, wind and water related risks to people, buildings and infrastructure [7], as well as through the regulation of natural pests, diseases and allergens.

The combined application of these objective categories ultimately results not only in the fulfilment of the defined spatial requirements within the project perimeter, but also in broader societal benefits and added value beyond the boundaries of the individual project.

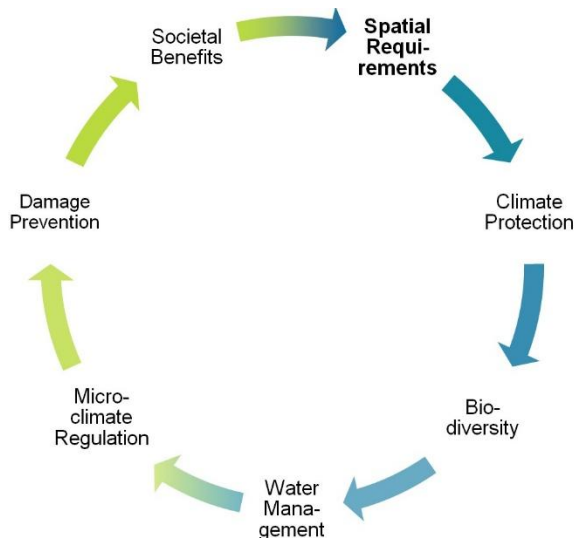


Figure 9: Impact Logic as a Hierarchy for Action / Source: NBI Working Group

The proposed sequence follows the principles of sustainable development [20] and an associated impact logic [29]. People primarily respond to immediately tangible benefits such as quality of place and comfort [24]. However, if these needs are met solely through built and technical systems, this results in high greenhouse gas emissions, significant environmental impacts and high resource consumption, making climate change mitigation necessary. Without effective climate action, biodiversity declines, which weakens the water cycle and microclimate regulation within the built environment [25] and increases the risk of damage.

Conversely, when the functioning of ecosystems is taken into account and the design and maintenance of open spaces are locally optimised and coordinated to maximise the effectiveness of ecosystem services, the need for built and technical infrastructure decreases. At the same time, the risk of damage is reduced [16] and quality of place improves. The proposed sequence should therefore be understood and applied as a hierarchy of priorities and actions.



4.2 Overarching Objectives

The following overarching objectives, also referred to as formal objectives or strategic objectives for impacts, can serve as a common basis for understanding and decision making in relation to nature-based infrastructure (see also SIA Factsheet 2066 [17]).

- Health
- Resilience
- Economic Viability
- Sustainability
- Open Space Quality
- (Building) Culture

4.3 Design Relevant Objective Categories

The following performance dimensions can be used as quantitative impact objectives [21], [22], serving as objective categories for nature-based infrastructure. Based on these categories, project specific and site-specific measures can be systematically derived to optimise the delivery of ecosystem services according to local conditions and requirements [29]:

Table 1: Description of the Performance Dimensions as Objective Categories

Dimension	Description
Spatial Comfort	Safety, Health, Quality of Place, Physical Activity Promotion, Recreation, Social Inclusion
Climate Change Mitigation and Resource Conservation	Emission Reduction, Substitution of Technical Systems, CO ₂ Sequestration and Storage, Preservation of Biologically Active Soils for the Regulation of Water, Nutrient and Carbon Cycles and thereby the Ecological Foundation of Nature-Based Infrastructure
Biodiversity	Species Diversity, Habitat Quality, Ecological Stability, Reduced Pest Pressure
Water Management	Water Use, Water Retention, Evaporation, Water Infiltration and Purification
Microclimate Regulation	Thermal Comfort, Heat Mitigation, Ventilation and Airflow
Damage Prevention	Remaining Structural Measures Required for Protection against Natural Hazards [23], for example the Reduction of Flood and Erosion Risks

4.4 Interactions and Planning Implications

The performance dimensions do not operate independently but interact as an interconnected system. Greater biodiversity improves water retention capacity and evapotranspiration, thereby contributing to microclimate regulation and stability. Effective water management helps prevent damage and reduces the need for structural and technical interventions. Thoughtful design, appropriate use and suitable maintenance practices are essential for sustaining ecological performance and ensuring the long-term stability and resilience of the system.

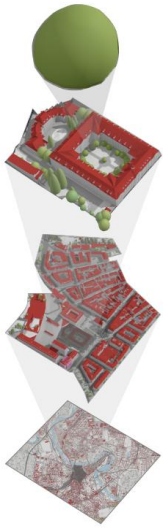
5 Levels of Analysis and Intervention

The planning of nature-based infrastructure takes place across four interconnected spatial levels [15], [16], [36], [29], whose impacts and information requirements are mutually dependent.



5.1 Overview of the Levels

Table 2: Functions of the Different Levels



	Level	Level Name	Function
Levels of Intervention = Units of Performance	Nano Level	Element	Vegetation Types, Trees, Substrate Layers, Microhabitats, Materials
	Micro Level	Plot	Operational Unit of Impact and Local Resources: Designable Open Space, Building Form, Building Placement and Access, Soil, Vegetation, Water Regime
Levels of Analysis = Framework Conditions	Meso Level	Neighbourhood	Settlement Structures, Governance Systems, Mobility Patterns, Land Use Profiles
	Macro Level	Region	Climate Systems, Topography, Hydrological Regimes, Ecological Infrastructure

Regional climatic conditions, hydrological regimes, ecological networks, as well as local risk profiles, pressures and opportunities at neighbourhood level define the overarching framework for action. At plot level, governance structures, patterns of use and resource flows influence both the demand for and the feasibility of nature-based infrastructure. This creates a need for cross scale integration and participatory planning approaches to ensure that nature-based measures are implemented effectively and maintained over the long term [17].

5.2 Levels of Analysis

For each project, the relevant content and required levels of detail are defined. To support this process, framework conditions, baseline information and influencing factors are analysed across different levels of analysis. Based on these findings, project requirements can be derived and the measures required for coordination and implementation can be determined for the respective level of intervention.

5.2.1 Regional Level

Regional framework conditions (national, cantonal, regional and municipal) form the macro level. Large scale climate systems, topographical conditions, hydrological regimes and ecological infrastructure determine the feasibility, urgency and direction of local interventions. Data sources such as national and cantonal GIS systems provide essential information on climate, soils, water regimes, habitat networks and natural hazards.

5.2.2 Neighbourhood Level

At the meso level of the neighbourhood (district, local community), local settlement structures, governance mechanisms, mobility patterns and social use profiles come into play. These factors influence the feasibility of nature-based measures, their integration with existing green and open space systems, and their acceptance and usability by the local population.

5.3 Levels of Intervention

At the levels of intervention, project specific spatial use requirements and quality objectives must be identified and coordinated with the conditions and constraints identified across the levels of analysis. This process enables the development of an integrated system that is optimised for the specific project requirements and the ecosystem services it is intended to deliver.



5.3.1 Plot Level

The micro level of the plot (or development area) forms the operational unit of impact at the centre of nature-based infrastructure planning. Building orientation, built morphology, topography, surface materials and existing vegetation influence key ecological processes such as soil functions, surface runoff, cold air drainage, slope winds, moisture dynamics and solar radiation.

At this level, overarching strategies and target values derived from spatial planning and development of the built environment (GIS based information) must be operationalised and translated into effective, interconnected and coordinated measures (BIM based information).

5.3.2 Element Level

At the nano level, the quality of individual elements, such as vegetation types, substrate layers, microhabitats, green façades and infiltration swales, determines temperature regulation, water and air movement, pollutant dynamics and, consequently, the ecological performance of the directly designable and usable open space, namely the operational unit of impact. The design and specification of these elements therefore represent a key measure for achieving the target values (KPIs) defined at plot level.

All elements that shape open spaces influence the delivery of ecosystem services. To create resilient and future-ready built environments, these elements must be designed, coordinated and maintained in a way that maximises positive ecosystem service outcomes across the intersection of their functions and associated requirements.

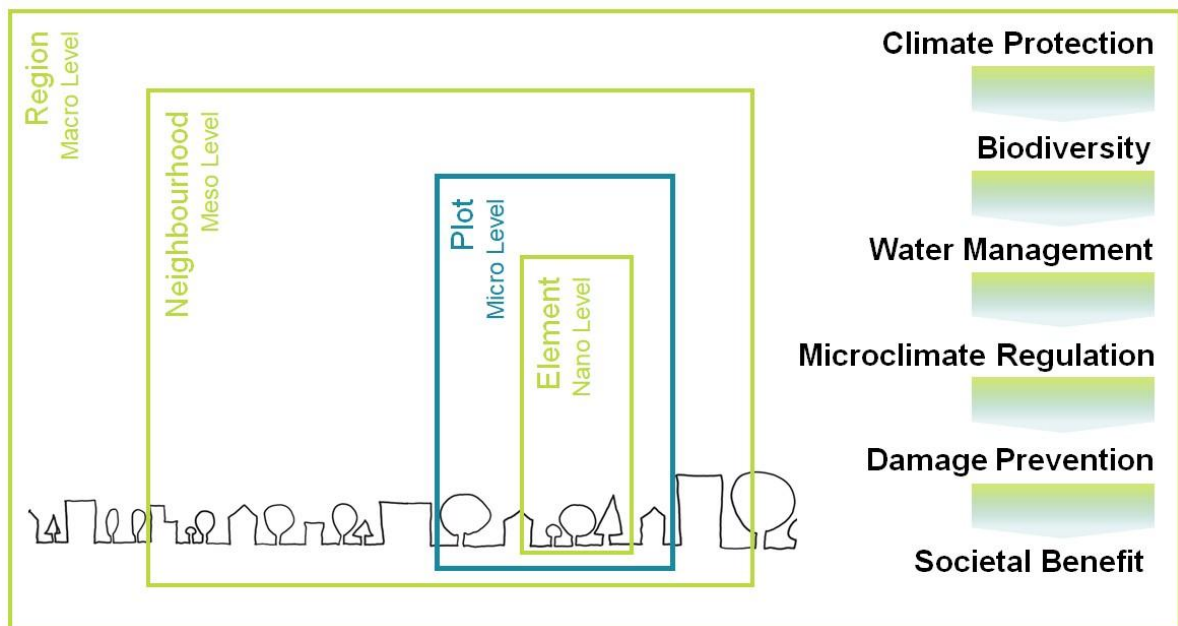


Figure 10: Levels of Analysis and Intervention with Performance Dimensions / Source: NBI Working Group

5.4 Connectivity and Connectedness

Nature-based infrastructure is only effective when information and processes are connected across all levels (vertical connectivity). This connectedness is essential for system performance: root zones, soil processes, water flows and habitat linkages must function together, comparable to technical infrastructure networks.

Spatial connectivity also plays a crucial role. It increases ecological value and improves social usability because orientation, comfort and the appropriation of space depend on coherent and interconnected environments (horizontal connectivity).



5.5 Impacts of Use

Humans and animals interact within the built environment. The way people design, use and maintain open spaces determines how these spaces develop, how much maintenance they require and, consequently, the ecosystem service capacity of nature-based infrastructure. At the same time, insects, birds, mammals and other organisms influence open spaces within the built environment and can either strengthen or reduce ecosystem service delivery. Balanced animal populations are therefore of particular importance. They pollinate plants, disperse seeds and regulate pests in a manner comparable to an immune system [25]. The foundation for these functions is a biodiverse design of open spaces.

6 Elements Influencing Ecosystem Services

Nature-based infrastructure functions through the interaction of different elements that collectively deliver ecosystem services.

6.1 Element Categories

The key elements include open spaces, surfaces, vegetation, soils, connections and site furnishings [28].

6.2 Open Spaces

Open spaces are the primary units of impact of NBI within the built environment [7]. They bring together the elements that deliver ecosystem services [7], [17] (see also Chapter 10.4). Their spatial structure (morphology) has a decisive influence on climatic and ecological processes and must therefore be deliberately and carefully designed.

6.3 Surfaces

Surfaces influence key ecological processes. They store and reflect heat, attenuate or amplify sound, and either allow water to infiltrate or direct it away as runoff. Their design and material properties determine the intensity of urban heat island effects, the rate of water runoff and the quality of local microclimatic conditions. Surfaces include roofs and façades, the exposed surfaces of retaining and protective structures, as well as paving and water bodies within open spaces.

6.4 Vegetation

Vegetation performs multiple functions simultaneously. It cools through shading and evapotranspiration, purifies air and water, provides habitats and reduces noise. At the same time, it shapes space, guides visual connections and contributes to quality of place. The effectiveness of vegetation depends largely on its diversity. Mixed plant communities with different rooting depths and leaf structures absorb more water, support higher evapotranspiration rates and are more resilient to environmental stress. Understorey vegetation beneath trees and shrubs helps retain soil moisture and further improves microclimatic conditions. An integrated example is provided in Appendix F – Examples.



6.5 Underground

Soils and the subsurface form the ecological foundation [12] of nature-based infrastructure. Existing soil qualities should be preserved wherever possible or deliberately enhanced. Soil filters and stores water, enables infiltration and regulates nutrient and carbon cycles. It provides habitat for roots and microorganisms and contributes to the cooling and health of open spaces.

At the same time, soil forms the physical basis of open spaces. Its structure, permeability and biological activity determine whether essential processes such as groundwater recharge, humus formation and pollutant degradation can function effectively.

6.6 Connections and Transitions

Above and below ground connections enable ecological processes and the movement of water. They ensure the continuity of root zones, canopy spaces and connected habitats. When these connections are disrupted, for example by sealed surfaces, walls, fences, roads or excessive artificial lighting, the effectiveness of nature-based infrastructure is significantly reduced.

Figure 11: Element Categories within the Ecosystem Service Interaction Framework of the Built Environment / Source: Future-Ready Built Environments through Systemic Open Space Design [28]

Open Space



Surfaces



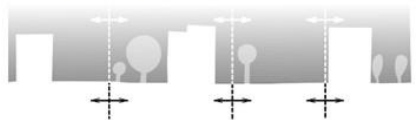
Vegetation



Underground



Connections



6.7 Furnishings

Site furnishings such as shading structures, fountains, seating, play equipment and nesting aids complement ecological functions through the provision of social and cultural benefits. They enhance usability, quality of place and opportunities for interaction. Depending on their design and materialisation, they may be considered part of either nature-based infrastructure or technical infrastructure.

6.8 Interplay of Elements

For planning purposes, four fundamental types of nature-based infrastructure elements can be distinguished [40]. Each type has specific requirements and delivers different ecosystem services (see also Chapter 6):

Table 3: Different Types of Elements

Form	Unit	Elements	Services	Notes
Punctual Elements	pcs.	Trees, Woody Vegetation, Utility Chambers	Shading, Evaporative Cooling, Carbon Sequestration and Storage, Habitat Creation	Ensure sufficient root volume and suitable soil conditions, select site appropriate species, secure long-term water availability, consider long-term maintenance and development requirements, and avoid creating traps or hazards for wildlife
Linear Elements	m ¹	Walls, Fences, Edge Restraints, Utility Lines, Roads, Surface Watercourses, Stairs	Access and Circulation, Protection, Resource Supply, Ecological Connectivity, Regulation of Water Flows and Animal Movement	Ensure permeability for water and living organisms, consider geometric and spatial requirements, minimise barriers, promote the integration of near natural elements, ensure accessibility and maintainability,



				and avoid creating traps or hazards for wildlife
Surface Elements	m ²	Green Spaces, Water Bodies, Roof Surfaces, Green Façades	Microclimate Regulation, Evapotranspiration, Water Retention, Biodiversity Enhancement, Quality of Place	Plan for structural diversity and site appropriate planting, avoid intensive monocultures, adapt maintenance practices to ecological processes, consider potential land use conflicts, and avoid creating traps or hazards for wildlife
Volumetric Elements	m ³	Soils, Substrates, Groundwater, Vegetation Supporting Layers within Roof and Façade Systems	Water Storage, Filtration, Nutrient Supply, Load Bearing Capacity, Foundation for Vegetation	Preserve natural soil functions, avoid soil compaction, enable infiltration, apply substrates strategically, and ensure long-term regeneration through adequate water and nutrient inputs as well as appropriate maintenance practices

7 Key Performance Indicators (KPIs)

The planning and assessment of nature-based infrastructure take place across different levels and involve a wide range of factors. Each level uses its own performance categories and indicators, which are currently only partially aligned with one another.

For assessment purposes, each factor should be associated with at least one qualitative indicator (see Appendix G – Glossary).

To ensure that nature-based infrastructure can be implemented effectively and maintained over the long term, these indicators must be meaningfully integrated across all levels. This enables the formulation of clear objectives, their verification and their application in project development, quality assurance and performance monitoring.

7.1 Indicators by Level

The indicators are based, among other sources, on the publication Reference Values and Quality Criteria for Biodiversity in the Built Environment [27].

A fundamental distinction should be made between:

Framework Conditions: Contextual conditions, baseline information and requirements that must be clarified before the start of a project.

Factors: Specific measures and design characteristics that directly influence and promote the delivery of ecosystem services.

Table 4: Overview of Indicator Types. For a detailed list of indicators, see Appendix A – Key Performance Indicators (KPIs)

Levels	Functions	Framework Conditions	Indicators by Factors
Region	Strategic Steering and Target Setting	Legal Framework Conditions, Overarching Strategies, Spatial Planning Governance and Coordination	e.g. Proportion of Biodiverse Areas, Tree Canopy Cover, Degree of Surface Unsealing



Neighbourhood	Coordination of Land Uses, Alignment of Infrastructure Requirements	Urban Design, Social and Economic Requirements, Mixed Use Patterns	e.g. Spatial Connectivity, Ecological Corridors, Social Uses and Interactions
Plot (Development Area)	Operational Translation of Objectives into Measures	Ownership Structures, Legal Requirements, Specific Project Requirements, Particularly Requirements for Open Space Quality and Open Space Climate (Safety, Health, Culture and Comfort)	e.g. Biotope Area Factor, Proportion of Ecologically Valuable Areas, Tree Canopy Cover Ratio, Structural Diversity, Habitat Connectivity, Infiltration Rate
Element	Direct, Site Appropriate Delivery of Ecosystem Services	Site Conditions, Technical and Ecological Requirements, Material Properties, Plant Provenance and Plant Characteristics	e.g. Surface Reflectance, Evapotranspiration Capacity and Ecological Contribution of Vegetation, Water Storage Capacity of Substrates, Surface Infiltration Capacity, Resource Consumption and Environmental Impacts

7.2 Requirements for Key Performance Indicators (KPIs) for Nature-Based Infrastructure

For a KPI system to function effectively, indicators must be standardised and clearly structured. They should be usable at the element level while also allowing aggregation and evaluation across plot, neighbourhood and regional scales.

To achieve this, indicators must be based on common, standardised factors and linked through a coherent logical structure. Such an integrated framework is currently lacking. Its development represents one of the key challenges for the scaling of nature-based infrastructure, as well as for its efficient, digitally supported implementation, management and long-term maintenance.

An overview of existing indicators is provided in Appendix A – Key Performance Indicators (KPIs). This overview serves solely as a collection of examples. The selection and application of indicators should be determined on a project specific basis according to the relevant framework conditions, objectives and performance requirements.

8 Collaboration Processes

The planning of nature-based infrastructure requires consideration across multiple levels (see Chapter 5). Each level contributes its own framework conditions, requirements and performance objectives. The system can only function effectively when these are consistently connected and coordinated across all levels. Appendix C – Process Matrix illustrates these relationships through a matrix structured according to SIA project phases and spatial levels. The following sections briefly describe key topics relevant to the long-term development, implementation and maintenance of nature-based infrastructure.

8.1 Common Understanding

A common challenge is the lack of fundamental knowledge about the performance and benefits of nature-based infrastructure. Clients, decision makers and project stakeholders require a basic understanding of ecosystem processes, performance dimensions and appropriate measures. Only with this shared foundation can nature-based infrastructure be systematically embedded in spatial planning instruments, design competitions, projects and contractual requirements, and subsequently be assessed, managed and maintained appropriately. This document serves as a concise reference framework to support a common understanding across disciplines and stakeholder groups.



8.2 Involved Disciplines and Collaborative Culture

A continuous process for nature-based infrastructure extends from strategic foundations through planning and implementation to operation and monitoring. For this process to function effectively, it requires clearly defined roles, standardised interfaces, aligned objectives and consistent data structures. Equally important is close collaboration [21], [22], [31] between planners and public authorities, as well as the involvement and participation of users and operators [17].

The development, implementation, management and long-term maintenance of nature-based infrastructure at plot level require interdisciplinary expertise from a range of professional fields:

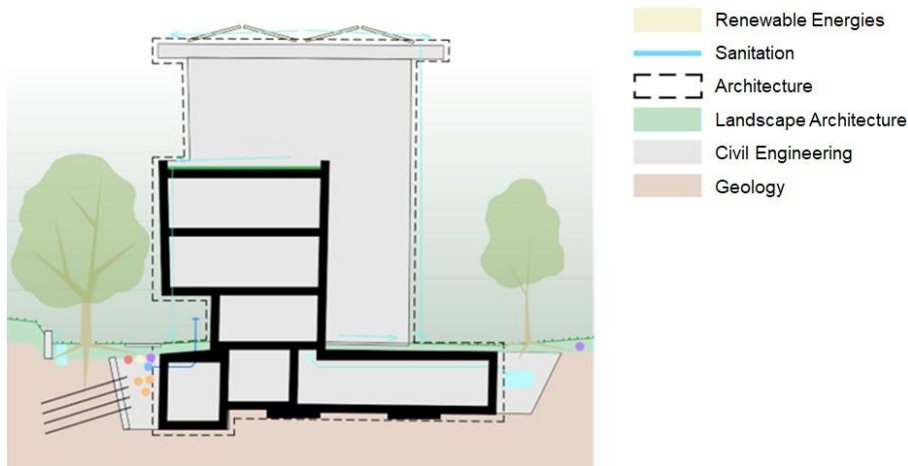


Figure 12: Minimum Planning Disciplines Required for Implementation / Source: sysTEAMatik GmbH

- Architecture and Urban Design
- Landscape Architecture
- Civil Engineering
- Urban Ecology
- Nature and Environmental Management
- Drainage and Stormwater Management
- Hydrogeology
- Soil Science
- Horticulture and Arboriculture
- Vertical Greening
- Green Roof Systems
- Operations and Maintenance
- User and Community Engagement
- Building Insurance

Because nature-based infrastructure requires collaboration between many different disciplines that often use different terminology, early and continuous development of a common understanding of the baseline conditions, objectives and solution approaches is particularly important. This alignment should be formally integrated into every new project constellation and maintained throughout the project lifecycle.

Collaborative project delivery models based on shared objectives, such as the principle of *Best for Project*, can further support project success [21], [22], [31].

The planning of resilient open spaces requires clearly defined overall leadership and coordination, for example by landscape architects acting as integrators across disciplines.

Operations, maintenance and, ideally, monitoring are integral components of nature-based infrastructure. They actively influence system performance and must therefore be defined at an early stage, contractually established and professionally supported to ensure effectiveness, resilience and economic viability throughout the entire life cycle.



8.3 Building the Case for Nature-Based Infrastructure

Nature-based infrastructure is often perceived in practice as expensive and of limited relevance for achieving net zero targets, particularly with regard to maintenance requirements and greenhouse gas emissions. Such assessments are, however, overly simplistic because they typically evaluate individual elements in isolation rather than considering the ecosystem services they provide.

A street tree with sufficient rooting volume, water supply and nutrient availability within structurally supportive substrate systems will not achieve a net zero greenhouse gas balance over its lifetime. However, if the services delivered by that tree, such as cooling, air purification, water retention and infiltration, as well as the prevention of heat and erosion related damage, had to be provided through separate built and technical systems, the resulting emissions, resource consumption and costs would be substantially higher. A similar situation can be observed when comparing purely technical approaches to stormwater management with nature-based solutions.

When a plot is understood as an integrated system comprising buildings, open spaces, technical infrastructure and nature-based infrastructure, both its performance capacity and its associated resource requirements change significantly. The critical consideration is therefore the comparison of functionally equivalent solutions provided by technical and nature-based infrastructure against clearly defined impact objectives such as climate change mitigation, water management, microclimate regulation and damage prevention across the entire life cycle of a property.

Insufficient coordination between technical and nature-based systems frequently results in parallel infrastructure, unnecessary redundancies, excessive resource consumption and increased operational and maintenance requirements. The deliberate integration of these systems into coherent and multifunctional solutions designed around defined objectives and performance requirements can therefore reduce costs while significantly lowering greenhouse gas emissions and resource consumption (examples are shown in Figure 13: Key Coordination Interfaces

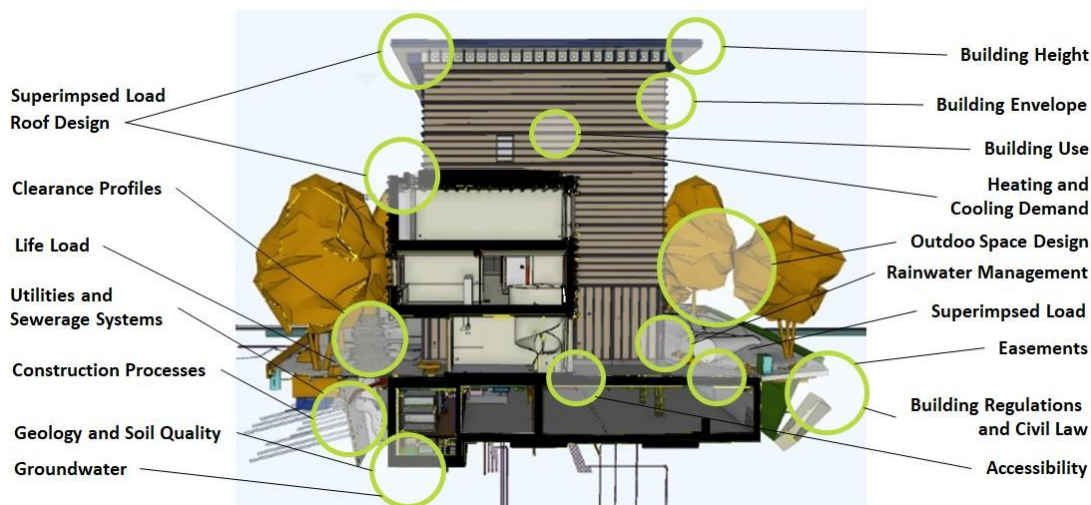


Figure 13: Key Coordination Interfaces between Built Space and Open Space at Plot Level. For Details, See Appendix F – Examples / Source: sysTEAMatik GmbH, based on Haus des Holzes, PIRMIN JUNG Schweiz AG

between Built Space and Open Space at Plot Level. For Details, See Appendix F – Examples / Source: sysTEAMatik GmbH, based on Haus des Holzes, PIRMIN JUNG Schweiz AG).

8.4 Information Requirements by Level

The efficient and long-term effective implementation of nature-based infrastructure requires a continuous digital information model. Framework conditions, requirements, impact objectives, measures and key performance indicators must be represented consistently from planning through operation and monitoring.

Nature-based infrastructure should be modelled as an integrated system, continuously assessed and managed through standardised indicators. Achieving this requires close integration of static baseline data sources, such as GIS, with dynamic planning and operational models, such as BIM.

The primary challenge today is not a lack of data, but rather insufficient standardisation and interoperability, whether in terms of accuracy and level of detail or in relation to logical structures and information models. Appendix B –



Element and Attribute List provides an example framework derived from the proposed objective categories and associated factors, serving as a basis for further development of use cases and digital applications.

9 Current Opportunities and Barriers for Nature-Based Infrastructure

Current development practices within the built environment often focus on individual construction projects and short term or narrowly profit driven objectives. Impacts on climate, resources and neighbouring areas are frequently insufficiently considered. Infrastructure systems are commonly designed as monofunctional solutions, despite the fact that their performance depends on interactions within interconnected systems. Appendix D – Gap Analysis summarises currently identified barriers and implementation gaps.

A common challenge is the absence of clearly defined performance objectives. Requirements often prescribe specific measures without defining the intended outcomes. This limits prioritisation, comparability and integrated planning. In addition, measures are frequently defined only within property boundaries, making it difficult to develop connected, context specific and sustainable solutions. To support integrated planning, requirements should therefore link objectives with suitable examples of measures while maintaining flexibility for project specific solutions. Complementary minimum quality standards and consistent performance requirements are also needed to ensure that elements can function effectively and contribute to resilience over the long term.

At the same time, many of the necessary building blocks already exist. Standards, assessment systems and tools such as SIA 2032, SIA 2066, Minergie ECO, SNBS, DGNB and ecoProducts (see Appendix E – Further Reading) provide important foundations. However, open spaces are not yet systematically represented within these frameworks. The greatest opportunity lies in further developing existing standards and tools and consistently aligning them with the delivery of ecosystem services within the built environment.

9.1 From Measures to Impact Objectives

Measures are often planned in isolation without being linked to clearly defined impact objectives, for example specifying permeable paving instead of defining a target for groundwater recharge. A key opportunity lies in establishing and coordinating desired outcomes such as heat mitigation, water retention or biodiversity enhancement at an early stage. This enables the targeted planning, implementation and maintenance of open spaces that support high performing nature-based infrastructure.

To achieve the objectives of climate change mitigation and resource conservation, open space planning currently lacks appropriate methodologies, tools and baseline data for assessment. In contrast, such foundations are already available for building construction and civil engineering and could serve as a basis for the development of equivalent approaches for open space planning.

Many shortcomings originate at the briefing stage. When impact objectives, minimum quality requirements and verification methods are not defined early in the process, nature-based solutions tend to be insufficiently considered during design competitions and project development. Strengthening client competence is therefore a key prerequisite for demanding quality, performance and long-term value.

9.2 Multifunctionality and Quality of Nature-Based Infrastructure Building Blocks

Existing sites offer substantial opportunities for nature-based infrastructure. Gardens, green spaces, residual transport areas, roofs and façades can be enhanced, connected and used in multifunctional ways. Even relatively simple measures such as surface unsealing, tree preservation and improvements to water and nutrient availability can deliver noticeable benefits.

The quality of individual elements is decisive. Soil management, ecological permeability, plant selection and plant communities, optimised material choices and appropriate maintenance practices all determine overall performance. The coordination of these factors can lead to significant differences in ecosystem service delivery and substantially reduce the need for technical infrastructure.

At the same time, a systematic description of nature-based infrastructure elements is often lacking. Information on function, performance, composition and maintenance is frequently fragmented and non-standardised. At element level, clear definitions are needed for materials, dimensions, service life, maintenance requirements, ecological performance and their digital representation. The absence of these foundations limits planning efficiency,



comparability and quality assurance. Developing such standardised information structures is therefore an essential prerequisite for the broader implementation and management of nature-based infrastructure.



Figure 14: Potential of Property Boundary Zones for Nature-Based Infrastructure Networks / Source: Master's Thesis, Anne Nyffeler [29]

9.3 Integrated Systems, Operations and Maintenance

A major barrier is the lack of coordination between nature-based and technical systems. When the requirements of built spaces are not aligned with those of open spaces, parallel solutions often emerge that either weaken one another or create unnecessary redundancies. Integrated planning increases overall performance while reducing resource consumption and costs.

In addition, a broader systems perspective is frequently missing. Interdependencies such as water flows, cold air movement and ecological connectivity are often insufficiently considered, resulting in isolated solutions with limited effectiveness. The link between larger spatial systems and site-specific measures also remains unclear in many projects.

Operations and maintenance are often addressed too late in the process, despite their decisive influence on long-term performance. An operations and maintenance strategy that is defined early and aligned with impact objectives is therefore a critical success factor for ensuring the effectiveness, resilience and economic viability of nature-based infrastructure over time.



Figure 15: Example of BIM Based Coordination of Open Space Elements / Source: Landscale AG, 2024

9.4 Data, Digitisation and Transformation

Many relevant data sources and information bases already exist. However, they are often inconsistent, difficult to access and not readily interoperable because they differ in structure, level of detail and format. For example, climate maps, hazard maps, soil and groundwater information, as well as inventories of protected areas and ecological infrastructure, are available at national, cantonal and municipal levels. GIS based datasets provide information on climate regimes, topography, land use, habitat types, flora and fauna, and in some cases ecological connectivity. The primary challenge lies in the lack of continuity between datasets and the limited discoverability and accessibility of information. Significant gaps also remain in both data availability and data integration. Information relating to climate, hydrology, soils and ecological structures is often incomplete, inconsistently prepared or difficult to combine across sources. Standardised metrics and assessment methods for evaluating and comparing technical, hybrid and nature-based solutions are largely absent. Reliable information on costs, emissions and benefits across the life cycle is particularly limited at plot level. A continuous information model for nature-based infrastructure that



integrates impact objectives and associated indicators throughout the entire life cycle offers considerable potential. If performance parameters are managed as model attributes, alternative solutions can be compared, coordinated and optimised more effectively. This requires a clear structuring and linkage of existing datasets together with the definition of relevant attributes at element level. Such an information model should provide an unambiguous description of nature-based infrastructure elements, link their attributes to ecosystem processes and allow integration into existing planning and management software. At the same time, it should provide the basis for automated compliance checks during planning, as well as monitoring, maintenance and continuous improvement throughout operation. The transformation towards the integration of nature-based infrastructure does not primarily require new tools. Rather, it depends on the consistent application, further development and interconnection of existing standards, datasets and methods. Critical success factors include the definition of clear ecosystem service objectives (impact objectives), the development of coordinated and integrated system solutions based on these objectives, and the early integration of operations and maintenance processes, all supported by interoperable data structures and accessible information.

10 Fields of Action

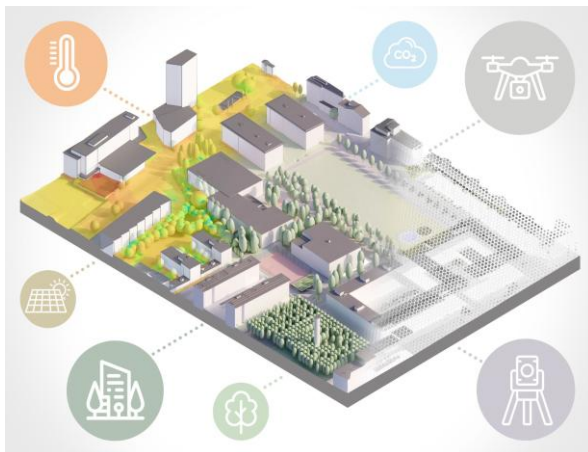


Figure 16: Integrated Digital and Model Based Planning of Nature-Based Infrastructure / Source: Landscale AG, 2026

These opportunities and barriers point to a number of clear priorities for action: defining objectives, establishing continuous information flows, coordinating systems, measuring performance and aligning operations and maintenance with intended outcomes.

Across all themes, it becomes evident that the effective integration of nature-based infrastructure requires consistent work across multiple spatial and organisational levels. Strategic objectives must be translated into spatial concepts, then into project requirements and ultimately into element specific specifications. The lack of continuity between these levels remains one of the most significant barriers to implementation.

At the same time, nature-based infrastructure requires a shared systems perspective among all stakeholders. Ecological processes, spatial interdependencies and long-term maintenance requirements must be considered collectively so that technical and nature-based systems can be integrated effectively and implemented in a robust and resilient manner.

10.1 A Shift in Perspective

The effective integration of nature-based infrastructure requires a shift in perspective. Rather than focusing on individual measures, clearly defined impact objectives should be established for climate change mitigation, water management, biodiversity enhancement, damage prevention and open space quality. These objectives must be spatially referenced, measurable wherever possible and capable of being represented within digital information models.

A critical requirement is the continuity of these objectives throughout planning, implementation, operation and maintenance. The lack of such continuity remains one of the most significant barriers to implementation. At the same time, minimum and consistent quality standards are needed to ensure that nature-based infrastructure elements can function effectively as long-term providers of ecosystem services and contributors to resilience.



10.2 Strategic Levers

A key strategic lever lies in making climate risks, vulnerabilities and the associated costs within the built environment visible at an early stage. Transparent life cycle cost benefit assessments that incorporate climate impacts, health effects and damage related costs provide a stronger basis for decision making and help build acceptance for nature-based infrastructure.

At the same time, clear visions and targets are required, together with the spatial and temporal safeguarding of areas designated for nature-based infrastructure within strategic and statutory planning instruments.

The development of nature-based infrastructure also requires broader societal and institutional change. Demonstration projects, reference cases and binding objectives at municipal and cantonal levels can support this transition. Equally important are the development of professional expertise in ecosystem processes and the raising of awareness among citizens, users and decision makers. Communicating the benefits and performance of nature-based infrastructure strengthens public acceptance, appreciation and voluntary support for implementation and maintenance. In addition, nature-based infrastructure should be integrated into vocational education, professional training and higher education programmes to ensure that the necessary competencies are developed across planning, administration, operations, maintenance and long-term management.

Client competence is another critical success factor. Clients and asset owners must define impact objectives, minimum requirements and verification procedures at an early stage and formally incorporate them into project briefs and procurement processes. This includes target values, option assessments and operations and maintenance concepts. Such measures make nature-based infrastructure more predictable, verifiable and manageable throughout its life cycle. Clear target frameworks, standardised planning tools and accessible decision support instruments also simplify communication, strengthen self-regulation among clients and encourage the consistent implementation of performance-oriented solutions.

Existing best practice examples, including publications by the Federal Office for the Environment (FOEN) [38] and platforms such as the Sponge City Information Platform [39], demonstrate the feasibility of individual measures. To achieve lasting impact, however, these approaches must evolve from isolated interventions towards interconnected and multifunctional infrastructure systems.

10.3 Organisational and Procedural Levers

Nature-based infrastructure must be planned as part of an integrated functional system comprising buildings, open spaces and technical infrastructure. This requires site and project specific objectives, clearly defined responsibilities throughout the entire life cycle, dedicated overall coordination for open spaces and nature-based infrastructure, and integrated option assessments that evaluate synergies and trade-offs across the objective categories described in Chapter 4 from the earliest planning stages. This also includes the formal appointment of an overarching coordination and management role responsible for open spaces and nature-based infrastructure.

A clear definition of system boundaries is equally important. The plot or development area should serve as the minimum mandatory assessment and planning unit, ensuring that buildings and open spaces are evaluated together as a functional system.

Standardised assessment methodologies are needed to enable objective comparisons between technical, hybrid and nature-based systems. Performance based cost benefit analyses, together with robust metrics for economic performance, life cycle costs and greenhouse gas emissions, provide an essential basis for informed decision making. Reliable indicators for economic performance, life cycle costs and greenhouse gas emissions at plot level are particularly important. Complementary assessment tools are also required to transparently demonstrate the performance potential of nature-based infrastructure in comparison with purely technical solutions.

Operations, maintenance and monitoring must be considered from the outset and embedded contractually within projects. These activities actively influence system performance and are essential for securing long-term effectiveness. All nature-based infrastructure elements, including individual measures, should be designed, implemented and maintained as part of an integrated system approach (see Appendix F for an example). The early definition of suitable monitoring indicators for each objective category, such as climate, biodiversity and water, is critical for verifying performance and demonstrating progress towards the intended outcomes.



10.4 Priorities for Further Development

Existing collections of best practice examples demonstrate what is already achievable.

In the publication «Nature-Based Solutions: Opportunities for Municipalities, Regions and Businesses – An Overview of Exemplary Measures for Biodiversity, Climate Change Mitigation and Climate Change Adaptation» [38] the Federal Office for the Environment (FOEN) provides a catalogue of example measures for nature-based solutions. For settlements and transport infrastructure, it includes valuable examples related to the creation and enhancement of urban green spaces, green roofs, green façades, surface unsealing, urban water bodies and sponge city approaches.

The Swiss Water Association (VSA) also provides a wide range of examples through its Sponge City Information Platform [39], together with tools to support the integration, development, implementation and maintenance of sponge city solutions.

To achieve lasting and large-scale impact, however, these approaches must be systematically advanced beyond individual measures towards interconnected and multifunctional infrastructure systems.

Key priorities for future development include:

- performance-oriented use cases for each performance dimension
- standardised performance descriptions and the derived element categories and attributes
- continuous, interoperable and easily accessible digital data foundations for planning, operation and maintenance

For further development, it is recommended to establish dedicated use cases aligned with the proposed performance dimensions, including:

- Open Space Climate and Comfort (building sector foundations available through SIA 416 and SIA 2024)
- Climate Change Mitigation (foundations available through preliminary life cycle assessments of open space elements developed by the City of Zurich) [41]
- Microclimate Regulation
- Water Management
- Biodiversity
- Damage Prevention (foundations available from the research project «Optimised Building Protection against Natural Hazards using BIM», Cantonal Building Insurance Association, 2019–2021) [32]

These use cases must define concrete planning processes, information flows and responsibilities while enabling integration into digital planning environments. An essential foundation for all specialised use cases is provided by the Level of Information Need (LOIN) framework for landscape architecture, the Landscape Architecture Element Plan and the Modelling Guideline for Model Based Cost Estimation (Quantity Take Off) in Landscape Architecture. Soil management should also be developed as a dedicated use case due to its central role in the performance of nature-based infrastructure.

Another key prerequisite is the standardisation of element information (see also Chapter 6).

Open spaces should be structured into clearly defined spatial categories and functional areas, analogous to the classification of buildings. Based on this structure, requirements can be systematically organised according to use, performance and material characteristics and subsequently integrated into digital information models.

SIA 416 Areas and Volumes of Buildings [30] distinguishes between different spatial categories that provide a framework for assigning category specific requirements and performance information. These include primary and secondary use areas, circulation areas and service areas (e.g. technical rooms and shafts). For building exteriors, outdoor use areas such as balconies and terraces are also defined. Within open space planning, however, only developed and undeveloped external areas are currently distinguished.

To enable a more detailed differentiation of spatial functions and their associated requirements, additional categories for open spaces could be adapted and defined for landscape and open space planning purposes:

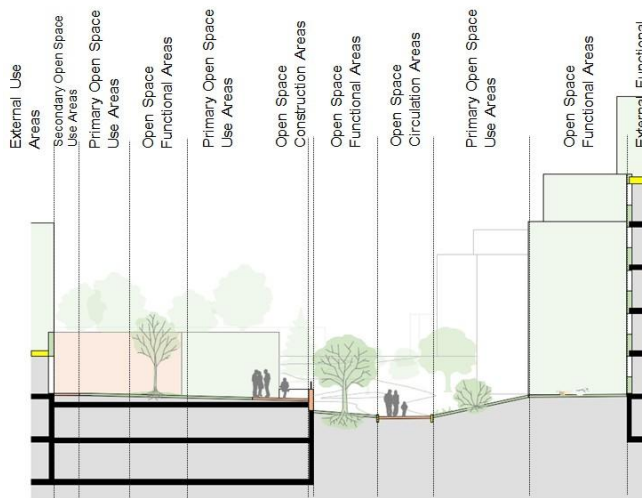


Figure 17: Potential Additional Open Space Subcategories. For an Application Example, See Appendix F – Examples / Source: NBI Working Group

- **Primary Open Space Use Areas:** Areas serving the principal purpose and use of the open space, including small structures such as pavilions and pergolas.
- **Secondary Open Space Use Areas:** Areas supporting the primary use, such as fire access and staging areas, bicycle parking and shelters, car parking spaces, garden sheds or animal shelters.
- **Open Space Circulation Areas:** Areas such as roads, access routes, pathways, stairs and ramps.
- **Open Space Functional Areas:** Areas primarily dedicated to the delivery of ecosystem services.
- **Open Space Construction Areas:** Areas occupied by structural elements, such as retaining walls and other engineering structures.
- **External Functional Areas:** Roof surfaces providing functions such as ecological enhancement, water retention, electricity generation or heat production.

Similarly, requirements for ecosystem service delivering elements could be logically structured and organised within the context of defined performance dimensions. These requirements can be differentiated into use related requirements (including circulation areas), performance related requirements (functions) and the resulting material and construction requirements.

Appendix B – Element and Attribute List presents an initial collection of relevant element categories and attributes linked to factors that influence the impact objectives and objective categories described in this document (see Chapter 4).

Building on this foundation, a standardised performance-based information model for open spaces can be developed. Such a model would provide a consistent framework for describing nature-based infrastructure elements, linking them to ecosystem processes and integrating them into existing digital planning and management systems. This would improve coordination across disciplines and enable automated assessments, monitoring and the continuous optimisation of nature-based infrastructure throughout its life cycle.

A further important component is the consistent documentation of open spaces through a digital open space logbook, analogous to a digital building logbook. Such a system would document the open space as an asset, including its objectives, performance requirements, maintenance strategies, modifications and development over time, thereby supporting long-term management and the preservation of ecosystem service delivery.

11 Outlook: Potential Tools and Next Development Steps

This whitepaper outlines the foundations, opportunities, barriers and action areas for the implementation of nature-based infrastructure. The next step is to strengthen the shared understanding among stakeholders, establish robust decision-making foundations and increase transparency regarding the factors, performance and costs associated with nature-based infrastructure. To support this transition, the following sections present initial concepts for practical tools and outline potential development pathways for the integration of nature-based infrastructure into planning, construction, operation and maintenance processes.



11.1 Web Based Awareness Raising Tool (Proof of Concept)

To support awareness raising and the development of a shared understanding of ecosystem processes, ecosystem services and impact pathways, a web-based tool was developed as a proof of concept. Based on simple user inputs relating to the extent and quality of open space elements, the tool illustrates how design and management decisions can influence open space comfort, safety and health, as well as broader impacts on buildings, infrastructure and resource consumption.

A logical next step would be the automated generation of a concise and accessible report based on the user inputs. Such a report could summarise key interdependencies, optimisation opportunities and suitable measures, while highlighting expected benefits and trade-offs. This would provide a low threshold entry point for clients, public authorities and planning teams, complementing more detailed technical assessment methods and supporting informed decision making at an early stage of project development.

The screenshot shows a web-based tool interface. On the left, there is a sidebar titled 'Projekttitel eingeben' with several sections of input fields, each with a '0' and a radio button:

- Untergrund (m²):** Baugrund sicherfähig, Baugrund schlecht sicherfähig, Auffüllung sicherfähig, Bauwerksüberdeckung < 40cm, Bauwerksüberdeckung < 60cm.
- Vegetation (m²):** Bäume, Sträucher, Stauden, Kraut.
- Oberflächen (m²):** Umgebungsbelag versiegelt hell, Umgebungsbelag versiegelt dunkel, Fugen > 15 mm hell, Fugen > 15 mm dunkel, Vegetationsfläche ruderal, Vegetationsfläche grün, Kronenbedeckung, Steildach / Nacktdach, Flachdach extensiv begrünt, Flachdach intensiv begrünt, Wasserfläche, Fassade kompakt hell, Fassade kompakt dunkel, Fassade leicht hell, Fassade begrünt, Fassade leicht dunkel.
- Übergänge (m):** Zufuss, Abfluss, offen, durchlässig, geschlossen, Baugrundsicherung geschlossen.

At the bottom of the sidebar are three buttons: 'CSV Export' (green), 'CSV Import' (green), and 'Export als PDF' (red).

The main area on the right features a diagram of a building and its surrounding environment. The diagram is annotated with various processes and their impacts:

- Evaporation / Retention:** CO₂-Fussabdruck, Kosten, Nachtauskühlung, Energieverbrauch, Kühlung.
- Reflektion / Absorption:** Luftreinigung, Lärmreduzierung, Kühlung, Gesundheit, Resilienz.
- Transpiration:** Versickerung, Verschattung, Oberflächenabfluss.
- Wassermengung / Grundwasser-Neubildung:** Wassermengung, Grundwasser-Neubildung, Versorgungssicherheit.
- Other impacts:** Starkniederschlag, Luftverschmutzung, Lärmbelastung, Hitze, Ökologie, technische Systeme, Schadensprävention, Leitungskapazität, Stauraum.

Small text at the bottom of the diagram reads: '* bei integrierter Koordination ab frühen Projektphasen oft auch naturbasierte Systeme möglich ** Speisung und Speicherung von Untergrund und Vegetation nicht berücksichtigt'. The logo '© 2019 TEAM-GmbH' is visible in the bottom right corner.

Figure 18: [PoC Web-Based Tool For Awareness Raising](#)

11.2 Assessment Methodology for Ecosystem Service Performance

A standardised assessment methodology is required to systematically evaluate projects at plot or development area level. Such a methodology should consider the factors relevant to defined impact objectives and enable the comparison of design alternatives comprising different combinations of nature-based infrastructure elements (see Chapter 5.3.2). The focus should not be on individual measures, but rather on determining whether the desired performance objectives can be achieved and identifying the most suitable solution in relation to the project specific combination of objectives.

The methodology should be based on a concise and consistent set of indicators that represent the key factors influencing each performance dimension. Standardised indicators (Appendix A – Key Performance Indicators (KPIs)) and standardised element and attribute definitions (Appendix B – Element and Attribute List) provide the foundation for such an approach.

An initial proposal for factors that could be considered at element level within each performance dimension is outlined below [29]:

- **Open Space Comfort:** Spatial accessibility, connectivity, noise exposure, social value
- **Climate Change Mitigation and Resource Conservation:** Preserved resources, avoided greenhouse gas emissions, carbon sequestration and carbon storage
- **Biodiversity:** Biotope area factor, species composition, structural diversity



- **Microclimate Regulation:** Shading, surface reflectance (albedo), mean radiant temperature, evapotranspiration
- **Water Management:** Runoff coefficient, infiltration capacity, filtration performance, surface structure
- **Damage Prevention:** Runoff coefficient, slope gradient, rainfall absorption, vegetation cover and erosion control

These factors are intended as a starting point and should be further refined, standardised and linked to measurable indicators. Their purpose is to provide a consistent basis for assessing how individual elements contribute to the delivery of ecosystem services and the achievement of project specific impact objectives.



Figure 19: Examples of Visualisations Based on a Standardised Assessment Methodology / Source: Master's Thesis, Anne Nyffeler [29]

11.3 Life Cycle Assessment Methodology for Open Space Design

In addition to performance assessment, a practical life cycle assessment (LCA) methodology for open space design is required. Such a methodology should quantify greenhouse gas emissions and broader environmental impacts across the entire life cycle and enable consistent comparison at the scale of a plot or development area.

To achieve this, functional units, system boundaries and appropriate levels of detail for different project phases must be defined, analogous to established standards in building construction and existing methodologies in civil engineering. The assessment framework should allow alternative open space design solutions to be compared quantitatively and transparently.

This would provide a robust basis for integrating open space design into net zero strategies and support evidence-based decision-making during option appraisal and project development. At the same time, it would enable the identification of trade-offs and synergies between climate change mitigation, resource conservation, ecosystem service delivery and long-term operational performance, thereby supporting more holistic and sustainable design decisions.



11.4 Pathway from Whitepaper to Standardisation

The next steps should follow an iterative development approach. The tools and methodologies proposed in this whitepaper should first be tested in pilot projects and validated using real world data. The insights gained can then be used to refine and further develop the underlying concepts and assessment approaches.

Based on these experiences, dedicated use cases for each performance dimension can be elaborated in greater detail. Subsequent steps should focus on the harmonisation of indicators, the standardisation of element attributes and the integration of these structures into digital planning, design and management workflows.

Together, these developments would establish a robust and scalable foundation for the planning, implementation, operation and long-term management of nature-based infrastructure. They would also support the consistent translation of ecosystem service objectives into measurable requirements, coordinated interventions and verifiable outcomes across the entire life cycle of the built environment.

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This document does not claim to be exhaustive. It is not a generally applicable recommendation or guideline in a legal sense. Rather, it is intended to support all stakeholders in the construction and real estate sector in understanding and correctly assigning the interdependencies between the individual steering instruments required.

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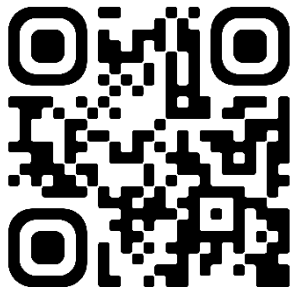
14 Appendix A – Key Performance Indicators (KPIs)

[Link to dynamic web version](#)



15 Appendix B – Element and Attribute List

[Link to dynamic web version](#)



16 Appendix C – Process Matrix

[Link to dynamic web version](#)

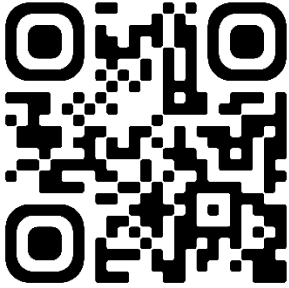


Dimension	Macro Level Region	Meso Level Neighbourhood	Micro Level Plot	Nano Level Elements and Actors	Tools
Spatial Requirements and Social Value	Regional Culture, Demographics and Identity	Social Resources, Cultural Infrastructure and Governance Networks	Social Spaces, Local Cultural Practices and Community Participation	Individual Human Actors, Behaviour, Perceptions and Preferences	GIS Analyses, Participatory Mapping, User Surveys and Value Proposition Design
Climate Change Mitigation	Climate Change Trends and Regional Mitigation Targets	Emissions from Neighbourhood Activities, Including Mobility and Energy Systems	Emissions from Building Related Services, Including Heating, Water Supply and Waste Management	Embodied Greenhouse Gas Emissions in Materials, Products and Building Components	GIS Analyses, Life Cycle Assessment Tools, EN and ISO Standards
Biodiversity	Ecological Infrastructure, Habitat Connectivity and Species Migration Corridors	Habitat Networks, Biodiversity Hotspots and Ecological Stepping Stones	Site-Specific Vegetation Composition and Structural Complexity	Characteristics of Plant and Animal Species, Functional Diversity and Ecological Interactions	GIS Analyses, Biodiversity Indices and Ecosystem Service Assessment Models
Water Management	Groundwater Levels, Surface Waters and Precipitation Patterns	Stormwater Infrastructure Capacity, Flood Retention Areas and Hydrological Connectivity	Infiltration Capacity, Retention Structures and Irrigation Systems	Soil Hydraulic Conductivity, Surface Infiltration Capacity, Evapotranspiration and Substrate Water Storage Capacity	GIS Analyses, Climate Models, Hydrological Models and Soil Moisture Sensors
Microclimate Regulation	Regional Climate and Climate Zone Classification	Heat Vulnerable Areas, Ventilation Corridors and Urban Heat Islands	Shading, Albedo, Heat Storage and Vegetation Distribution	Leaf Area Index, Stomatal Conductance and Soil Moisture	GIS Analyses, BIM Simulations, Thermal Comfort Models and Field Sensors
Damage Prevention	Extreme Weather Risks and Wildfire Susceptibility	Flood Risks, Soil and Slope Stability, and Hazard Zoning	Drainage, Wind Protection, Fire Resistant Vegetation Systems and Safe Access	Wind Resistance, Flame Spread Resistance and Material Durability	GIS Risk Maps, BIM Coordination and Ecosystem Service Profiles



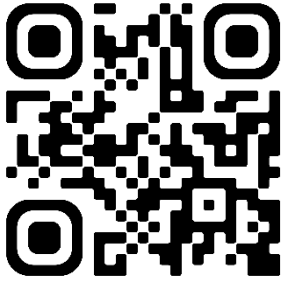
17 Appendix D – Gap Analysis

[Link to dynamic web version](#)



18 Appendix E – Further Reading

[Link to dynamic web version](#)

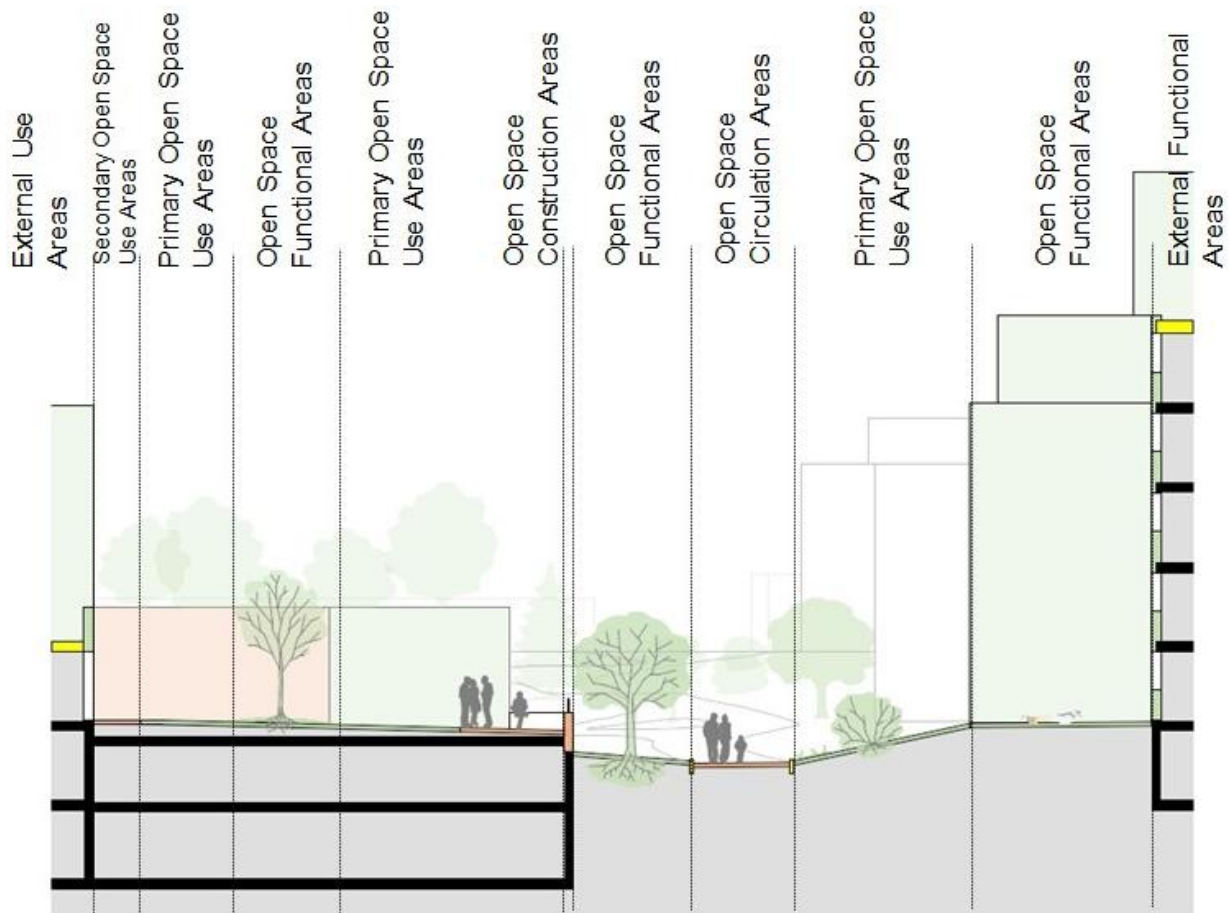




19 Appendix F – Examples

Examples of Priorities and Requirements by Open Space Area Category

Open space uses can be grouped into different categories with typical requirements (area categories). From these typical spatial requirements, corresponding requirements for the elements that form and structure these spaces can be derived. This enables the definition of both mandatory performance requirements and quality standards, while also identifying areas where design flexibility can be maintained. The following overview presents possible design priorities, functions and requirements for the proposed area categories. The examples are illustrative and not intended to be exhaustive.



Primary Open Space Use Areas:

Areas dedicated to the primary function and intended use of an open space, including associated small-scale structures such as pavilions and pergolas

Focus: Optimisation of positive contributions to ecosystem services.

Typical Design Priorities and Requirements: Design as spaces for social interaction, with differentiation between functions such as seating and recreation areas, play areas, sports areas and gardens for food production. Consideration of different user groups and their associated requirements, including shading, accessibility and travel distances, barrier free access, opportunities for interaction with water, and user specific amenities and infrastructure.

Secondary Open Space Use Areas:

Areas that support the primary use of an open space,

Focus: Optimisation of positive impacts on ecosystem services.



such as fire access and staging areas, bicycle parking and shelters, parking spaces, garden sheds and animal shelters

Differentiation of requirements according to the respective functions.

Open Space Circulation Areas:
Areas such as roads, access routes, pathways, stairs and ramps

Focus: Minimisation of negative impacts on ecosystem services.

Differentiation between functions such as carriageways, emergency access routes, pedestrian paths, service access for deliveries and moving activities, postal access routes, rights of way (easements), driveways and entrances. Associated requirements may include load bearing capacity, sight lines, surface materials, drainage, edge treatments, clearance profiles (width and height), turning radii, junctions and manoeuvring areas, barrier free access, potential shared use as play areas, and maintenance obligations, including safety related requirements such as winter service operations.

Open Space Functional Areas:
Areas primarily dedicated to the delivery of ecosystem services

Focus: Optimisation of positive impacts on ecosystem services.

Areas whose primary function is the delivery of ecosystem services, including designed elements such as planting beds, rather than direct human use. Design should focus on species optimised plant communities, for example through targeted underplanting beneath trees to increase robustness and resilience. Maintenance should minimise water loss, for example through mulching, while ensuring adequate water supply and preventing waterlogging where necessary. Management practices may include minimal and seasonally staggered mowing to support habitat provision, regular control of invasive alien species, and the maintenance of ecological connectivity through the minimisation of physical barriers.

Open Space Construction Areas: Areas occupied by structural elements such as retaining walls and comparable construction components.

Focus: Minimisation of negative impacts on ecosystem services and maximisation of multifunctionality.

e.g. vertical greening

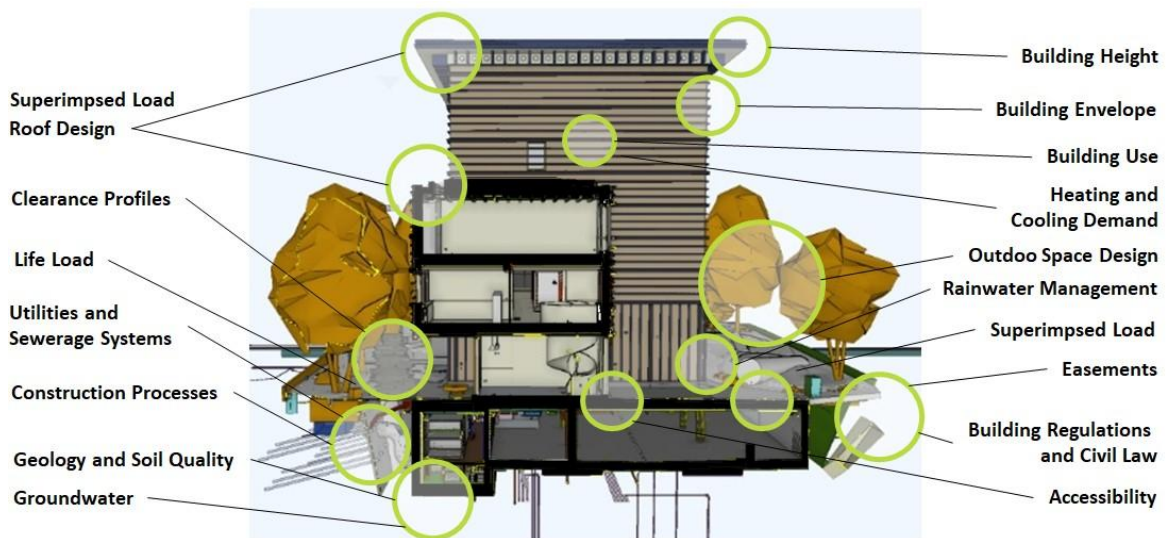
External Functional Areas: Roof surfaces with functions such as ecological enhancement, water retention, or the generation of electricity or heat.

Focus: Optimisation of positive impacts on ecosystem services.

In addition to conventional outdoor use areas such as terraces, loggias and balconies, these areas can contribute to biodiversity enhancement, water management, microclimate regulation and renewable energy generation. Design principles are similar to those applied to Open Space Functional Areas, with regular monitoring and control of invasive alien species being particularly important.



Examples of Coordination Interfaces at Plot Level



Groundwater

The presence of groundwater has a significant influence on fundamental construction measures, including excavation support systems, foundations, structural dimensions and, where necessary, temporary groundwater lowering during the construction process. As a result, construction activities often require deeper intervention into natural soils and consequently cause greater disturbance to natural processes. In addition, underground structures and infrastructure occupy valuable subsurface space, reducing the area available for nature-based infrastructure and its supporting systems. To enable effective nature-based infrastructure, the requirements of groundwater conditions, underground construction and open space functions must therefore be coordinated at an early stage of project development.

Geology and Soil Quality

Local geological and hydrological conditions, together with soil characteristics and soil quality, influence not only the ecosystem services that can be delivered and the range of suitable planting options, but also key construction requirements such as excavation support systems, foundation measures and the dimensions of underground structures. These factors therefore directly affect the depth and extent of interventions into the subsurface. They must be investigated, coordinated and integrated at an early stage of project development to ensure that both construction requirements and nature-based infrastructure objectives can be effectively accommodated.

Construction Process

The extent of disturbed open space should be kept to a minimum, and natural conditions should be preserved wherever possible. Excavation support systems should preferably be designed as unreinforced earth slopes. Where permanent structural support systems are required, they should be removed wherever feasible once construction is completed in order to restore natural soil processes as far as possible. If such structures remain in the ground, they can create subsurface barriers that disrupt natural hydrological processes, including groundwater movement and subsurface water flows. They may also affect soil chemistry, for example through the carbonation of concrete or the corrosion of reinforcing steel. These changes can significantly alter growing conditions for vegetation and reduce the natural functionality and ecosystem service capacity of soils.

Utilities and Sewerage Systems

Underground utilities and installations can occupy substantial subsurface space and should therefore be minimised and coordinated in a way that preserves sufficient space for natural processes and plant rooting zones, particularly for trees.



Tree roots do not actively seek out and damage utility lines. Rather, they are attracted to water escaping from leaking pipes and defective connections. The integrity and maintenance of underground infrastructure are therefore important factors in preventing root related conflicts. In addition, plastic-based underground installations may release microplastics and, in some cases, harmful substances such as PFAS during degradation. The use of plastic based components should therefore be minimised wherever feasible. Experimental studies have shown that fine sand can, for example, be used as a root protection measure around underground utility lines while maintaining favourable conditions for soil functions and root development.

Live Load kN/m². Defines the load capacity for which a floor or roof structure is designed in relation to its intended use. It determines, for example, whether a slab above an underground level can support vehicle traffic or whether planters containing trees and other vegetation can be placed on it. Live load requirements directly influence structural dimensions and construction depths, which in turn affect planning levels, regulatory approvals and construction costs. These requirements should therefore be clarified and coordinated with the responsible structural engineers at an early stage of the project.

Clearance Profiles Clearance profiles define the unobstructed space required along circulation routes. These are zones that must remain free from obstructions such as branches, vegetation and other physical elements. They are particularly important along roads, emergency access routes and pavements, where they ensure adequate sight lines, traffic safety and unrestricted accessibility. Clearance profiles are also relevant, although typically with less stringent requirements, along internal access routes and pedestrian pathways within a property. For this reason, clearance profile requirements must be considered during planting design and incorporated into long-term maintenance and management practices to ensure continued compliance throughout the life cycle of the vegetation.

Roof Design Particular attention must be paid to liability interfaces where flat roof waterproofing and green roof systems are installed by different contractors. To avoid damage and associated costs, it is essential that the intended functions, performance objectives and construction build ups are clearly defined, communicated and understood by all parties involved, from planning through to construction. Qualified specialists should be engaged for both waterproofing and green roof installation. There is also a risk of damage to roof waterproofing systems during maintenance activities if personnel are not familiar with working on roofs with relatively shallow substrate depths. Conversely, inadequate maintenance by personnel without horticultural expertise may lead to poor vegetation development or the spread of invasive alien species. The use of appropriately qualified personnel, together with the early definition and clear communication of functions, objectives and maintenance requirements, is therefore essential to ensure the long-term performance of both the roof construction and the associated nature-based infrastructure.

Superimposed Load kN/m². Defines the load for which a floor or roof structure is designed from layers and elements applied above the structural slab, such as floor build ups, roof assemblies, substrates and other finishes. It determines, for example, whether a slab above an underground level can support trees and the associated increased substrate depths, or whether rainwater can be retained on a flat roof up to a specified depth. Superimposed load requirements directly influence structural dimensions and construction costs and must therefore be clarified and coordinated with the responsible structural engineers at an early stage of project development.

Building Height Maximum building heights are typically defined in zoning regulations, development plans or site-specific planning instruments, often together with limits on the number of storeys. At the same time, minimum room heights are usually prescribed for interior spaces.



Roof build ups associated with extensive green roofs, biodiverse roof systems or roof-based water retention generally require greater construction depths and correspondingly higher roof edge details. This can increase the overall building height. If the permitted building height is exceeded, efforts are often made to reduce internal room heights wherever possible. Where minimum room height requirements would be compromised, extensive roof build ups or large roof retention systems are frequently omitted because they reduce the amount of leasable or usable indoor space and may therefore affect project profitability. Levels and height relationships between indoor and outdoor spaces are therefore closely linked to the design of roof assemblies and are often subject to planning approval requirements. For this reason, they must be considered, coordinated and integrated into the project design before the building permit application is submitted.

Building Envelope

Building envelopes are key elements that shape and define open spaces. Their design therefore has a significant influence on the resulting microclimate and on the development and performance of nature-based infrastructure. For example, dark materials contribute to the overheating of adjacent open spaces. Dense materials with high thermal mass absorb heat during the day and release it during the night, further intensifying urban heat island effects. Highly reflective surfaces can create ecological traps for animals, while reflected sunlight may act like a magnifying glass and adversely affect vegetation growth or cause direct damage to plants. Biocides such as insecticides, herbicides, algacides and fungicides contained in building materials or surface treatments may be washed out by rainfall, affect nature-based elements and eventually reach groundwater, potentially impacting drinking water quality. Similar concerns apply to large metal surfaces and materials or surface treatments containing PFAS, such as hydrophobic coatings and impregnations. Requirements relating to fire safety, maintainability and access for protection and emergency services must always be considered, particularly when implementing green façades. For façade based greening systems, irrigation, water consumption, nutrient supply and drainage must also be addressed. Runoff from intensively fertilised systems may conflict with nature oriented open space design and therefore requires careful coordination. In addition, façade greening systems should be assessed and optimised with regard to embodied greenhouse gas emissions and their overall contribution to climate change mitigation.

Building Use

In addition to general functional requirements, the intended use of a building influences requirements related to protection and emergency services, including fire safety, firefighting operations and emergency response. These requirements depend on factors such as building height, building use, occupancy levels, occupant vulnerability, the presence of sensitive stored materials and the level of technical fire protection systems. In the context of nature-based infrastructure, these requirements can affect access routes, clearance profiles, turning radii, the number and location of emergency access areas, and the accessibility of façade openings for firefighting and rescue operations. These interfaces must therefore be considered and coordinated at an early stage to ensure that both safety requirements and ecosystem service objectives can be achieved.

Heating and Cooling Demand

Vegetation and planted areas have a temperature moderating and cooling effect on open spaces, thereby reducing heating demand and, in particular, the increasingly important cooling demand of indoor environments. Lower temperatures in open spaces also improve the effectiveness of nighttime cooling through natural ventilation, which is essential for maintaining comfortable and healthy sleeping conditions during summer and prolonged heat periods. For this reason, the construction and maintenance costs of buildings and open spaces incorporating nature-based infrastructure should be assessed in relation to the ecosystem services they provide and over the entire service life of the development. A life cycle perspective allows the benefits of reduced energy demand, improved thermal comfort and other ecosystem



services to be considered alongside the associated investment and maintenance costs.

Outdoor Space Design

The external works of building projects are always part of the wider open space network within settlements and the broader settlement landscape. High quality design, an integrated planning approach and the early involvement of qualified professionals, particularly landscape architects, are essential. For implementation, long-term development and maintenance, specialists in operation, maintenance and horticultural management should also be involved from an early stage. When selecting surface materials, the same considerations apply as for building envelopes, including impacts on microclimate, water management, biodiversity and environmental quality. Trees are among the most important performance delivering elements within nature-based infrastructure. To establish and thrive over the long term, they require sufficient rooting space. Rooting zones must therefore be coordinated at an early stage with underground utilities and structures. In addition to spatial use requirements (see examples of open space area categories above) and design considerations, standards and requirements relating to access and accessibility for emergency and rescue services are particularly important coordination factors in the planning of nature-based infrastructure. Animals are also essential users and inhabitants of nature-based infrastructure. Together with microorganisms and fungi, they form a natural maintenance system that contributes to ecosystem health and resilience by decomposing organic matter and regulating pest populations. Open space design should therefore provide suitable habitat, shelter and food resources while simultaneously avoiding barriers and traps that may harm wildlife. This includes, for example, ensuring permeability across plot boundaries through openings in or beneath fences and boundary structures, limiting the height of thresholds and obstacles, and reducing hazards at the interface between buildings and open spaces. Examples include the use of fine mesh covers over light wells, providing escape routes from shafts and stairwells, and implementing measures to reduce bird and wildlife collisions with glass surfaces.

Rainwater Management

Rainwater is a key water resource within settlements. It contributes to groundwater recharge, thereby supporting the freshwater supply for people, flora and fauna, and acts as a cooling medium through evaporation from retained water volumes and open water surfaces. Water management within settlements is a core objective of nature-based infrastructure, making rainwater management an integral component of these systems. At the same time, rainwater management contributes significantly to the objective of damage prevention. Particularly important in the context of damage prevention are the interfaces between indoor and outdoor spaces, such as door thresholds, balcony and terrace doors, light wells, ramps and basement stairways. These elements must be designed to prevent surface water from entering buildings during heavy rainfall events and periods of high surface runoff. Possible measures include appropriately dimensioned drainage channels, raised thresholds, elevated floor levels and temporary flood protection barriers. As these measures influence both building and open space design, they require early coordination between all relevant disciplines.

Easements

Easements are legally registered rights recorded in the land register. They may grant specific rights to neighbouring property owners, utility providers or the public, such as increased setback distances, rights of way or access rights. Easements are often associated with defined responsibilities and obligations regarding maintenance and operation. The parties identified in these agreements must therefore be involved in the planning and development of nature-based infrastructure. Related requirements must be considered and coordinated throughout planning, implementation and maintenance. Examples include clearance profile requirements, winter maintenance practices involving de-icing salts, and responsibilities for the management of leaves, pruning material and vegetation along shared boundaries and access routes.



Building Regulations and Civil Law

Building regulations are governed at the municipal level and may vary considerably between jurisdictions. Road legislation is generally regulated at the cantonal level, and in some cases also at the municipal level. Civil law provisions are likewise subject to cantonal regulations. In addition, numerous other legal requirements may need to be clarified on a project specific basis. In the context of nature-based infrastructure, particularly relevant legal provisions include building rights across property boundaries, minimum setbacks for underground structures, mandatory setback distances for trees and hedges, in some cases differentiated by species, as well as maintenance obligations and rights relating to the pruning or removal of trees and woody vegetation along property boundaries. These legal framework conditions must be identified and assessed at an early stage and incorporated as project requirements during planning and project development.

Accessibility

Accessibility requirements for open spaces include provisions relating to path widths, gradients, edge treatments, manoeuvring areas, level changes, surface materials, signage and tactile guidance. Nature-based surface materials often have higher rolling resistance and must therefore be coordinated at an early stage with accessibility requirements. Accessibility is also important from the perspective of social inclusion and equal participation. Access to different types of open space use, such as recreation, social interaction, gardening and play, should be ensured through appropriate circulation networks and barrier free design. To support people with reduced mobility and older adults, the generally smaller range of movement should be considered. Suitable seating opportunities with shade should therefore be provided along routes connecting different open space functions and destinations. At the interface between indoor and outdoor spaces, door and balcony threshold heights are among the most important factors influencing accessibility. At the same time, thresholds must satisfy additional technical requirements, including waterproofing performance and protection against water ingress during heavy rainfall events and periods of high surface runoff. These potentially conflicting requirements must therefore be carefully coordinated during planning and design.

Example of an Integrally Planned and Designed Nature-Based Infrastructure Module



Fragmented design of open space elements occurs when different functional components and infrastructure systems, such as roads, building placement, building envelopes, drainage systems, footpaths, trees and green spaces, are planned, implemented and managed in isolation.

An integrated approach is therefore essential to ensure that these elements function together as a coherent system. Only through early coordination can synergies between built and natural systems be realised, conflicts avoided and ecosystem services optimised over the long term.

Figure 20: Example of a Fragmented Open Space Design Approach

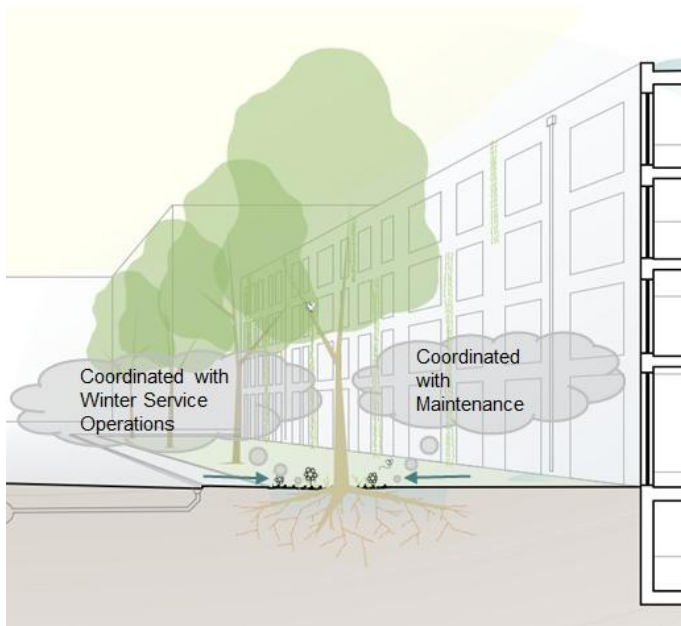


Figure 21: Example of Integrated and Regenerative Open Space Design Approach

When overarching functions (see examples of area categories above), quality requirements (see SIA 2066 [17]) and performance objectives (see Chapter 4) are defined for open spaces, and the measures required to achieve them (see Chapters 5 onwards) are coordinated, nature-based solutions can be conceived and connected as nature-based infrastructure for the targeted delivery of ecosystem services. This creates integrated and regenerative systems of buildings and open spaces. Such systems can form the foundation for safe, healthy and resilient settlements and contribute to a prosperous and future proof society.



20 Appendix G – Glossary

Term	Definition
BIM	Building Information Modelling
Binary Indicator	A criterion that can be assessed using only two possible outcomes, such as <i>yes/no</i> , <i>fulfilled/not fulfilled</i> , <i>present/absent</i> or <i>compliant/non-compliant</i> .
Biotope Area Factor (BAF)	An indicator used to assess the ecological value of surfaces within a defined area.
Open Space, Outdoor Space and Site Design	These terms are often used by different disciplines and may refer to similar or overlapping concepts. <i>Open space</i> places the strongest emphasis on space that is not enclosed by buildings and on the relationship between settlements and the surrounding landscape. It therefore best reflects the understanding of open, interconnected spaces in contrast to enclosed indoor environments. For this reason, the term <i>open space</i> is used throughout this document unless direct reference is made to terminology defined in existing standards, such as SIA 416.
GIS	Geographic Information System
KIG	Climate and Innovation Act (Federal Act)
Connectivity	The functional connection between habitats, root spaces and hydrological systems.
KPI (Key Performance Indicator)	A key indicator used to assess the performance delivered by a system, element or measure in relation to defined objectives.
Performance Dimension	A planning relevant objective category for nature-based infrastructure, such as open space comfort, climate change mitigation, biodiversity, water management, microclimate regulation or damage prevention.
Level of Information Need (LOIN)	The required level of construction related information. It describes the necessary scope and level of detail needed for a specific planning, delivery or operational task.
Nature-Based Infrastructure (NBI)	A coherent settlement wide network of natural and semi natural areas and elements that delivers ecosystem services through natural processes.
Ecological Infrastructure (EI)	An interconnected network of biodiversity reservoirs and ecological corridors that supports species movement and ecological processes. Ecological infrastructure is defined through the assessment of habitat quality, species occurrence and selected ecosystem services. Only habitats meeting specified ecological quality criteria are included. To ensure its long-term functionality, ecological infrastructure requires continuous monitoring, evaluation and enhancement based on these quality metrics.
Ecosystem Services (ES)	The contributions of ecosystems and natural processes to human well-being and prosperity
Qualitative Indicator	An indicator based on a criterion description, quality definition or specification of required characteristics.
Quantitative Indicator	A metric with a target value that can be measured using a numerical value, such as a percentage, intensity or count.



resilient, Resilience	The ability of a social, ecological or infrastructural system to respond to disturbances while maintaining its structure and functioning, its capacity for self-organisation and its adaptability to pressures and change. This also includes the capacity for long-term transformation through adaptation and learning processes. Climate Resilience, in this context, is the capacity to adapt to climate change.
Sponge City	An approach to nature-based water management that serves as a strategy for damage prevention and climate change adaptation by retaining, infiltrating, storing, evaporating and reusing rainwater as close as possible to where it falls.
Sequestering	The process of removing and fixating a substance, such as carbon dioxide (CO ₂), from the atmosphere or another environmental compartment in a stable form over an extended period of time.
Greenhouse Gas Footprint, Greenhouse Gas Emissions	Emissions of greenhouse gases expressed as carbon dioxide equivalents (CO ₂ e), quantified according to their contribution to global warming potential (GWP).
Urban Forest	According to the Food and Agriculture Organization of the United Nations (FAO), urban forests are networks or systems that encompass all forests, tree groups and individual trees in urban and peri-urban areas. They include forests, street trees, trees in parks and gardens, and trees on vacant and residual land. Urban forests form the backbone of [nature-based] infrastructure, connect rural and urban areas, and contribute to reducing the ecological footprint of settlements.
Urban Forestry	The strategic planning, management and stewardship of tree based vegetation and forest structures within urban and peri-urban environments.
Use Case	Here: An application scenario for construction related information exchange, defined for a specific project objective, process or project milestone. See also: https://ucm.buildingsmart.org/
USG	Environmental Protection Act (Federal Act)