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Promoting Nature-based Solutions and Sustainable Infrastructure in the ECE Region:
Environmental and Health Co-benefits

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Foreword

Ministers of the region of the United Nations Economic Commission for Europe (ECE), in their Declaration adopted at the Ninth Environment for Europe Ministerial Conference (Nicosia, 2022), recognized the important role that sustainable infrastructure plays in the green economy transition and in the achievement of the Sustainable Development Goals. Ministers underlined that sustainable and resilient infrastructure investment should be at the core of green economy policies and commitments. Furthermore, Ministers commended the ECE Environmental Performance Review (EPR) Programme as an effective and practical policy tool with a proven track record stretching back over more than a quarter of a century, and recognized the role it plays in supporting the achievement and monitoring of the Sustainable Development Goals in the pan-European region.

Italy is leading efforts to advance sustainable infrastructure through diverse nature-based solutions (NbS). It supports initiatives to develop and implement NbS adapted to national and local circumstances to accelerate the transition to sustainable infrastructure in the light of converging environmental, health and climate challenges. Italy has also been an active supporter, promoter and participant in the activities under the EPR Programme.

The report *Promoting Nature-Based Solutions and Sustainable Infrastructure in the ECE Region: Environmental and Health Co-Benefits* is a timely and ambitious effort underscoring the transformative potential of NbS to deliver sustainable infrastructure services while generating wide-ranging co-benefits, from climate resilience and ecosystem restoration to improved public health and well-being. It highlights how NbS, such as forests, wetlands, green urban spaces and permeable landscapes, can serve as effective, low-cost alternatives to conventional infrastructure, helping to mitigate environmental risks, enhance biodiversity and improve air and water quality.

Drawing on EPR findings, case studies, and expert consultations, the report offers actionable policy recommendations to help ECE member States integrate NbS into infrastructure planning and decision-making. It provides a roadmap for scaling up NbS across sectors and regions, contributing to climate and biodiversity targets, improved health outcomes and enhanced resilience.

The preparation of this report was made possible through the generous financial support of the Government of Italy and the close collaboration between the ECE secretariat and the Italian Ministry for the Environment and Energy Security. This partnership exemplifies the value of international cooperation in fostering innovation, knowledge exchange and capacity building for sustainable development.

We hope this report will inspire renewed commitment and collaboration across the ECE region and beyond, and we look forward to continued engagement with member States and partners in advancing nature-based and sustainable infrastructure solutions.

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United Nations Economic Commission for Europe

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Director-General for European and International Affairs and Sustainable Finance
Ministry for the Environment and Energy Security of Italy

Preface

Nature-based solutions (NbS) are increasingly recognized as essential tools for addressing the complex challenges posed by climate change, environmental degradation and infrastructure vulnerability. This report explores how NbS can be applied to strengthen both existing and new infrastructure assets, offering practical insights and implementation guidance.

As climate pressures intensify, infrastructure systems must evolve to remain functional and resilient. NbS offer scalable, cost-effective solutions that not only enhance infrastructure performance but also deliver co-benefits for communities and ecosystems. From protecting transport networks against dust storms and extreme weather to improving urban liveability and reducing wildfire risks near energy grids, NbS provide a versatile and adaptive approach.

A particularly promising area examined in this report is port infrastructure, where NbS can improve logistics efficiency, reduce emissions and enhance coastal resilience. The report also highlights the potential for low-cost NbS to extend the lifespan of existing infrastructure and delay costly refurbishments.

This publication contributes to the reference framework for the Nature-Based Solutions Innovation Accelerator (NBS-IA), a new initiative promoted by Italy and implemented by the United Nations environment Programme. The NBS-IA initiative aims to foster the application of NbS in infrastructure planning, particularly in Central Asia and Africa, while supporting ECE countries in translating EPR recommendations into actionable policies, supported by concrete examples of potential NbS and an overview of available financial instruments.

We trust this report will serve as a valuable resource for policymakers, practitioners and stakeholders seeking to integrate NbS into infrastructure development and climate adaptation efforts.

Alessandra Fidanza

Vice-chair, ECE Committee on Environmental Policy, Italy*

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Remarks

It is with great satisfaction that I present the report *Promoting Nature-Based Solutions and Sustainable Infrastructure in the ECE Region: Environmental and Health Co-Benefits*. This publication represents a timely and valuable contribution to the international debate on sustainable development and climate action.

Italy is proud to have supported the preparation of this study, in close collaboration with the UNECE Secretariat and through the active involvement of the Ministry for the Environment and Energy Security. This partnership reflects Italy's long-standing commitment to advancing nature-based solutions (NbS) as an effective instrument to reconcile environmental protection, infrastructure resilience and socio-economic progress.

The report highlights the transformative potential of NbS across multiple sectors, from water and energy to transport and urban planning. Italy is particularly pleased that the analysis includes concrete examples of national practice. Among them, the NAWAMED project in the Lazio Region illustrates how the integration of constructed wetlands and green walls into urban infrastructure can reduce domestic water consumption, promote wastewater reuse, and foster innovative models of sustainable urban transformation.

Furthermore, Italy's action is not confined to the national level. Through the establishment of the *Italian Climate Fund*, my country has committed significant resources to support climate adaptation and biodiversity protection in Central Asia. Likewise, initiatives such as the *Nature-Based Solutions Innovation Accelerator*, promoted by Italy and implemented by UNEP, further demonstrate our determination to facilitate the wider uptake of NbS in infrastructure planning at both regional and global scales.

This report stands as a concrete outcome of international cooperation, offering guidance to policymakers, practitioners, and stakeholders across the UNECE region. Italy believes that the adoption and scaling-up of NbS are essential to achieve the goals of the Paris Agreement, the 2030 Agenda for Sustainable Development, and the Kunming-Montreal Global Biodiversity Framework.

I trust that this publication will inspire renewed commitment among Member States and encourage the creation of synergies between governments, civil society, academia, and the private sector. Italy remains committed to supporting the work of UNECE and in promoting a multilateral approach to sustainable, resilient, and inclusive infrastructure development.

Ambassador Vincenzo Grassi

Permanent Representative of Italy to the United Nations Office at Geneva

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The views expressed in this report are those of the authors and do not necessarily reflect the views of the United Nations or its Member States.

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Executive summary

The ECE region is experiencing multiple interlinked environmental and health challenges which are increasing with the acceleration of climate change and the loss of natural ecosystems and biodiversity. More frequent and severe climate impacts across ECE countries, such as floods, droughts, extreme heat, wildfires, landslides, mudflows and air and water pollution, are contributing to escalating public health issues across the region. Compounded by unsustainable infrastructure systems, such as the energy sector which remains dominated by fossil fuels, and the water sector which is polluted by the discharge of untreated municipal sewage, industrial wastewater and other pollutants, adverse physical and mental health issues including premature mortality, cardiovascular disease, respiratory conditions, cancer, obesity, stress, reduced life quality, shorter life expectancy, higher healthcare costs and lower labour productivity are affecting the region's societies.

To date, infrastructure investment has prioritized conventional built (grey) infrastructure solutions. While built infrastructure provides many essential services, including energy, mobility, waste removal and water, the historically disproportionate focus on unsustainable grey solutions has been a driving factor in the issues experienced across the region. A growing evidence base is showing that nature-based solutions (NbS)—actions that protect, restore, manage and create natural and semi-natural ecosystems to address societal challenges and provide benefits to people and biodiversity locally—have potential to support a broad range of infrastructure-relevant services and generate numerous additional benefits that are integral for positive environmental and health outcomes.

This report highlights the key role that NbS can play in addressing the ECE region's intertwined challenges. By collating existing research and drawing upon case studies and expert interviews, it offers new insights tailored to the ECE region to help highlight the value of NbS for the environment, health and sustainable infrastructure. Specifically, it emphasizes the importance of embedding and promoting NbS within the recommendations of ECE Environmental Performance Reviews with a view to scaling uptake of NbS within sustainable infrastructure systems.

As ECE countries look to meet development needs and environmental commitments through investments in new infrastructure, increase the sustainability and resilience of their existing infrastructure systems, and respond to the environmental and health challenges ongoing within the region, there is an opportunity to provide some of these services and generate a more holistic range of benefits through nature-based (green) and hybrid (green-grey) solutions. There are five functions through which NbS can provide infrastructure-relevant services and wider benefits. NbS can:

1. Deliver infrastructure services, substituting for built assets;
2. Enhance infrastructure services by complementing built assets;
3. Protect infrastructure services by safeguarding built assets and natural resource inputs from climate hazards;
4. Benefit workforces, the human capital that underpins the provision of infrastructure services;
5. Support multiple additional benefits, for societies, economies and the environment.

Much of the value of NbS compared to grey infrastructure lies in the inherent multifunctionality of NbS—their ability to perform multiple functions and provide a range of services that can address different needs across sectors and policy objectives simultaneously. NbS and hybrid solutions have been shown to be more cost-effective than traditional infrastructure solutions in some contexts owing to their ability to generate a range of benefits including for health, the environment and the economy that would otherwise require separate investments. They have potential to reduce investment requirements associated with built infrastructure, lower maintenance requirements and reduce economic damage to infrastructure from climate change while supporting economic recovery, and can appreciate in value as the NbS develops.

As ECE countries work to address these multifaceted challenges, many are developing and updating national plans and commitments, including through the development and submission of Nationally Determined Contributions (NDCs) and National Adaptation Plans (NAPs) under the Paris Agreement on climate change. While several countries in the region are taking steps to integrate ecosystems into their climate policy frameworks, this is not yet comprehensive or systematic. ECE countries have an opportunity to enhance commitments and strengthen the inclusion of NbS in NDCs and NAPs, including by coordinating synergized mitigation and adaptation strategies through NbS to achieve more integrated and sustainable outcomes.

Protecting, restoring, managing and creating natural and semi-natural ecosystems will be central to supporting positive environmental outcomes across the region, including for mitigating and adapting to climate change and halting biodiversity loss. NbS can support integrated progress towards addressing both climate mitigation and adaptation at the same time. While NbS cannot substitute for the need for rapid decarbonization across all infrastructure sectors, scaling NbS and hybrid infrastructure approaches within sustainable infrastructure systems offers potential to reduce greenhouse gas (GHG) emissions embedded within built infrastructure, reduce emissions from land-use change and sequester carbon in natural sinks through the multiple additional benefits that NbS can provide. At the same time, NbS can help to reduce the frequency and severity of a wide range of climate impacts such as flooding, drought, heat, landslides, wildfire, water pollution and air pollution. In doing so, NbS and hybrid infrastructure can protect infrastructure services across all sectors and generate multiple additional benefits, including increased job opportunities, which can support broader societal resilience for the people who live in ECE countries.

NbS are integral to supporting positive physical and mental health outcomes within the region. By lowering temperatures, NbS can reduce heat stress and heat-related mortality, while improved air and water quality can reduce incidences of respiratory and waterborne diseases. Increasing green spaces in cities through the creation of accessible parks, gardens and other NbS can increase societal benefits and improve workforce well-being through opportunities for relaxation, exercise and socializing. At a small scale, food-supporting NbS such as allotments and community gardens, green roofs and agroecology practices can contribute to food security, diversify income streams and improve livelihoods for communities.

NbS can be strategically integrated into infrastructure systems to achieve many of these benefits through the functions outlined above. They can substitute for built assets in the water sector and enhance service provision across transport, energy, housing and solid waste. Many of the benefits of NbS can have positive knock-on effects—for example, building insulation and green roofs and walls can provide passive cooling, reducing demand for energy for air conditioning and associated GHG emissions and alleviating the financial burden of cooling for poor and vulnerable communities. Where NbS support water storage and reuse, such as through constructed wetlands and green roofs that are combined with water storage technologies, this can amplify benefits across sectors for water-stressed countries by reducing pressure on national water supplies.

Trade-offs are inherent within sustainability investments—as is common with built infrastructure development. If NbS are not carefully planned, designed, implemented and maintained long-term, there is a risk that they may cause harmful negative impacts. For example, selecting non-native, poorly adapted species can exacerbate water scarcity in water scarce regions, while poorly selected locations for tree planting may inadvertently increase river flood risks. To maximize benefits and minimize potential negative consequences, informed planning is vital. To inform planning of NbS, enable comparison of NbS options relative to other green, hybrid and built solutions, and attract funding, requires an ability to measure their benefits, costs and outcomes long-term. Measuring the effectiveness of NbS and their broad range of wider benefits will be integral to making the case for investing in and scaling NbS. The implementation of demonstration projects and quantification of benefits can help countries to build confidence and track record in NbS in order to support their scale-up.

The ECE Environmental Performance Review programme provides a unique platform and cross-cutting mechanism for countries to align data, plans and strategies for climate, development and biodiversity and to drive integrated and synergized progress across them. While ecosystem-based approaches have been undertaken in ECE countries for many years and are included to an extent within existing EPRs, there is scope to systematically embed the concept of NbS into national planning processes and strengthen their inclusion within EPRs as new reviews are conducted. NbS are not a "silver bullet" to be implemented in isolation, but they represent a critical part of national policy toolkits alongside hybrid and built solutions and should be considered systematically from the outset of planning, rather than as an afterthought to be added as a later stage. With support from a team of experts, the EPR process can play an integral role in the development of plans and strategies, including relevant policy actions, for scaling NbS. Integrating NbS strategically into the recommendations of EPRs provides a critical starting point on the pathway to unlocking the benefits that NbS can provide in countries that request EPRs.

In addition to integrating NbS into EPRs, scaling NbS will require a concerted effort to build an evidence base on the costs and benefits of NbS, mobilize climate finance, develop supportive policy frameworks and develop capacity at all levels for implementation. A key issue that has been identified is "old fashioned" design standards which are enshrined in infrastructure planning and development processes. Flexibility and reform here would help to promote innovative approaches including NbS. The sharing of knowledge, lessons learned and good practices as countries implement green and hybrid approaches can help to demonstrate the effectiveness and outcomes of NbS, including how NbS can support environmental, health and infrastructure objectives in different ECE contexts.

As ECE countries are experiencing growing environmental and health challenges, there is an urgent need to mitigate and adapt to climate change, transition to more sustainable and inclusive infrastructure systems and reverse the loss of natural ecosystems and biodiversity. The research synthesized in this report highlights the critical opportunity that NbS provides for addressing these challenges. Case studies and examples highlight the benefits that NbS can provide in practice, while recommendations show where efforts can be focused to support the scaling of NbS and to realize the benefits that they offer for the ECE region.

- **Besides examining their environmental and health co-benefits, this report also serves as a practical guide to NbS.**
- **To this end, practical considerations when planning NbS for many types of sustainable infrastructure are included in Chapter 6, with numerous links to useful resources. Practical tips are included in the text and highlighted at the start of each Chapter, alongside key messages.**
- **Case studies, with links for further reading, are included throughout; short case studies illustrate ongoing projects in the region, whereas longer ones provide more in-depth practical information.**
- **Key considerations for planning NbS and success across the lifecycle are set out in Chapter 10. Broader policy recommendations are set out in Chapter 12.**

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Abbreviations

ADB	Asian Development Bank
Capex	capital expenditure
CBD	Convention on Biological Diversity
CO_2	carbon dioxide
COP	Conference of the Parties
EBRD	European Bank for Reconstruction and Development
ECE	United Nations Economic Commission for Europe
EEA	European Environment Agency
EIB	European Investment Bank
EPR	Environmental Performance Review
ESG	environmental, social and governance
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
GBF	Global Biodiversity Framework
GCF	Green Climate Fund
GEF	Global Environment Facility
GHG	greenhouse gas
Gt	gigatonne
ha	hectare
IFI	international financial institution
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
Mt	megaton
NAP	National Adaptation Plans
NbS	nature-based solution(s)
NBSAP	National Biodiversity Strategies and Action Plan
NDC	Nationally Determined Contributions
NGO	non-governmental organization
OECD	Organisation for Economic Co-operation and Development
Opex	operating expenses
PV	photovoltaic
SDG	Sustainable Development Goal
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
WHO	World Health Organization
WWF	World Wide Fund for Nature

Glossary

There are several terms that are used consistently in the context of nature-based solutions and sustainable infrastructure. The definitions below outline how these terms are used in this report:

Nature-based solutions (NbS): this report follows the United Nations Environment Assembly (UNEA) (2022) definition of NbS: "actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems that address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services, resilience and biodiversity benefits". While NbS encompass a range of ecosystem-based solutions, they do not include nature-inspired solutions such as biomimicry or nature derived solutions, such as wind, wave or solar energy. It is an umbrella term, encompassing other pre-existing ecosystem-based concepts, including green infrastructure, natural climate solutions and ecosystem-based adaptation (Cohen-Shacham *et al.*, 2019).

Built infrastructure: also known as "grey", "hard", or "engineered" infrastructure, refers to built infrastructure networks and assets that provide or enable the delivery of infrastructure services. This includes roads and railways, buildings, water pipelines, hospitals and power plants.

Hybrid infrastructure: includes both built infrastructure and nature-based solutions to varying degrees and may also be known as "green-grey" infrastructure. For example, coastal ecosystems, such as salt marshes can work together with built infrastructure such as seawalls to protect against coastal hazards, such as coastal erosion and flooding.

Enabling environment: refers to the foundational frameworks which underpin infrastructure, including knowledge, institutions, policies, regulations, laws, human resources, financial resources, processes, tools and information. The enabling environment is relevant across the entire infrastructure lifecycle, from the planning and design of infrastructure systems to construction, operations, maintenance and decommissioning.

Sustainable infrastructure systems: sometimes known as green infrastructure systems, are systems that ensure sustainability across the whole infrastructure lifecycle, spanning planning, design, construction, operation and decommissioning (UNEP, 2023). Sustainable infrastructure ensures all aspects of sustainability, including economic, financial, social, environmental and institutional, and embeds climate resilience. Such infrastructure can encompass built, natural, soft, or hybrid infrastructure. Within this report, the term "sustainable infrastructure" is adopted.

1. Introduction

Key messages in this chapter

- NbS offer a powerful and integrated approach to address the ECE region's interlinked challenges of climate change, environmental degradation and public health.
- Sustainable infrastructure systems must combine built, nature-based and enabling environments (policy, institutional, financial) to deliver essential services while improving resilience.
- NbS are multifunctional, providing multiple benefits (co-benefits) across sectors and policy goals—such as climate mitigation, habitat conservation and health—often outperforming conventional grey infrastructure in terms of cost-effectiveness and adaptability.
- There is a strategic opportunity to scale NbS through national frameworks like NDCs, NAPs and Environmental Performance Reviews (EPRs), aligning infrastructure investment with climate and biodiversity goals.
- This report aims to mainstream NbS in infrastructure planning across the ECE region, offering practical guidance and policy recommendations to support uptake.

1.1 Brief background on nature-based solutions (NbS) and sustainable infrastructure

Countries across the region of the United Nations Economic Commission for Europe (ECE) and beyond are facing the intertwined challenges of meeting development needs whilst mitigating and adapting to climate change, halting environmental degradation and biodiversity loss, addressing poor health across the region, and recovering from the COVID-19 pandemic. Many ECE member States are already feeling the tangible impacts of climate change and are simultaneously experiencing a broad range of environmental and health issues, including poor air quality, flooding, water pollution, landslides, ecosystem fragmentation, degradation and biodiversity loss, and their impacts on human health, such as respiratory illnesses, cardiovascular disease, heat-related mortality and flood casualties.

International agendas, including the Paris Agreement, Sustainable Development Goals (SDGs), and Kunming-Montreal Global Biodiversity Framework (GBF) under the Convention on Biological Diversity (CBD), outline targets to help overcome these challenges. National frameworks, such as Nationally Determined Contributions (NDCs) and National Adaptation Plans (NAPs) under the Paris Agreement, and Environmental Performance Reviews (EPRs), support countries in developing and implementing actions to achieve the targets. As countries look to develop new strategies and investments, there is both a need and an opportunity to design solutions that can address these issues in an integrated manner and contribute to lasting environmental, social and health benefits.

The way infrastructure is planned, developed and managed is central to overcoming these challenges (Thacker *et al.*, 2019; Fuldauer *et al.*, 2022). Infrastructure systems consist of built infrastructure, nature-based infrastructure and the enabling environment, which encompasses the policy, institutional and financial systems that enable their delivery (Thacker *et al.*, 2021). They underpin social and economic outcomes, providing essential services such as water, energy, transport, sanitation and healthcare, and have important implications for environmental and health outcomes across countries. Historically, infrastructure development has relied heavily on conventional "grey" solutions, often overlooking or undermining the role of natural ecosystems. This approach has contributed to habitat loss, ecosystem fragmentation, greenhouse gas (GHG) emissions and pollution of air, soil and water, and driven growing environmental and health vulnerabilities in the region.

A more sustainable approach to infrastructure is urgently needed to reverse the negative trends, which embeds climate resilience and ensures sustainability across the entire infrastructure lifecycle, from the planning and design of projects to their operation and decommissioning. Growing evidence is showing that NbS—actions that protect, restore, sustainably manage or create ecosystems to address societal challenges and provide social and biodiversity benefits locally (UNEA, 2022)—can work in synergy with built infrastructure as a key component of sustainable infrastructure systems, help to mitigate these challenges and generate a wide range of economic, social and environmental co-benefits simultaneously (Haggis *et al.*, forthcoming; Seddon *et al.*, 2020a).

NbS encompass a broad range of actions related to natural and semi-natural terrestrial and marine ecosystems, as shown in Table 1.1. Actions are classified within four categories:

1. **Protecting** ecosystems
2. **Restoring** degraded landscapes
3. Improving the **management** of ecosystems
4. **Creating** new ecosystems.

Table 1.1: Typology of NbS for sustainable infrastructure (Haggis *et al.*, forthcoming)

		Habitat Ecosystem	Protect	Restore	Manage	Create
Terrestrial	Natural & semi-natural	Floodplain	x	x	x	
		Riparian buffer	x	x	x	
		Rivers & streams	x	x	x	
		Forest	x	x	x	
		Wetland	x	x	x	
		Peatland	x	x	x	
		Lake	x	x	x	
		Pond	x	x	x	
		Desert	x	x	x	
		Shrubland & heathland	x	x	x	
		Grassland	x	x	x	
		Savanna	x	x	x	
	Created	Created lake / reservoir	x	x	x	x
		Created pond	x	x	x	x
		Green roof	x	x	x	x
		Green wall	x	x	x	x
		Urban park	x	x	x	x
		Rain garden	x	x	x	x
		Bioswale	x	x	x	x
		Detention basin	x	x	x	x
		Planter box	x	x	x	x
		Retention basin	x	x	x	x
		Nature-based overpass / underpass	x	x	x	x
		Phytocaps	x	x	x	x
		Living fence / shelterbelt	x	x	x	x
		Agroecology	x	x	x	x
		Street trees	x	x	x	x
		Gardens	x	x	x	x
		Amenity grassland and recreational grass	x	x	x	x
		Allotments and community gardens	x	x	x	x
		Churchyards and cemeteries	x	x	x	x
		Constructed wetland	x	x	x	x

		Habitat Ecosystem	Protect	Restore	Manage	Create
Marine	Natural & semi-natural	Mangrove	x	x	x	
		Coral reef (natural)	x	x	x	
		Shellfish reef (natural)	x	x	x	
		Kelp forest	x	x	x	
		Seagrass	x	x	x	
		Salt marsh	x	x	x	
		Beaches, dunes & other natural shorelines	x	x	x	
		Deltas & estuaries	x	x	x	
	Created	Artificial coral reef	x	x	x	x
		Artificial shellfish reef	x	x	x	x
		Created beach, dunes & other shorelines	x	x	x	x

NbS cover a range of ecosystem-based solutions, but do not include nature-inspired solutions, such as biomimicry, or nature-derived solutions, such as wind, wave or solar energy (Cohen-Shacham *et al.*, 2019; IUCN, 2020). The concept of NbS is based on the principle that healthy, well-functioning ecosystems can support multiple benefits that underpin societal and environmental well-being. It is an umbrella term, encompassing other ecosystem-related terms, such as "green infrastructure", "ecosystem-based adaptation" and "natural climate solutions", in recognition that NbS can generate much broader benefits than these more specific terms imply (Cohen-Shacham, 2016). For example, planting of street trees can be part of "green infrastructure", "ecosystem-based mitigation", and "ecosystem-based adaptation" to heat stress in cities, simultaneously.

To be considered an NbS, a solution must result in measurable benefits to both people and biodiversity locally (Seddon *et al.*, 2021). Therefore, solutions which benefit people through the provision of infrastructure services, but which result in biodiversity disbenefits, will not be counted as NbS. Actions which would *not* fall under the concept of NbS include, for example, the use of monoculture or low-diversity plantations, or replacing native species with non-native alternatives (for example, planting trees on native grasslands), as this would result in lower local biodiversity compared to diverse, native landscapes (Seddon *et al*, 2021). Biodiversity is foundational to the functioning of NbS, its persistence long-term and capacity to provide services, and is not simply an additional co-benefit (Seddon *et al.*, 2021; Key *et al.*, 2022; Haggis *et al.*, forthcoming).

The role that NbS can play as part of sustainable infrastructure systems can be understood through five functions through which NbS provide infrastructure services and broader benefits (Haggis *et al.*, forthcoming) (see Table 1.2).

Table 1.2: Functions through which NbS provide infrastructure services and broader benefits

	Function	Example
1	**Deliver the service of the infrastructure sector directly, substituting for built assets partially or entirely.**	Protection of forests and agroecology practices can deliver water quality and substitute for the need to build a new water treatment plant, as demonstrated in New York State.
2	**Enhance a sector's service, complementing built assets by improving their functioning, reducing operational requirements such as maintenance or inputs, and improving the quality and efficiency of service provision.**	Green roofs have been shown to improve the energy efficiency of solar panels by as much as 20 per cent, improving their functioning and energy generation.
3	**Protect assets or sector natural resources from climate impacts and natural disasters, safeguarding service provision.**	Street trees can support local microclimate regulation and provide shade to paved roads, reducing heat-related damage.
4	**Benefit sector workforces, the human capital that underpins infrastructure service provision by improving the health and well-being of people operating infrastructure.**	The integration of green walls and gardens into office buildings can provide physical and mental health benefits to employees, including opportunities for movement, improved air quality, and stress reduction that can transfer to increased work productivity, staff retention, and economic benefits for the sector.
5	**Generate multiple additional benefits, often termed co-benefits or secondary benefits for societies, economies and the environment, beyond the provision of the primary infrastructure service for which the NbS is deployed.**	Networks of urban parks, bioswales and ponds in cities can support habitat connectivity, provide opportunities for recreation and exercise, and sequester carbon.

Source: after Haggis *et al.*, forthcoming.

NbS have been shown to have the potential to benefit all infrastructure sectors via three or more functions. They can deliver key services in three sectors—water, culture and recreation, and healthcare and social care—enhance the performance across more than 20 sectors, and support protection against all climate hazards (Haggis *et al.*, forthcoming; UNEP, 2023). NbS can provide much broader benefits, with scope for all NbS to provide benefits to workforces and wider benefits, including for the environment and health. Conversely, the loss and degradation of ecosystems weaken infrastructure performance, reduce resilience to climate change, increase economic and social risks and undermine progress towards national and global targets (Seddon *et al.*, 2021; Fuldauer *et al.*, 2022; Ranger *et al.*, 2023).

1.2 Importance of NbS in addressing environmental and health challenges

NbS are gaining prominence as scalable strategies to address a wide range of integrated environmental and public health challenges. Strategically integrating NbS into sustainable infrastructure systems across the ECE region can support positive environmental outcomes, including regulating water flows and water quality, reducing air pollution, regulating temperatures, mitigating the impact of drought, sequestering carbon and supporting soil fertility (Choi *et al.*, 2021; Chausson *et al.*, 2020). By creating, protecting, restoring and sustainably managing ecosystems, countries can address habitat loss and fragmentation, and land degradation, all of which underpin positive biodiversity outcomes.

These environmental benefits are closely aligned with public health outcomes. By mitigating climate impacts and supporting a healthy, nature-rich environment, NbS can generate a range of direct and indirect health benefits, significantly contributing to primary disease prevention. For example, clean air and water reduce the occurrence of respiratory and waterborne diseases, lower temperatures and reduce heat-related mortality, and NbS can help to build wider societal resilience to disease and climate shocks through diversification of livelihoods and economic opportunities (Woroniecki *et al.*, 2023). Furthermore, access to green space can boost physical and mental health outcomes, including reducing obesity levels and cardiovascular disease through opportunities for exercise, and reducing stress levels and improving overall well-being through views of nature, opportunities for social interaction and improved quality of life.

Unlike conventional built infrastructure solutions, which often target a single objective, NbS are inherently multifunctional (Haggis *et al.*, forthcoming). They can address multiple challenges across different infrastructure sectors, climate hazards and stakeholder groups simultaneously, providing a more integrated and flexible approach. For example, a restored wetland may simultaneously reduce climate impacts such as flood risk, filter pollutants from water, increase habitat for biodiversity and provide recreational opportunities that improve mental and physical health.

1.3 Investment needs and strategic opportunities for scaling NbS

The coming decades will require unprecedented investment in infrastructure, with an estimated US$65 trillion needed globally between 2025 and 2040 to meet development objectives and achieve the SDGs (Global Infrastructure Hub, 2017). In parallel, delivering on global commitments for climate change, biodiversity and land degradation will require an estimated US$484 billion annually in nature-based investment by 2030 (UNEP, 2022b). NbS offer an opportunity for countries to invest strategically in solutions that can support progress towards development, climate and nature objectives simultaneously and generate positive environmental and health outcomes through the same investment (UNEP, 2023).

The economic case for NbS is growing. NbS are more cost-effective than traditional infrastructure solutions in some contexts and have potential to reduce both capital and operational costs of infrastructure investments (Vuik *et al.*, 2019; Anderson *et al.*, 2022; González-García *et al.*, 2025). Through the services that they provide, NbS can reduce investment requirements associated with built infrastructure, lower maintenance needs, and help to extend asset lifespans, reducing related costs (UNEP, 2023). By protecting infrastructure systems from climate impacts and increasing their climate resilience, NbS can help to avoid economic damage to assets and wider economic losses, whilst generating a range of benefits, including improved health outcomes, increased biodiversity and carbon sequestration, that would otherwise require separate investment streams (Ranger *et al.*, 2023; UNEP, 2023). By working with, rather than against, nature, NbS can support integrated outcomes that improve the efficiency and effectiveness of public and private spending and contribute to economic recovery, while appreciating in value as the NbS develops.

Continuing to disproportionately invest in traditional grey infrastructure approaches, which are often capital-intensive, difficult to reverse and ecologically damaging, risks locking countries into unsustainable development trajectories which further undermine environmental and health outcomes (Thacker *et al.*, 2019). In contrast, redirecting some of the finance earmarked for infrastructure towards green and hybrid (green-grey) solutions can support governments to achieve multiple policy goals simultaneously, including those related to climate adaptation, biodiversity and health (UNEP, 2023).

Despite their potential, NbS remain undervalued in mainstream decision-making. Their broader benefits are often overlooked in economic appraisals of investment options, which typically rely on metrics of economic value and growth as overarching decision criteria, or they may not be quantified due to a lack of process, methodology, or capacity to do so (Haggis *et al.*, forthcoming). Recognizing and accounting for these wider benefits in sustainable infrastructure planning and project evaluation is essential for shifting investment towards more sustainable, inclusive and resilient options that can generate greater environmental and health benefits than traditional approaches. Unlocking the potential of NbS and mainstreaming them in sustainable infrastructure planning at scale will require careful planning and appraisal of the full spectrum of costs and benefits, and significant and sustained investment across the whole project lifecycle.

1.4 Scope and objectives of the report

This report focuses on promoting the use of NbS as sustainable infrastructure across the ECE region, with a particular emphasis on the environmental and health co-benefits that NbS can provide. As ECE countries face increasing and interlinked challenges of rising climate risks, ecosystem degradation and health vulnerabilities, there is a pressing need for integrated, sustainable solutions. Drawing on evidence from case studies, expert consultations and existing EPRs, this report provides practical information and guidance on NbS in the ECE region and beyond. Among ECE policy advice mechanisms, EPRs offer a powerful opportunity to promote NbS through their policy recommendations. The following chapters of the report demonstrate why countries should integrate NbS more prominently and systematically in the recommendations of their EPRs and ultimately scale uptake of NbS across the region.

Overview of chapters

Chapter 2	**Overview of the context of the ECE region and beyond, highlighting key environmental and health challenges in the region and current policies and initiatives related to NbS**
Chapter 3	**Potential of NbS in the context of global climate policy targets, and how NbS can support integrated progress on mitigation and adaptation outcomes under the Paris Agreement on climate change**
Chapters 4, 5 and 6	**Key benefits that NbS can provide for the environment, public health and sustainable infrastructure in ECE countries, if planned properly and carefully monitored and stewarded long-term**
Chapter 7	**Overview of existing metrics, methods and tools for measuring the effectiveness of NbS**
Chapter 8	**NbS in the EPRs, outlining the value of EPRs, examples of how NbS have been integrated in EPRs to date, lessons learned and good practices**
Chapter 9	**Funding-related opportunities, challenges and barriers to NbS**
Chapter 10	**Practical considerations across the lifecycle of NbS projects, from planning and design to monitoring and maintenance**
Chapter 11	**Summary of key findings from the report**
Chapter 12	**Recommendations to support and accelerate NbS scale-up as part of sustainable infrastructure systems in the ECE region and beyond, including by embedding them within EPRs**

2. Context of the ECE region and beyond

Key messages

- The ECE region faces complex and interconnected environmental and health challenges, including climate hazards, pollution, ecosystem degradation and rising health inequalities.
- Climate impacts are already occurring across the region, with floods, droughts, heatwaves, wildfires and landslides threatening infrastructure, ecosystems and populations.
- Unsustainable infrastructure systems and land-use practices—including intensive agriculture and legacy pollution—are compounding environmental pressures and health risks.
- There is growing recognition of the role of NbS in addressing these challenges, with increasing policy interest and pilot initiatives across the region.
- Regional and global frameworks, including the Paris Agreement, SDGs and the Kunming-Montreal Global Biodiversity Framework, provide strategic entry points for scaling NbS.

Practical tips

- Target NbS in climate-vulnerable zones, such as flood-prone urban areas or drought-affected agricultural lands, to maximize impact.
- Integrate NbS into national biodiversity and climate strategies.
- Use transboundary cooperation mechanisms to manage shared ecosystems and water resources sustainably.
- Leverage existing initiatives, including those of ECE, to mainstream NbS.
- Prioritize NbS in urban planning to address heat stress, air pollution and lack of green space, especially in underserved communities.

This chapter provides an overview of the key environmental and health issues occurring across ECE countries to provide a comprehensive understanding of the intertwined challenges that the region is experiencing. All ECE countries are vulnerable to climate hazards, including the most developed, and many impacts are already occurring throughout the region. Floods, droughts, heatwaves, wildfire, landslides, air and water pollution threaten infrastructure networks, ecosystems and populations. Compounded by unsustainable and outdated infrastructure systems, intensive agriculture, legacy pollution from the Soviet era and the loss and degradation of native ecosystems, the region is experiencing a range of related health challenges, many of which disproportionately affect vulnerable groups of society. These include heat-related illnesses and mortality, respiratory diseases, cardiovascular disease, obesity, higher stress levels, waterborne illnesses, reduced quality of life and higher healthcare costs. There is growing recognition that many of these challenges are linked to unsustainable infrastructure systems and the loss and degradation of natural ecosystems and biodiversity. This has led to an increasing number of policies and initiatives related to ecosystems and nature-based solutions.

2.1 Key environmental and health challenges in the region

The ECE region spans over 47 million km^2 and encompasses 56 member States, covering Europe, Central Asia and North America (see Annex 1) (ECE, 2022b; ECE, no date, a). It is an ecologically rich area with a range of ecosystems, including forests, grasslands, drylands, wetlands, rivers and lakes, and harbouring endemic biodiversity that is crucial for people's livelihoods and well-being (OECD, 2024b; ECE, no date, a). This diverse region includes some of the world's most advanced industrialized economies alongside countries with economies in transition (ECE, no date, b). Home to 17 per cent of the global population, and amongst the biggest consumers of natural resources and energy, the ECE region plays a central role in global environmental trends, accounting for approximately two-thirds of global pollution and 34 per cent of carbon dioxide emissions from fossil fuel combustion (ECE, no date, c).

Countries across the region face complex and interconnected environmental and health challenges. All countries of the ECE region, including the most developed, are vulnerable to climate hazards (ECE no date, d). Climate impacts are already occurring, including heatwaves, floods, droughts, wildfires and landslides, which threaten populations, infrastructure and ecosystems (ECE, no date, c). ECE countries can experience very different climates within their borders, bringing multiple challenges. Outdated and unsustainable infrastructure systems combined with the expansion of urban areas and intensive agricultural systems compound these challenges, and exacerbate pressures on air and water quality, water availability and biodiversity, with substantial consequences for human health and well-being (ECE, 2022). Many of these impacts disproportionately affect the vulnerable, including the poor, women, elderly and those with existing health conditions and disabilities (ECE, no date, e).

The impacts of rising temperatures are evident, increasing the frequency of heatwaves, urban heat stress and heat-related illnesses and mortality (ECE, 2022). Countries such as Armenia and Azerbaijan are recording elevated temperatures and severe droughts. At the same time, parts of Western Europe, including Belgium, Germany, Luxembourg, the Netherlands (the Kingdom of) and the United Kingdom of Great Britain and Northern Ireland have experienced record high temperatures, as demonstrated during two heatwaves in Europe in 2019 which resulted in almost 1,500 deaths (ECE, no date, d). Temperature extremes raise energy demand for cooling, further driving GHG emissions and monetary expenditure for cooling, increasing financial pressures and further burdening poor communities who cannot afford air conditioning. Many countries experience huge temperature variations, ranging from extreme lows to extreme highs, which increases the challenges associated with finding solutions that can withstand such fluctuating temperatures. For example, in Tajikistan, mountainous areas have recorded winter temperatures as low as -60°C, while lowland areas can experience summer temperatures exceeding 45°C.

At the same time, changing rainfall patterns induced by climate change are increasing flood risk across the region, threatening people and infrastructure. Many countries, including Georgia, the Republic of Moldova and Ukraine, face significant exposure to extreme rainfall and flood events. For example, more than 13 per cent of Georgia's population is at risk of a river flood event within 10 years (OECD, 2021), while in the European Union future costs to protect bridges from flooding are estimated at more than €500 million annually (ECE, 2020). Increased rainfall and flooding in turn increase the probability of mass-movement hazards such as landslides and mudflows, compounding risks. At the same time, melting glaciers bring additional flood risks, as well as desertification as glaciers retreat.

Air pollution is a major concern for health across the ECE region, especially in urban areas, contributing to over 300,000 deaths in 2021 (ECE, no date, f). Fine particulate matter ($PM_{2.5}$), consisting of suspended particles with a diameter of less than 2.5 micrometres, originates from sources including vehicle emissions, pollution from power generation, urban heating, hydrocarbon production (e.g., in Azerbaijan) and heavy industry (e.g., Ukraine). This poses a significant threat to public health—Azerbaijan, Armenia and Ukraine report elevated exposure which has been linked to respiratory diseases, cardiovascular disease and premature mortality. Despite some progress in reducing nitrogen oxides and particulate matter, by 13 per cent and 54 per cent respectively across 41 European countries between 2009–2018, levels of ground-level ozone have increased, and air quality continues to fall short of World Health Organization (WHO) guidelines (ECE, 2022). The phasing out of hydrochlorofluorocarbons present as coolant in refrigerators and air-conditioning systems also remains incomplete, especially in countries with economies in transition.

Dust storms are prevalent and extend across ECE country borders, carrying toxic salts and pesticides, and exacerbating air quality issues across countries. In Uzbekistan, atmospheric dust and sandstorms pose significant environmental and health challenges, particularly in arid and semi-arid regions. They contribute to poor air quality, reduce visibility, harm crops and infrastructure, and significantly impact health via respiratory problems and reduced quality of life (Akramkhanov *et al.*, 2024; FAO, 2024). Sandstorms are common in the arid and semi-arid regions of Central Asia, which have scarce vegetation cover and experience strong winds, long and dry summers, and frequent droughts (Indoitu, Orlovsky and Orlovsky, 2012). Wildfire is an emerging hazard that is projected to exacerbate poor air quality as temperatures increase (OECD, 2021). The Republic of Moldova, for example, is considered high risk as a combination of climate change and land-use change are increasing the risk of uncontrolled fires (OECD, 2024b). Record-breaking wildfire levels during the summer of 2025 have occurred across Portugal, Spain and other ECE countries, sending smoke as far as France and the United Kingdom, and leading to deteriorated air quality across parts of the region (Dawson, 2025).

Alongside air pollutants, net GHG emissions in the region are rising, with continued reliance on fossil fuels in energy and transport contributing to environmental and climate risks (ECE, 2022b). Fossil fuels account for over half of electricity generation in the region, and 78 per cent on average of the total final energy consumption in the pan-European region, despite increasing use of renewables (ECE, no date, g). Buildings account for 40 per cent of CO_2 emissions through the energy services that they require. The proportion of renewables in the region's energy mix is rising at a slower rate than the increase in total final energy consumption (ECE, 2022). While decarbonization is becoming a prominent narrative across the pan-European region, action to decarbonize sectors is still lagging across countries.

Water resources across the ECE region are under multiple pressures, posing risks to people, ecosystems and infrastructure sectors that depend upon them, with nearly 140 million people without access to safe drinking water (ECE, no date, i). Water scarcity is a major issue for ECE countries, many of which rank amongst the most water-stressed globally (OECD, 2024b), and is a particularly acute issue for landlocked countries such as Uzbekistan. Droughts are expected to increase with climate change, affecting water-reliant sectors including hydropower, agriculture and potable water. The Caucuses ecoregion, for example, is one of the World Wildlife Fund's global priority areas. Water quality challenges are also pervasive across surface and groundwater systems—many natural water sources, including rivers, lakes and aquifers, are polluted by untreated municipal sewage, household waste, uncontrolled industrial wastewater discharges, mining pollutants and agricultural runoff. Legacy pollution from the Soviet era is also apparent, including pollutants from uranium mining sites. This poses risks to both human health and aquatic ecosystems, including the risk of water-related diseases (ECE, 2022b).

Both drought and flood events can exacerbate water quality issues, as decreased precipitation increases pollutant concentrations in water bodies as freshwater resources deplete, while intense precipitation and flooding bring risks of overflow of untreated sewage into water bodies (ECE, no date, e). Soil erosion exacerbated by deforestation and unsustainable agriculture compounds these issues, posing a risk to both storage capacity and water quality. At the same time, some ECE countries are facing the impacts of glacier retreat—for example, snow and glacier melting from the Tian Shan provides an essential source of water for Central Asian countries such as Kazakhstan, Kyrgyzstan and Uzbekistan. As glaciers retreat, this has direct impacts on freshwater supplies, hydropower, irrigation and mountain recreation, as well as societies and ecosystems in the region (Fu *et al.*, 2017). Similar risks are faced by Switzerland, which is projected to experience reductions in hydropower production as a result of glacier retreat (Schaefli *et al.*, 2019). Outdated water infrastructure and inefficient water management practices pose additional challenges to addressing water-related issues across the ECE region.

Many major water bodies in the ECE region are transboundary, meaning that water abstraction or pollution in upstream countries can directly affect water availability and quality in those located downstream. For example, in Central Asia, Kyrgyzstan and Tajikistan are located near key headwaters for the Amu Darya and Syr Darya rivers, which originate in the countries' highlands. Their water management decisions have a direct impact on Kazakhstan, Turkmenistan and Uzbekistan, which rely heavily on these rivers for irrigation, hydropower and drinking water. Transboundary management decisions concerning rivers, lakes and aquifers remain a major challenge, particularly where upstream retention or withdrawal is high, and downstream countries lack alternative water resources (ECE, 2022). The Aral Sea disaster is a notable example of the risks that can come from poor management decisions, where large-scale irrigation projects in the mid-20th century diverted water from these rivers, causing the Aral Sea to shrink by over 90 per cent, devastating regional ecosystems, collapsing the fishing industry and contributing to a public health crisis. The Aral Sea story remains a stark reminder of the consequences of unsustainable resource management and the need for collaborative, cross-border decision-making and governance.

Habitat loss, ecosystem degradation and fragmentation continue across the ECE region, threatening biodiversity and people's health and well-being. Drivers include agricultural expansion, unsustainable land use, urban expansion, pollution, invasive species, infrastructure development and climate change (ECE, 2022b). Despite progress in expanding protected areas and increasing total forest cover, overall biodiversity loss and land degradation continues, and only a minority of habitats assessed in the European Union (EU) have a good conservation status (ECE, 2022; ECE, no date, a).

Public health outcomes are increasingly linked to environmental degradation. Due to human exposure to various environmental stressors, often compounded by unhealthy lifestyles, several adverse health impacts are occurring. These include premature mortality, cardiovascular disease, respiratory conditions, cancer, obesity, stress, reduced quality of life, shorter life expectancy, higher healthcare costs and lower labour productivity. Food security is also threatened by degradation of agricultural lands and poor soil health, including salinization of soils. Climate-sensitive health endpoints including respiratory and waterborne illnesses are rising, as well as noncommunicable diseases linked to pollution and urban lifestyles. Climate impacts can have significant and lasting mental health impacts such as post-traumatic stress disorders. Urban areas, which are home to 73 per cent of the ECE population, well above the global average (ECE, 2021), are particularly affected by ecosystem loss. Over 60 per cent of residents in European cities lack adequate access to green spaces, as defined by WHO standards, impacting mental and physical health. Some cities are notable exceptions, with green space accessible to 90 per cent of the population (ECE, 2021).

The COVID-19 pandemic emphasized the importance of protecting and caring for ecosystems and biodiversity, given the links that have been made between the emergence of the COVID-19 pandemic and the ongoing destruction of ecosystems and exploitation of species (UNEP, 2021a). The protection, restoration and management of ecosystems can help to prevent future pandemics, by reducing the risks of disease transmission between wildlife and people and helping to address the global increase in non-communicable diseases. COVID-19 triggered an appreciation of NbS for infrastructure, including increased appreciation of urban trees and forests, as many people who had access to green space and were allowed outdoors were able to use nature for leisure, recreation and exercise (ECE, 2021). Climate change, combined with habitat loss for many species, is expected to contribute to the emergence and spread of vector-borne diseases, including in areas that were previously unaffected (OECD, 2021), underscoring the need to protect, restore and sustainably manage natural ecosystems as a critical step to prevent future pandemics and safeguard health in the ECE region. The pandemic has also raised the prominence of nature in political agendas as policymakers and other stakeholders realized that nature underpins many services we depend upon and is key to a resilient and sustainable future. Development decision-makers are now increasingly looking to nature for solutions, including across ECE countries. The section below provides an overview of some of the initiatives and policies related to NbS that are present in the region.

2.2 Current progress related to NbS

The challenges described above are complex but present an opportunity to redefine the region's approach to infrastructure and environmental management. Countries have demonstrated commitment and progress towards adopting sustainable development strategies. Many have made efforts towards enhancing relevant policy documents and implementing pilot projects to decouple growth from environmental degradation in recent years (OECD, 2024b).

There is increasing recognition of the benefits of nature, including its importance for reducing climate-related risks and improving health. The region is already undertaking some conservation efforts, as demonstrated by small-scale projects that are seeking to restore degraded and fragmented habitats, such as forests and peatlands, improve agricultural management practices and create new NbS, such as constructed wetlands and green spaces in urban areas. Forest areas designated primarily for biodiversity conservation have continually increased over the past 30 years and, in contrast to global trends, have grown by about 33.5 million ha. Today, forests in the region account for 43 per cent of the global total with a higher forest cover rate (37 per cent) and more forest per person (1.4 ha) than the global average. The region accounts for nearly half of the world's primary forests, demonstrating the importance of protection efforts.

The protected areas in the pan-European region have almost tripled. The coverage of terrestrial and marine protected areas has increased since 2000, accounting for 13.6 per cent and 9.2 per cent, respectively, for the overall pan-European area. This represents an increase of 22 per cent and 66 per cent, respectively, over the past 5 years (ECE, 2022). However, protected areas remain below the respective 17 per cent and 10 per cent goals in Aichi Target 11, and in some countries protected area coverage is low. For example, in the Republic of Moldova and Ukraine, terrestrial areas designated as national parks remain at less than 2 per cent and 4 per cent, respectively, risking ecosystem loss (OECD, 2024b). The rate of land take has decreased in most European Economic Area (EEA) member countries and reversed in Eastern Europe (ECE, 2022). However, despite progress in terrestrial and marine protected areas, overall biodiversity loss continues to occur.

NbS as a concept

NbS have been used in various forms across the ECE region for millennia, implemented as natural solutions to challenges by local communities. The adoption of NbS is rising in countries across the ECE region, including Armenia, Azerbaijan, Georgia, the Republic of Moldova and Ukraine (EU4Environment-Water and Data Consortium, 2024). However, the formal use of the term and associated plans and activities are yet to be mainstreamed into national policies, plans or implementation strategies across the region.

Examples of national initiatives relevant to NbS and biodiversity

Many countries in the ECE region are running major national initiatives and have adapted their national legislation framework to mainstream biodiversity and to align their national efforts with global frameworks that promote ecosystem and biodiversity benefits. Many have adopted National Biodiversity Strategies and Action Plans (NBSAPs) under the Kunming-Montreal GBF of the Convention on Biological Diversity, which includes goals such as ecosystem restoration (Target 2), sustainable forest management (Target 10) and integration of biodiversity in urban and spatial planning (Target 1). The *UN Decade on Ecosystem Restoration* and the new *UN Decade for Afforestation and Reforestation in line with Sustainable Forest Management (2027–2036)* (UN General Assembly, 2025) provides further motivation for ECE countries to participate in national and regional restoration efforts. Country submissions of NDCs and NAPs under the Paris Agreement include references to the benefits that ecosystems can provide for mitigation and adaptation, to varying degrees, as discussed in Chapter 3.

Examples of national initiatives are outlined for 4 countries below, while other examples of NbS projects across ECE countries can be found throughout the rest of this report. Various regional initiatives by ECE including on forest and land restoration, urban nature and green infrastructure, water and ecosystem-based adaptation, EU policies relevant to NbS, and wider initiatives which focus on reducing pressures on ecosystems are described in Annex 2.

Armenia

In 2020, Armenia developed its National Strategy for the Inventory of Forests. This was undertaken within the framework of the *Mainstreaming Sustainable Land and Forest Management in the Mountainous Landscapes of North-eastern Armenia Project*. Under this project, new forest management plans are being developed for 6 of the 19 forest enterprises in the country, integrating high conservation value forests, biodiversity, ecosystem services and forest carbon (ECE, 2024b). More information on the importance of baseline assessments for developing successful NbS projects are provided in Chapter 10.

Serbia

In Serbia, under the project *Enhancing Nature-based Solutions in Serbia: the role of ecosystems in disaster risk reduction and climate adaptation*, a scoping study was undertaken to understand the Serbian national institutional, policy and legal context along with key challenges for the development of NbS. The study was undertaken by IUCN and provided a series of recommendations and entry points for mainstreaming NbS into national disaster risk reduction and climate change policies and strategies (Popovicki, 2022). The Serbian Ministry of Environmental Protection has also developed a *Programme of Adaptation to Climate Change* for the period 2023–2030, in accordance with the provisions of the law on Climate Change (UN Serbia, 2023). It has been established within the framework of their NAP and includes an accompanying Action Plan for the period 2023–2026 (UNDP, 2025b). This Programme aims to identify the impact of climate change on the most vulnerable sectors, define measures to reduce those impacts, and improve capacities for informing the public about climate hazards so as to increase their preparedness. Within this programme, multiple activities have been identified, including 25 priority measures to increase resilience to climate challenges in areas including agriculture, forestry, biodiversity, infrastructure and health (Ibid).

United Kingdom

In the United Kingdom, the English Government has made Biodiversity Net Gain (BNG) a legal requirement for all new infrastructure developments. This requires developers to provide at least 110 per cent of the biodiversity value found on the relevant site prior to the development, meaning that all projects must result in an overall increase in biodiversity by 10 per cent. This policy strategy will, for the first time, see all habitats and their value for nature and people recognized in the planning system (Burke, 2024), and is a key legal mechanism for channelling funding and other resources into nature restoration. More information on BNG can be found in Case Study 9.3.

Uzbekistan

Uzbekistan is also taking significant steps towards the protection and restoration of its native ecosystems and biodiversity. The Ministry of Ecology, Environmental Protection and Climate Change and UNDP are undertaking two international projects which total $6.5 million, funded by the Global Environment Facility (GEF) (Gazeta, 2025):

- The first initiative is the *Comprehensive programme to support the renewal of the National Biodiversity Strategy and action plan (NBSAP)*. This aims to help develop an updated NBSAP aligned with the Global Biodiversity Framework, including new national targets for Uzbekistan based on the framework. The initiative intends to shape the long-term national policy on the protection, conservation and restoration of biodiversity, and notes that it will require active collaboration of multiple stakeholders, including government agencies, businesses and civil society.
- The second initiative is the *Integrated management for the protection and restoration of highly valuable landscapes in Uzbekistan*, and is undertaken in partnership with the IUCN. This focuses on practical measures to create the conditions necessary for the restoration of ecosystems. It will involve inclusive and well-considered policies, innovative approaches for ecosystem restoration, and the development and testing of effective and sustainable financing mechanisms for biodiversity conservation. This project has selected pilot locations including the areas of Western Tien Shan, Nuratau mountains and Kugitangtau.

EPRs as a basis for improving policies and actions related to NbS

The ECE programme on Environmental Performance Reviews (EPRs) (ECE, no date, h) provides country-specific guidance to improve environmental policies and implement activities, including the integration and mainstreaming of nature-based approaches in development planning. They provide support across areas such as improving monitoring, legal, policy and institutional frameworks, and implementing actions. Increasingly, these reviews address opportunities to explicitly incorporate NbS, especially in support of national biodiversity commitments. More information on EPRs and NbS is provided in Chapter 8.

Summary of progress

Despite a growing portfolio of policies and initiatives, the integration of NbS into national policy frameworks remains limited across much of the ECE region, particularly outside the European Union. Where policies exist for non-EU countries, nature-related requirements are generally not yet mandated by law. The mainstreaming of NbS into national policy has been identified by stakeholders as a key strategic priority going forward. To date, pilot projects have played a significant role in raising awareness of NbS, demonstrating potential benefits, building an evidence base and contributing to the evidence base for further investment. While these pilot projects represent a promising start, the embedding of NbS into core planning and decision-making processes is still at an early stage. Most countries in the ECE region have yet to develop mechanisms for systematically incorporating sustainability considerations, such as climate risk analysis or the co-benefits that NbS can provide, into the cost-benefit analysis of large infrastructure projects, which limits scaling (ECE, 2022). The sections below outline the potential benefits of NbS, starting with an assessment of their potential to support ECE countries to meet their national climate change targets under the Paris Agreement.

3. NbS aligning with the global climate targets

Key messages

- NbS can play a vital role in achieving both mitigation and adaptation goals under the Paris Agreement, but they must complement—not replace—decarbonization efforts.
- While many ECE countries reference ecosystems in their NDCs and NAPs, the integration of NbS remains inconsistent and often lacks quantifiable targets.
- NbS can provide up to 37 per cent of the cost-effective mitigation needed by 2030 to limit warming to 2°C, while also enhancing resilience to climate impacts such as floods, droughts and heatwaves.
- Aligning NDCs and NAPs offers a strategic opportunity to scale NbS, especially by coordinating mitigation and adaptation strategies.
- There is a need for stronger commitments, better data and more systematic inclusion of NbS in national climate strategies across the ECE region.

Practical tips

- Use NbS to bridge mitigation and adaptation goals through ecosystem-based actions, such as restoring peatlands which both store carbon and reduce flood risk.
- Explicitly reference NbS in both mitigation and adaptation components of NDCs and NAPs to strengthen their visibility and policy traction.
- Set quantifiable targets for NbS to improve accountability and attract funding.
- Include diverse native ecosystems—not just forests—in climate strategies, such as wetlands, grasslands and agroecosystems.
- Establish cross-ministerial coordination mechanisms (e.g., working group, or task force) to ensure coherent NbS integration in national planning.
- Leverage regional cooperation to share good practices and align NbS approaches across transboundary ecosystems.

As ECE countries work to address the interlinked environmental and health challenges, many are developing and updating national plans and commitments, including through the development and submission of Nationally Determined Contributions (NDCs) and National Adaptation Plans (NAPs) under the Paris Agreement. This chapter provides an introduction to the Paris Agreement, a legally binding international climate change treaty, and discusses the importance of NbS in supporting integrated progress on the mitigation and adaptation components. While several countries in the region are taking steps to integrate ecosystems into their climate policy frameworks, this is not yet comprehensive or systematic. There is an opportunity to enhance commitment and strengthen the inclusion of NbS in NDCs and NAPs, including by coordinating synergized mitigation and adaptation strategies to achieve more integrated and sustainable outcomes.

3.1 Targets of the Paris Agreement

The Paris Agreement, adopted under the United Nations Framework Convention on Climate Change (UNFCCC), is a legally binding international treaty on climate change. It was adopted by 195 Parties at the United Nations Climate Conference (COP21) in Paris on 12 December 2015 and entered into force on 4 November 2016. Its central goal is to limit the increase in global average temperature to well below 2°C above pre-industrial levels by 2100, while pursuing efforts to restrict temperature rise to the more stringent goal of 1.5°C (UNFCCC, 2015). However, in recent years, countries have highlighted the need to limit global temperature increase to 1.5°C, given the severity of climate impacts. The Paris Agreement emphasizes both mitigation, through reducing and avoiding GHG emissions, and adaptation, to manage the unavoidable consequences of climate change. Since 2020, countries have submitted national climate action plans, called Nationally Determined Contributions, which outline the actions that they will take to reduce GHG emissions and build resilience, in line with the Paris Agreement goals. To remain within the 2°C trajectory, ECE countries must collectively cut or capture at least 90 gigatons (Gt) of CO_2 emissions by 2050 (ECE, 2020 c).

To meet the mitigation goal of the Paris Agreement, decarbonization across all sectors is vital. The adoption of **nature-based approaches cannot substitute for this need to decarbonize** and must not be thought of as an alternative. However, NbS can potentially play a significant role on the pathway to achieving the Paris Agreement's goals. Healthy, carefully stewarded ecosystems can absorb and store carbon, reduce emissions by avoiding land-use change and improving land-use management, potentially reduce some of the emissions embedded within infrastructure systems, and enhance the resilience of infrastructure, people and ecosystems by helping to reduce vulnerability to climate-related hazards, such as floods, droughts and heatwaves (Anderson *et al.*, 2019; UNFCCC, 2015; Seddon *et al.*, 2019).

The importance of ecosystems and biodiversity is explicitly recognized throughout the Paris Agreement. For example, the preamble highlights "*the importance of ensuring the integrity of all ecosystems, including oceans, and the protection of biodiversity*." Core articles of the Paris Agreement call for actions including the sustainable management and enhancement of natural carbon sinks, including forests, oceans and other ecosystems (Seddon *et al.*, 2019). For the first time, in 2022, the 27th Conference of the Parties (COP) to the Paris Agreement formally included the term "nature-based solutions" within the COP cover decision text, reinforcing their importance for mitigation and adaptation outcomes (UN, 2022).

Estimates suggest that NbS can provide up to 37 per cent of the cost-effective mitigation needed by 2030 to limit warming to 2°C (Griscom *et al.*, 2017), whilst simultaneously addressing biodiversity loss and land degradation (GI Hub, 2023). The IPCC's *Climate Change and Land* report and its *Sixth Assessment* report affirm that all 1.5°C-consistent scenarios require land-based mitigation alongside decarbonization (IPCC, 2019; IPCC, 2022). Examples include the protection, restoration and sustainable management of peatlands, wetlands, grasslands, mangroves and forests, all of which have the potential to store carbon while enhancing resilience through flood mitigation, soil stabilization and water security if they are carefully designed and managed (Kapos *et al.*, 2019). Some ECE countries have already recognized the synergistic benefits that NbS can provide for their national climate change strategies. For example, the United Kingdom references NbS in both its NAP and NDC and recognizes adaptation and mitigation linkages in actions across water management and landscape restoration. Germany has also committed €700 million to forest conservation and sustainable forest management that supports both mitigation and adaptation (OECD, 2021). Realizing the full potential of NbS under the Paris Agreement will require widespread integration into national strategies, backed by science-based targets, sustained financing and coordination across mitigation and adaptation goals.

3.2 NbS in national climate commitments

NbS in National Adaptation Plans

NAPs were established in 2010 under the Cancun Adaptation Framework during COP16 to the UNFCCC. Designed as strategic roadmaps for adaptation actions (UNFCCC, 2024), NAPs aim to reduce vulnerability and build adaptive capacity and climate resilience across people, ecosystems and economies. The process of formulating and implementing NAPs remains a critical mechanism for building resilience and reducing vulnerability to climate change. Although the NAP process predates the Paris Agreement, its goals and priorities can inform and complement NDCs, helping to align national adaptation strategies with broader climate commitments.

NAPs represent a shift from ad hoc, project-based targets and actions that are focused on short-term needs towards more systematic medium-and long-term strategic planning that is informed by climate science and traditional knowledge. They aim to integrate adaptation into core development planning within all relevant sectors and levels, ensuring that it is not treated as a separate or secondary environmental issue (NAP Global Network, 2020). The NAP process is intended to facilitate a supportive enabling environment, through the integration of adaptation, in a coherent manner, into new and existing policies, programmes and activities, by supporting the establishment of institutional structures for adaptation decision-making and supporting resource mobilization (UNEP, no date, a; UNFCCC, 2019). The process involves assessing current and future climate risks, identifying vulnerabilities, and assessing and prioritizing adaptation options. NAPs are intended to take a participatory and transparent approach, be gender-sensitive and inclusive of vulnerable groups and ecosystems, and follow an approach which is continuous, progressive and iterative.

The Paris Agreement encourages coherence between adaptation and mitigation efforts (UNDP, 2025). While NDCs present a country's overall commitments to climate mitigation and adaptation, NAPs provide detailed, context-specific guidance for adaptation planning and implementation. Ideally, both instruments should be aligned in terms of objectives, commitments and plans to achieve them, drawing on common datasets and analyses, articulating shared goals, and using consistent metrics to track progress. Countries can also use the NAP process and its outcomes to improve and update the adaptation components of their NDCs. Aligning NAPs with NDCs is considered crucial for building resilience and meeting commitments under the Paris Agreement. This presents a strategic opportunity to increase uptake and implementation of NbS approaches (Terton, Qui & Jang, 2024; UNEP, 2023b), plan solutions strategically within national planning processes and leverage the synergies that NbS can provide for mitigation and adaptation.

As of August 2025, 64 countries globally have formally submitted their NAPs to the UNFCCC's Secretariat via NAP Central. However, this does not reflect all progress on NAPs, as several countries have not yet communicated documents to the UNFCCC. Among those submitted, seven are from the ECE region: Albania, Armenia, Azerbaijan, Bosnia and Herzegovina, Israel, Republic of Moldova, and Serbia (see Annex 3).

Some ECE countries refer to green or natural infrastructure in their NAPs, particularly in urban contexts. For example, the Republic of Moldova's NAP emphasizes the critical role of native species in enhancing the adaptive capacity of its forests to withstand climate impacts (Republic of Moldova, 2024). In another example, Serbia's NAP emphasizes urban green infrastructure as a tool to mitigate climate hazards and enhance environmental and public health outcomes and quality of life in urban areas. The Serbian government also commissioned a study in 2021, called "*Nature-based Solutions for Climate Change and the Potential for their Implementation in Serbia*", to detail how NbS could be adopted and implemented in Serbia, which guided planning and prioritization of NbS actions in the country's NAP (Republic of Serbia, 2024; Vuković *et al.*, 2021; Terton, Qi & Jang, 2024).

Despite progress, adaptation planning and implementation has not kept up with growing climate risks across countries. There remains a need for more ECE countries to develop, formalize and communicate their adaptation plans. In doing so, they have an opportunity to integrate and strengthen NbS as sustainable approaches that can contribute to climate resilience and generate broader economic, environmental and health benefits.

Nationally Determined Contributions

Under the Paris Agreement, signatory countries are required to set out their national climate commitments in the form of NDCs, outlining targets, policies and actions for reducing GHG emissions and, optionally, adapting to the impacts of climate change (UNFCCC, 2021). While mitigation components are mandatory, the inclusion of adaptation commitments remains voluntary. In recent years, there has been increasing recognition of the role of NbS within NDCs, both globally and within the ECE region.

As of March 2020, 54 of the 56 ECE countries had submitted at least one NDC (see Annex 4). Of these, 12 included an adaptation component: Albania, Andorra, Armenia, Bosnia and Herzegovina, Georgia, Israel, Kyrgyzstan, Republic of Moldova, Monaco, Tajikistan, Turkmenistan and Uzbekistan. Only four countries explicitly linked adaptation and mitigation objectives within their strategies: Armenia, the Republic of Moldova, Monaco and Montenegro. Four countries addressed mitigation and adaptation actions together: Canada, Iceland, Montenegro and the United Kingdom.

Only seven countries explicitly referenced the term "NbS" or "nature-based" in their NDC strategies: Albania, Andorra, Canada, Iceland, Republic of Moldova, Tajikistan and the United States of America. Of these, four referenced them explicitly in the adaptation component (Albania, Andorra, Republic of Moldova, Tajikistan) and four in the mitigation component (Andorra, Canada, Iceland, United States of America). One country, Tajikistan, referred to NbS as being cross-cutting, or co-beneficial. Although NDC commitments under the Paris Agreement have since been renewed across the region, more concrete plans for actions are generally needed, and these must be followed by implementation (OECD, 2021).

Ecosystems, on the other hand, were referred to within NDCs, though the extent to which they were integrated into these commitments varied. Ten countries included reference to ecosystem-based adaptation or traditional conservation: Albania, Armenia, Canada, Georgia, Iceland, Kyrgyzstan, Republic of Moldova, Monaco, Tajikistan, the United Kingdom, the United States of America and Uzbekistan. For example, Armenia noted an ecosystem-based vision in its NDC, to "*apply an ecosystem-based approach to mitigation and adaptation actions, giving preference to balanced and combined actions.*"

Where ecosystems were included in NDCs, there was a general lack of robust, evidence-based targets (Seddon *et al.*, 2019). Only four of the ECE region's 2020 NDCs with current or planned actions involving NbS for adaptation set quantifiable targets: Armenia, Canada, Kyrgyzstan and Monaco. Non-forest ecosystems, such as wetlands, grasslands, mangroves, reefs and soils, were significantly underrepresented in the region's NDCs despite their important role in climate adaptation and mitigation. Forest ecosystems were included in all 12 NDCs, compared to 6 referencing river catchment habitats (including wetlands), 5 referencing coastal and marine ecosystems, 3 referencing montane habitats, 5 referencing grasslands and rangelands and 3 referencing agroforestry. Among ecosystem-related commitments, only three countries (Albania, Georgia and Kyrgyzstan) included a biodiversity indicator (e.g., species richness), while only Monaco specified multiple indicators for measuring diversity, including connectivity and use of native species.

3.3 Opportunities for strengthening NbS in national climate commitments

Despite growing recognition of NbS, national-level implementation under the Paris Agreement remains uneven. While several countries are taking concrete steps to integrate ecosystems into their climate policy frameworks, this is not yet comprehensive across the ECE region. As they update their NAPs and NDCs further, ECE member States have a critical opportunity to enhance commitments and strengthen the role of NbS across both adaptation and mitigation components. This includes (Seddon *et al.*, 2020):

- **Build on the increasing global recognition of the importance of ecosystems for addressing both climate mitigation and adaptation and fully incorporate NbS into future NDCs and NAPs**. All countries, rich or poor, can strengthen their national climate commitments by substantially incorporating NbS. High-income countries in particular may benefit from more explicitly recognizing the potential of NbS to help achieve the goals of the Paris Agreement without lowering their level of ambition in other sectors.
- **Include NbS actions across a wide range of key naturally occurring ecosystems.** This means, in addition to forests, also include other NbS that are carbon rich and able to support adaptation outcomes, such as mangroves, wetlands, grasslands, seagrass, where they naturally occur.
- **Step up NbS actions that simultaneously address climate adaptation and mitigation, as well as support sustainable development and biodiversity conservation.** This would help to support the development of integrated climate, development and biodiversity action plans. It is recommended that synergies between mitigation and adaptation actions are made explicit (highlighted in Articles 4.7 and 5.2) as well as potential trade-offs between different policy goals. For example, countries could:
  - Prioritize ecosystem restoration activities that both enhance carbon storage *and* contribute to adaptation.
  - Favour protecting and / or restoring biodiverse and climate-resilient natural ecosystems (as opposed to establishing plantations with single non-native species).
  - Ensure that adaptation and other development actions (e.g., building desalination plants to improve water security) do not come at the cost of ecosystem health, e.g., through pollution of coastal and marine ecosystems.
  - Prioritize the funding of actions that promote synergies, whether direct actions or enabling conditions.
- **Include measurable (quantifiable) and robust NbS targets in NDCs and NAPs and associated national implementation plans.**
  - For adaptation, targets should aim to address specific vulnerabilities to climate change. Information may include the ways in which specific ecosystems are impacted by different climate hazards, and the ways in which human communities benefit from intact ecosystems.
  - For mitigation, targets should be based on well-supported carbon estimates and accounting. For example, explain the carbon sequestration and storage potential of key ecosystems and how they can help to meet national emission reduction targets.

  - In general, targets should be clearly informed by scientific and local indigenous knowledge about ecosystems, their sustainable management and their local dependencies (Seddon *et al.*, 2021).
  - A stronger dialogue between scientists, local and indigenous communities and policy makers would enable this by allowing the co-creation of knowledge about the effectiveness of NbS. It would also help to foster societal participation in their implementation and ensure the avoidance of perverse and inequitable outcomes on the ground.
  - Improve data and monitoring systems with measurable indicators.
  - It is recommended that policy makers consider designing the structure of future NDCs and NAPs in a manner that allows the systematic tracking of ambition for nature, including measurable targets in national plans drawn on best available scientific evidence, local knowledge and good practice.

- **Align NDCs and NAPs with other relevant national plans and internal processes.** For example, with other relevant international policy processes outside the UNFCCC and the Paris agreement. Particularly, in relation to NbS, it could be beneficial to have more explicit links with the SDGs and the other two Rio Conventions, and with national plans and targets associated with these, such as the Aichi Targets and NBSAPs under the Convention on Biological Diversity and the Land Degradation Neutrality (LDN) targets under the United Nations Convention to Combat Desertification (UNCCD). It would also be beneficial to develop common frameworks and indicators for reporting and tracking NbS-related actions under these.
- **Mobilize funding for NbS to climate change:** a number of countries that include NbS in their NDCs have made these conditional on external support. Mobilizing more funding would enable greater and more effective action on the ground. It would also support building capacity to research, design and implement cost-effective and equitable NbS policies and actions at national, subnational and local levels.
  - Leading global finance platforms and associated bilateral support initiatives could consider a more holistic approach to climate and biodiversity action by highlighting and supporting NbS, noting their wide-ranging co-benefits for sustainable development.
  - Climate and development finance could prioritize overlapping priorities of NDCs and NAPs with SDGs and the CBD Aichi and post-2020 targets, thereby providing an incentive for greater coherence amongst these processes.

Coordination between mitigation and adaptation stakeholders, development of tools to support decision-making, and more systematic exchange of good practices and reporting mechanisms represent useful enabling measures to support scale up (OECD, 2021). Regional cooperation can support countries as they communicate, update and implement their commitments, particularly concerning adaptation and mitigation strategies for transboundary resources, and for the sharing of good practices, providing technical support and mobilizing climate finance. A national example of integrating NbS in an NDC is provided in case study 3.1.

Box 3.1: Practical resources

The UNDP **NbS for NDCs Toolkit** and associated **Framework** have identified more than 100 tools and resources on NbS that can support decision-makers in enhancing their NDCs, including spatial datasets, guidance documents and other toolkits (UNDP, 2019), provide practical tools for integrating nature into national climate planning.

IUCN's **Guidance on NbS in NDCs** (Seddon, 2019) identifies key information that should be included in NDCs to help track ambition on nature more systematically.

UNEP's (2021) **Guidelines for Integrating Ecosystem-based Adaptation into National Adaptation Plans** aim to help practitioners at national and local levels factor in ecosystem functions and services into National Adaptation Plans. It provides examples from countries implementing NbS for adaptation planning, tools for advancing NbS for adaptation, and guidance on:

- Making the case for mainstreaming NbS in adaptation planning;
- Engaging stakeholders for budgeting and financing of NbS;
- Steps for integrating NbS at any stage along the NAP process (formulation, implementation and review); includes steps for monitoring & evaluation;
- How to identify entry points for NbS within the national and local adaptation planning process;
- An enabling environment for factoring in NbS.

Other resources:

- The Nature-based Solutions Initiative **platform on best practice for integration of NbS into revised NDCs**: https://naturebasedsolutionsinitiative.org/news/best-practice-nbs-ndcs-policy-platform/
- UNFCCC LDC Expert Group (2012) **Technical guidelines for the national adaptation plan process**.

Case study 3.1: Example of good practice for an NDC, Morocco

NbS vision: "The protection of natural heritage, biodiversity, forestry and fishery resources through an ecosystem-based adaptation approach. Morocco [also] commits to restoring ecosystems and strengthening their resilience, to combat soil erosion and prevent flooding."

Planned NbS actions: "(i) rehabilitate ecosystems and protect and promote natural areas as well as endangered species as resources. (ii) protect water basins against erosion and siltation of dams. (iii) develop forestry and surrounding areas. Finalize land demarcation and registry of forested areas."

NbS target or measure: "(i) renewal or afforestation of approximately 50,000 ha per year. (ii) Conversion of nearly 1 million ha of grain crops to fruit plantations that are likely to protect agricultural areas from all forms of erosion, especially water erosion."

Source: Seddon *et al.* (2020).

4. Environmental benefits of NbS

Key messages

- NbS offer significant mitigation benefits, including carbon sequestration, reduced GHG emissions and enhanced energy efficiency.
- NbS can protect infrastructure systems from a wide range of climate hazards—such as heat, floods, droughts, landslides and air pollution—while also providing co-benefits for ecosystems and biodiversity.
- NbS contribute to broader resilience, including resilient economies, health systems and workforces, by improving environmental conditions and reducing vulnerability.
- Biodiversity is foundational to the effectiveness of NbS. Healthy, diverse ecosystems are more resilient and capable of delivering long-term services.
- Strategic planning and long-term stewardship are essential to maximize environmental benefits and minimize trade-offs, such as water use conflicts or unintended ecological impacts.

Practical tips

- Design NbS to address multiple hazards—e.g., wetlands for flood control, water purification and carbon storage.
- Assess multifunctionality when comparing NbS to grey infrastructure—consider co-benefits like carbon sequestration, health outcomes and air quality.
- Integrate NbS into watershed and catchment-level planning to manage water quality, erosion and flood risks effectively.
- Consider effectiveness—e.g., green roofs and walls may perform better in summer.
- Anticipate trade-offs—e.g., methane emissions from wetlands—and mitigate through careful design and species selection.
- Use native, locally adapted species to ensure NbS are resilient to local climate conditions and support biodiversity. Avoid monocultures and invasive species, which can undermine ecosystem health and long-term functionality.

This chapter brings together existing research to demonstrate how NbS can address the environmental challenges occurring in the region, including helping ECE countries mitigate and adapt to climate change, generate wider benefits for resilience and halt biodiversity loss. NbS are found to offer potential **protection** of infrastructure systems (the third of the five functions through which NbS benefit infrastructure—see Chapter 1) from a broad range of climate hazards, including heat, river floods, surface floods, coastal floods, water pollution, drought, landslides and mudflows, erosion and air pollution. They can also generate **multiple additional benefits** (the fifth function) that can support wider resilience to environmental challenges, including supporting the resilience of infrastructure workforces, food systems, infrastructure systems, and ecosystems and biodiversity. However, if NbS are not properly designed, they may result in negative impacts that can exacerbate environmental challenges, for example, where non-native species reinforce problems of water scarcity. To maximize and sustain environmental benefits and minimize potential negative trade-offs, NbS should be strategically planned, use a diverse mix of native and locally adapted species, and be carefully stewarded long-term to ensure local benefits to people and biodiversity.

4.1 Mitigation

Carbon sequestration

Effective mitigation of climate change requires both rapid reduction of GHG emissions and carbon sequestration. NbS are increasingly recognized as a critical element of national mitigation strategies. When strategically integrated into sustainable infrastructure systems, NbS can support significant additional benefits, including carbon storage and reduced GHG emissions. However, NbS should not be viewed as an alternative to the urgent need to decarbonize infrastructure across all sectors. They should instead be implemented alongside decarbonization strategies to support wider mitigation benefits (Seddon *et al.*, 2020).

Healthy ecosystems, such as forests, wetlands, peatlands, grasslands and mangroves, function as natural carbon sinks, removing CO_2 from the atmosphere and storing it in biomass and soils (European Commission, 2024; IPCC, 2019). Carbon sequestration potential varies by factors such as ecosystem type, species composition and management. For example, peatlands cover approximately 3% of the world's surface, yet store almost a third of the world's carbon (UNEP,-WCMC, 2023). Mangroves can sequester three to five times more carbon per unit area than terrestrial forests (Opperman *et al.*, 2021), while grasslands, which hold over 10 per cent of global biomass carbon, could sequester up to 1 Gt of carbon annually if managed sustainably (Chausson *et al.*, 2020). In grasslands, salt marshes and agricultural lands, soil-based carbon storage offers large opportunities for sequestration through sustainable management and practices such as agroecology (IPCC, 2019; OECD, 2021). Correspondingly, the loss and degradation of natural carbon sinks can release stored carbon and exacerbate climate change. For example, it is estimated that the loss and degradation of forests release approximately 4.4 Gt CO_2 annually, which represents 12 per cent of anthropogenic emissions as of 2019 (IPCC, 2019). The pan-European region is home to a diverse range of ecosystems, including 42 per cent of the world's forests, which account for a net biomass carbon sink of 433 Mt of carbon per year and living biomass stock of 93 Gt (ECE, no date, g). Protecting, restoring and sustainably managing these forests, along with other native ecosystems, will be essential for preserving the ECE region's valuable natural carbon sinks.

Despite their potential, there are limits to the mitigation capacities of NbS. As ecosystems mature, they can reach a saturation point beyond which they no longer absorb carbon, and some may become carbon sources (World Bank, 2021; Hubai *et al.*, 2020). Ecosystems are also vulnerable to disturbance, including climate impacts, whereby stored carbon can be released due to floods, pests and wildfires, offsetting mitigation benefits (IUCN, 2019; OECD, 2021). At the same time, there are concerns around the longevity of NbS, for example, during socio-political change, which can lead to changes to the management of ecosystems or their transition to alternative land uses. Equally, in some contexts, trade-offs may arise. For example, some NbS projects will require the use of mechanized machinery such as diggers for site preparation, or the transport of materials such as seedlings, which have associated GHG emissions. Equally, where the preservation of green spaces in cities encourages urban sprawl, this may lead to higher emissions related to transport, as people drive further to reach their destinations (OECD, 2021). It is critical to plan NbS over the long term, with consideration of the local socio-ecological context, incorporate a diverse mix of native, locally-adapted species, and manage projects adaptively to maximize and sustain their potential benefits. Managing NbS for carbon sequestration benefits must also consider local communities, who may depend on those ecosystems for their livelihoods, and ensure that their access is maintained and their needs are met to avoid social disbenefits (OECD, 2021).

The integration of NbS into national mitigation strategies varies across the ECE region. For example, Kyrgyzstan's Third Environmental Performance Review (2024) notes that NbS for carbon storage or avoided GHG emissions have not yet been considered. Conversely, Armenia's Second EPR (2024) highlights carbon sequestration in soils as a core strategy for mitigating climate change and recommends that the Government establish a specific programme to restore degraded lands using phytoremediation and other NbS to remove and stabilize soil contaminants, noting that NbS can support crop productivity while protecting soil and ecosystem health. In Ukraine, the Hlukhanya peat bog is degraded, leading to emissions of GHG including methane and nitrous oxide; peatland restoration is being undertaken, particularly in upland areas, as a mitigation strategy (Konovalenko, 2023).

Avoided GHG emissions

Infrastructure accounts for 87 per cent of GHG emissions globally (Thacker *et al.*, 2019). NbS can reduce requirements for built infrastructure assets and lower maintenance requirements and associated embedded GHG emissions. For example, case study 4.1 demonstrates how small-scale NbS, such as the creation of green roofs, can extend the lifespan of roofs and reduce embedded emissions by reducing the frequency at which they need to be replaced. Equally, restoring and protecting larger-scale ecosystems, such as floodplains and wetlands, can provide protective benefits by reducing river flooding, thereby minimizing damage to infrastructure and emissions associated with repairing and replacing built assets.

Case study 4.1: Green roofs at Chicago O'Hare Airport, United States of America

Chicago O'Hare Airport has implemented green roofs across several of its buildings, totalling 445,590 ft^2 (over 10 acres). This included the first vegetated roof ever to be installed on an airport traffic control tower administration building. The sedum plant species used by the Chicago Department of Aviation (CDA) are tolerant to drought. They can retain up to 90 per cent of precipitation, totalling 2 million gallons of stormwater every year. This has helped to double the lifespan of the roof, reduce the frequency at which the roof must be replaced and thereby avoided GHG associated with roof replacement, and saved the airport US$1.5 million in replacement costs.

NbS: creation of green roofs.

Sector: transport – airports (but applicable to buildings across all sectors).

Benefits: reduced embedded emissions and operational and maintenance cost savings result from increased roof life, decreased energy use, reduced stormwater runoff, reduced heat island effect, as well as noise insulation and air quality benefits.

Who: CDA.

Maintenance requirements of green roofs: pruning, pest and weed control, weed removal.

Wider airport-related considerations: there are some unique challenges and regulatory factors associated with airports that present challenges to expanding NbS. This includes the risk of attracting wildlife that may pose a hazard to aviation, such as birds, protection of vital equipment, height limitations during construction, secure access restrictions, and prevention of foreign object debris which can cause damage to aircraft.

The CDA and its tenants have addressed this by designing green roofs in compliance with wind speed requirements to prevent the plants or bedding from blowing off the roof and onto areas where there are moving aircrafts. The roof planting must also be a species unattractive to wildlife that can pose hazards to aircraft (i.e. birds) to minimize the potential for aircraft bird strikes. However, to be considered an NbS, the solution must result in biodiversity benefits. Therefore, consideration is required when designing NbS for airports to ensure biodiversity benefits while avoiding risks to air transport.

Source: AT (2016); Pérez *et al.* (2020); Fly Chicago (a), Fly Chicago (b).

By substituting for built infrastructure, NbS can reduce requirements for conventional infrastructure assets, avoiding emissions embedded in construction materials and their transport. For example, the restoration and protection of floodplains and wetlands for river flood reduction, as discussed above, may replace the need for built adaptation options such as dykes and levees. In some sectors, such as airports and energy transmission, there are examples where mechanized mowing has been replaced by livestock grazing, lowering emissions from mechanized maintenance practices, whilst providing benefits to local farmers. However, such interventions require careful assessment as NbS can also increase emissions of other GHGs, such as methane.

Energy efficiency and energy security

Beyond sequestration, NbS can contribute to mitigation by reducing energy demand. For example, constructed wetlands can perform some water treatment processes more efficiently and with lower energy use than conventional systems, reducing emissions associated with operations (WWAP, 2018). Urban NbS, such as green roofs, street trees and urban parks, can reduce ambient temperatures and provide thermal insulation to buildings, lowering energy consumption associated with heating and cooling, while providing substantial health co-benefits (ECE, 2021; Enzi *et al.*, 2017). For example, green roofs installed in Canadian cities have been shown to reduce daily energy demand for air conditioning by more than two-thirds during peak heat periods (OECD, 2021). Improved agricultural land management practices can reduce irrigation requirements and associated energy demands (OECD, 2021). Cumulatively, this can reduce pressure on local energy networks and increase the reliability of energy networks and the other infrastructure sectors that depend upon them. At the same time, this can support wider benefits to people by reducing energy demand and therefore costs associated with energy payments, reducing financial pressures on people within the ECE region.

Box 4.1: Practical aspects to consider for climate mitigation

- **Mitigation potential:** the mitigation potential of NbS varies across ecosystem types, species, time, space, age and management strategies. Some NbS can even become carbon sources. Understanding the potential mitigation benefits of different NbS options in relation to the current context and being mindful of potential saturation points will be an essential part of evaluating and prioritizing options.
- **Maintenance:** the management and maintenance of NbS will be integral to sustaining mitigation benefits long-term. Maintenance strategies should be developed at the planning stage and implemented across the lifecycle options. Sufficient budget should be allocated for maintenance that extends long-term; this may require the use of national budgets as many funders only provide funding for shorter timescales (under 5 years).
- **Consider potential sources of GHG emissions that may arise from NbS:** activities relating to NbS can result in additional GHG emissions. For example, the use of livestock to provide non-mechanized mowing of areas can lead to methane emissions, a more potent gas than CO_2. Equally, where sites are prepared for restoration, this can result in GHG emissions from the transport of materials, workforces and operation of equipment such as diggers. These need to be accounted for in the evaluation process to understand the full range of costs and benefits.
- **Consider non-forest NbS:** there has been much discussion on the role of forests in carbon sequestration. However, non-forest NbS, such as peatlands, wetlands, mangroves and the soils below them, can offer equal or greater benefits in terms of GHG emissions reduction, and greater benefits for biodiversity where they are deployed in their native locations.
- **Societal outcomes:** NbS for mitigation should not come at the expense of local communities and their access to natural resources. Practitioners should take care to ensure that mitigation projects do not exclude local communities or cause adverse impacts upon them.
- **Continue to decarbonize all sectors:** NbS should not detract from the urgent need to decarbonize all sectors.
- **Quantify benefits:** measurable data on the effectiveness of NbS, including for mitigation, is needed to inform future planning decisions. Gathering data on carbon storage per area (e.g., m^2 or hectares) during the monitoring process will help to build the evidence base.

Relevant tools and datasets:

- There are tools that can help to spatially estimate the potential value of NbS in terms of carbon, including the Carbon module in the Integrated Valuation of Ecosystem Services and Trade-offs (InVEST).
- Publicly available geospatial datasets, e.g., on global carbon density can be found online, e.g., from Spawn & Gibbs (2020).

4.2 Adaptation

While efforts to reduce emissions across the region are being planned and scaled up, it is now widely acknowledged that a significant degree of climate change has already been locked in. Adaptation is therefore essential to strengthen resilience to climate impacts. Across the ECE region and beyond, the impacts of climate change are already being felt, with increased risks to infrastructure, the environment and human health. There is growing recognition of the role that NbS can play in strengthening resilience and reducing exposure and vulnerability to climate impacts, including floods, droughts, extreme temperatures, landslides and poor water quality (UNEP, 2021a). The following section explores how NbS can be applied across a range of climate hazards, and how, when implemented strategically, they can contribute to the broader resilience of people and ecosystems across the ECE region. Case study 4.2 provides an example of a project in Turkmenistan where NbS pilot initiatives have been implemented to support multiple benefits, including climate mitigation, adaptation and biodiversity, laying the groundwork for mainstreaming NbS into Turkmenistan's environmental strategies.

Case study 4.2: Enhancing capacities for climate-resilient water management in Turkmenistan

Nature-based solutions (NbS) are increasingly recognized as cost-effective and inclusive approaches to mitigate and adapt to climate change impacts, especially in arid and semi-arid regions such as Central Asia. The FAO Technical Cooperation Programme project "*Strengthening Capacities for Climate-Resilient Water Resources Management*," implemented from June 2023 to June 2025 in close cooperation with the Ministry of Environmental Protection of Turkmenistan, aimed to support the introduction and institutionalization of NbS in Turkmenistan.

The project focused on the Lebap velayat, a region highly vulnerable to climate change, desertification, and land degradation due to increasingly hot and dry conditions, recurrent droughts, and increasing salinization of soils. Within this context, NbS — such as sustainable forest management, rainwater harvesting, and halophyte-based agroforestry — offer tangible solutions that are accessible to local communities and enhance ecosystem resilience.

In January 2025, a significant afforestation initiative was carried out in the Jeýhun forestry unit of the Çärjew *etrap*, Lebap region, as part of the project's ecosystem restoration component.

From 21 to 25 January, an expert team from the Regional Environmental Centre for Central Asia (CAREC), in collaboration with Turkmenistan's Ministry of Environmental Protection, conducted large-scale reforestation activities on two designated pilot sites covering more than six hectares. The objective of the planting campaign was manifold: to contribute to the expansion of carbon sinks, reduce soil salinization through the use of salt-tolerant native species, and enhance community awareness and stakeholder engagement in forest ecosystem restoration.

The first site, a 4.42-hectare area located on the outskirts of Farap city (coordinates: 39.162575, 63.625523), was prepared as a future forest-park zone. The site was divided into 4x4 metre squares, where black saxaul (*Haloxylon aphyllum*) seeds were sown in shallow pits at each corner. To protect the germinating seeds from wind erosion, a perimeter shelterbelt was established using saplings of Russian olive (*Elaeagnus angustifolia*), another hardy halophyte species that also provides fruit for local bird populations. This approach not only contributes to biodiversity conservation but also addresses land degradation in sandy and saline-prone soils.

The second site (coordinates: 39.162150, 63.622853), measuring approximately 2.27 hectares, was designated as an open-air nursery for black saxaul cultivation. Traditional forestry methods were applied, including the creation of shallow furrows in triple rows, where seeds were sown and covered with river sand. The clay soils in the area tend to harden, which can hinder seed germination; thus, sand was used to improve emergence rates.

In total, 55 individuals took part in the planting mission, including staff from the Ministry's regional departments, the Jeýhun forestry unit, the Repetek Biosphere Reserve, the National Institute of Deserts, local government offices (*häkimlik* and *gengeshlik*), and public organizations such as Täze Zaman, Ýaş Tebigatçy and the Nature Protection Society. The mission began with technical briefings by national forestry experts and concluded with the construction of an irrigation channel and the first watering of the saplings, ensuring initial survival under arid conditions.

Capacity building: in parallel to these field activities, the project also focused on strengthening local capacities through knowledge dissemination. A key milestone of the project was the delivery of a three-day training held in April 2025 in Turkmenabad under the title "Assessment and Application of Nature-Based Solutions". The training, attended by 38 participants from local government, environmental organizations, public associations, and civil society, aimed to:

- Introduce and assess NbS for climate change adaptation;
- Identify appropriate NbS for local application in water and land management;
- Conduct practical exercises including transplanting saxaul seedlings and evaluating rainwater harvesting systems.

The training emphasized the accessibility of NbS to rural communities, highlighting their potential to restore degraded lands, enhance agricultural sustainability, and reduce vulnerability to climate risks. Participants were also exposed to successful NbS examples from across Central Asia, fostering cross-regional learning.

The agenda featured thematic presentations on:

- NbS integration into local planning and policy;
- Climate trends and vulnerability in the Lebap velayat;
- Legal frameworks and strategic programmes on forestry and land protection;
- The role of native trees (e.g., black saxaul and oleaster) in halting desertification and salinization.

Practical sessions included calculating the benefits of rainwater harvesting, forest restoration, and small-scale beekeeping—demonstrating the economic and environmental returns of NbS. Site visits to pilot plots in the Farab district provided firsthand exposure to local afforestation efforts and greenhouse-based seedling cultivation.

Through this initiative, FAO and national partners laid the groundwork for mainstreaming NbS into Turkmenistan's environmental and agricultural strategies. The project not only built technical and institutional capacity but also mobilized local stakeholders to adopt nature-positive practices that address some of the region's most pressing ecological challenges—including land degradation, water scarcity, and climate-induced biodiversity loss.

NbS: forest restoration; agroforestry, creation of living fences (shelterbelts).

Benefits: carbon sequestration, reduced soil salinization and desertification, drought mitigation, food for local wildlife, capacity building, improved agricultural stability, reduced biodiversity loss.

Who: FAO in cooperation with the Ministry of Environmental Protection of Turkmenistan. Various stakeholders were involved throughout the project, including local government, public organizations, and civil society.

Source: Personal communication from Evetta Zenina (FAO), no date.

Heat

As outlined in Chapter 1, ECE countries are experiencing rising temperatures and urban heat islands as a result of climate change. These pose risks to human health, well-being and the reliability of infrastructure systems, such as roads and railways, particularly in cities and for those living in vulnerable and disadvantaged areas. Heatwaves are increasing in frequency and intensity, exacerbating health burdens. The differential impacts of extreme heat on health are driven by socioeconomic disparities—poorer and vulnerable people, who have limited access to air conditioning and green space, are at greater risk from heat-related health problems (UNEP, 2021b; Wong *et al.*, 2021).

Infrastructure and people living in urban areas are particularly susceptible to rising temperatures and associated impacts as a result of the urban heat island effect. Built infrastructure, comprising impervious, low-albedo surfaces such as buildings, roads, pavements and car parks, absorbs, stores and radiates heat, causing cities to retain warmth long after sunset. This is compounded by the generation of heat from transport, energy use and buildings, which further increase local temperatures and air pollution. These rising temperatures also have implications for energy demand. Globally, cooling degree days, the days in which a day's average temperature exceeds a specific degree threshold beyond which air conditioning is required, are projected to increase by an average of 25 per cent by 2050, which would lead to a threefold increase in energy demand for cooling (Hall *et al.*, 2019). Much of this demand will be met through electricity-powered air conditioning, which further contributes to GHG emissions and warming, exacerbating energy requirements for cooling and associated costs for residents in urban areas (UNEP, 2021b). This can create a vicious cycle of rising heat and energy use.

Where air-conditioning incurs high costs, NbS offer cost-effective and sustainable options to mitigate urban heat and provide access to passive cooling for residents. Protection from trees and water bodies, restoration of wetlands and creation of green infrastructure can reduce temperatures through the provision of shade and evaporative cooling (Kapos *et al.*, 2019). Studies show that urban areas can be up to 4°C warmer than natural areas, with trees reducing local air temperatures by up to 8°C, and water bodies reducing urban temperatures by up to 0.9°C (Ibid). Equally, surfaces that are shaded can be 11 to 25°C cooler than the peak temperatures recorded for unshaded surfaces (UNEP, 2023). Some studies have shown that trees within cities can reduce costs required for air conditioning by 10 per cent (Ibid). These measures can be integrated with other heat adaptation solutions, such as using light colours which have high-albedo for non-vegetated roofs, walls and pavements, to better reflect sunlight. Case studies 4.3 and 4.4 provide examples from Kyrgyzstan and Romania, respectively, where NbS are being implemented to tackle urban heat islands.

Case study 4.3: Increasing green spaces in Bishkek, Kyrgyzstan

The city of Bishkek is restoring urban rivers and planting more than 33,000 mature trees, 13,500 shrubs and 570,000 living fences in the form of hedges, while also expanding green spaces and installing green walls on building surfaces to mitigate urban heat island effects. The authorities are undertaking a feasibility study on urban river restoration focusing on the Ala-Archa and Alamudun rivers and Big Chui Channel as well as reconstructing their scientific research institute's botanical garden which can deliver both cooling and flood resilience benefits.

The green corridor is intended to be incorporated with infrastructure to capture rainwater runoff from the city which can be reused for water green spaces.

NbS: restoration of rivers; restoration of trees and shrubs; creation of living fences; creation of green walls, garden restoration.

Why: to address urban heat island effect and increase flood resilience.

Benefits: renaturation of watercourses will provide benefits including air cooling, shade creation, soil stabilization, biodiversity protection, soil and water cleaning, reduced flood risk and reduced infiltration of pollutants into groundwater.

Source: Barza (2025). More information on the EBRD Green City Action Plan may be found at EBRD (no date).

Case study 4.4: Tackling urban heat islands in Timișoara, Romania

Cooling and thermal comfort is an increasing priority in Timișoara, which is facing high summer temperatures. The buildings and paved surfaces create higher temperatures and restrict air circulation, producing heat islands. In 2020, average August temperatures were 23.6°C, with a maximum of 34.7°C. The surface temperature difference between rural and urbanized areas can reach 10°C on hot days, demonstrating the need for increased green space in cities. Various NbS measures are planned as part of Timișoara's Green Action Plan:

- Creating tree canopy in heat island areas on pedestrian and micro-mobility corridors to provide shade, including on squares, parking lots, traffic roads and private properties;
- Installing green rooftops and walls on blocks of flats and major retailers and companies, supermarkets hotels, hospitals or schools;
- Creating green coverage in cemeteries;
- Creation of a sponge city to improve water storage, water quality and reduce heat islands;
- Devising policies for resilient construction and retrofitting.

Specific heat-related NbS targets include:

- Five new green connectivity projects in the Southern part of the city;
- Tree canopy cover on major pedestrian corridors increased by 25 per cent;
- 50 km of streets redesigned as green corridors, reducing impermeable surfaces and increasing tree canopy coverage;
- Green roofs installed on 50 buildings.

NbS: creation of street trees, creation of green roofs, creation of green corridors.

Why: heat reduction.

Heat reduction benefits: Including green infrastructure in the city at the highest possible extent may lead to a temperature reduction of approximately 2°C. When peak daily temperature drops by 0.1°C, the percentage of heat-related mortality decreases on average by 3.0 per cent.

Timeframe for implementation: 2024–2028.

GHG savings / year: 772.6 tCO_2eq.

Capex: €4,610,000.

How:

- Spatial analysis of hotspots; identify and map heat island areas and micro-mobility corridors prone to thermal discomfort due to lack of shading. Define targeted actions for these areas. Identify and map buildings within heat islands along major grey infrastructure that have large, flat rooftops;
- Decide on the location of 5–10 pilot projects that should be prioritized based on the mapping exercise and through citizen engagement;
- Implement pilot projects for increasing green space in the pilot areas of Ronat neighbourhood and Calea Şagului area and rooftop greening in Calea Şagului and Buziaşului area;
- Launch tender for urban redesign and implementation of green projects of up to 10 pilot locations and 50 buildings for green roof development. Communicate regularly to citizens and stakeholders during design and implementation;
- Define, approve and enforce urban regulations and incentives for resilient construction and retrofitting to reduce heat island effects.

Costs:

Activity	*Capex (€)*	*Opex (€/Y)*
• Mapping heat islands, micro-mobility corridors subject to thermal discomfort and infrastructure on major roads to identify greening needs	60,000	•
• Define and implement pilot projects for shading and green rooftop installations	300,000	5,000
• Design and implement up to 10 pilot projects	3,000,0000	25,000
• Installation of green rooftops on 50 buildings	1,250,0000	•
• Enforcement of urban regeneration for heat island reduction in construction and infrastructure development, with incentives	•	25,000

Finance source: for greening streets, the local budget, national Government, Environmental Funds, IFIs and crowdfunding are most relevant. The municipality may facilitate green roofs by raising money through well-designed property taxes and development fees for subsidizing green infrastructure.

Participatory approach: the project aims to engage citizens and local stakeholders. The planning, design and participatory activities could be performed through engagement of architecture and urban development studies at the Technical University to capitalize on local expertise.

Enabling environment: policies are required to reprioritize functional green space planning, risk-informed planning to retrofit urban areas with more greenery, and use of materials with high albedo.

Who: the European Bank for Reconstruction and Development (EBRD) is implementing the pilot programme. The pilot will serve as a model for developing targeted investment programmes at the city level to combat extreme heat and may be replicated in other EBRD Green Cities and beyond.

Additional benefits: improved air quality, carbon sequestration, biodiversity, green corridors connect recreational areas by alternative modes of transport, improved health through lower heat.

Source: Municipiul Timişoara (2023).

In urban areas that are already heavily developed and space-limited, existing infrastructure can be upgraded by incorporating small-scale natural elements, such as green roofs and walls, into offices, car parks, bus stops and railway stations. At the same time, this can support biodiversity, such as insects, through the provision of habitat and food resources (Diamond, Bellino & Deme, 2023). The effectiveness of NbS can vary seasonally, however (Browder *et al.*, 2019). For example, it is reported that the effectiveness of vertical and rooftop greenery is higher in the summer season, during which there is higher foliage density and higher evapotranspiration rates (Wong *et al.*, 2021). Equally, it is crucial to ensure that the species selected for an NbS can adapt to the high temperatures. For example, in Morocco, locally adapted native species from Morocco and other North African countries are used to ensure that the solution can survive and provide benefits long-term.

For networked infrastructure, such as roads and railways, ecological corridors can mitigate heat stress on built assets. For example, street trees can provide shade and cooling, helping to protect paved roads and sidewalks from heat damage, reduce cracking, prolong lifespans and delay the need for repairs. In California, United States of America, shading from street trees was found to protect roads from heat stress sufficiently that it delayed the need for repaving by 10–25 years (McPherson and Muchnick, 2005). Similarly, the protection and restoration of ecological corridors along railway tracks can help to reduce the buckling of tracks from extreme heat and associated disruptions to rail transport networks (Blackwood *et al*., 2022).

Heat has important implications for the health of workforces. Also in California, the State's Division of Occupational Safety and Health (OSHA) has legally mandated shade provision for outdoor workers in specific sectors including energy and construction, to reduce the impact of heat on the health and well-being of workforces (California Illness Prevention Standard, no date; UNEP, 2023). The protection or creation of NbS, such as living fences or shelterbelts and agroforestry, can provide shade to agricultural employees while generating opportunities for food and revenue creation where fruit trees are used. Investment in NbS across city offices and infrastructure sites, such as ports and highway service stations, can improve workplace conditions more broadly, contributing to improved physical and mental health of workforces, and generating benefits such as better cognitive function, reduced stress, enhanced attention spans and better performance at work (Sturm and Cohen, 2014). Case study 4.5 demonstrates an example from the United Kingdom where nature has been brought indoors in the form of a created green wall to provide benefits including cooling, improved air quality and improved mental health of workers.

Box 4.2: Practical aspects to consider for heat

- **Location:** identify surfaces with exposure to high levels of solar irradiance. Social vulnerability can help to inform planning decisions and prioritization. Tree or shrub placement can also influence ventilation and, if poorly located, may result in inadvertent trapping of pollutants and heat in urban areas.
- **Orientation:** for certain NbS, such as green walls, orientation can determine effectiveness.
- **Space for deployment:** in many urban environments, built infrastructure is already established, leaving little room to create new large greenspaces. Informed planning can help to identify opportunities, such as for adding smaller-scale green walls and roofs to buildings, creating planter boxes, improving greenery in graveyards and along roads. As built infrastructure is upgraded, NbS can be enhanced further.
- **NbS type and species selection:** plant species should be selected based on evapotranspiration and shade quality. Trees will offer greater cooling benefits compared to grasses and shrubs. For example, in Germany, in situ estimates indicate mean radiant temperature reductions of 39.1°C under trees but only 7.5°C under grassland. A mix of small trees and shrubs can maximize benefits by trapping cooler air more efficiently than less diverse NbS. For green roofs, leaf size of selected plants can be related to overall cooling effects.
- **Diurnal and seasonal variation in effectiveness:** cooling potential of NbS is influenced by both diurnal and seasonal cycles.
- **Proximity:** NbS can cool areas directly under them through the provision of shade, and within the local vicinity due to the regulation of the local microclimate. Heat reduction benefits decay with distance. For example, in London, United Kingdom, park-induced cooling was apparent up to 330m away from the green space. In Gothenburg, Sweden, cooling was evident up to 1.1km away from a 156-ha park.
- **Wind flow:** cooling potential is increased under stronger wind conditions. Therefore, planners may consider designing the surrounding areas to maximize air flow.
- **Extent:** shape and size can impact effectiveness, with larger parks exerting a stronger influence on cooling. Smaller parks in some cases may be warmer than surroundings, owing to human and urban influences. Green spaces should be interspersed throughout cities. It is recommended that in cities, parks should be placed at appropriate intervals (less than 1km) and have a minimum size (at least 1ha).
- **Canopy density:** higher density canopies and higher leaf areas intercept greater solar radiation and lead to greater cooling benefits. Plant evapotranspiration also varies across species.
- **Quantify benefits:** recording temperature benefits at different distance thresholds along with data on NbS type, size and attributes can help to build an evidence base.
- **Multiple strategies:** where most cooling is required, multiple strategies can be used.
- **Hybrid options:** NbS can be integrated alongside other solutions, such as use of high-albedo light colours to reflect sunlight.

Relevant tools and approaches:

- Tools exist that can help to spatially estimate the potential value of NbS in reducing heat, including the Urban Cooling module in the Integrated Valuation of Ecosystem Services and Trade-offs (InVEST) tool.
- Thermal imagery, social vulnerability and activity maps can be used to prioritize neighbourhoods.

Source: Wong *et al.* (2021).

Case study 4.5: Bringing nature indoors for cooling, United Kingdom

The implementation of NbS can also be applied indoors. The David Attenborough Building in Cambridge has a three-storey-tall (50ft) Viritopia living green wall. This naturally cools the building, supports air quality through natural filtration and improves the health and well-being of workforces. The building is now used as a new global conservation hub.

NbS: creation of green walls.

Why: biophilia, social impact, air quality; also provides cooling, improved health and well-being of workforces.

Sector: education (university), but applicable to buildings across all sectors.

Size: 25–150 m^2.

Who: Nicholas Hare Architects LLP,[1] specifiers of the wall, was aided by the Green Infrastructure Consultancy (formerly the Green Roof Consultancy) in the design of the living wall as well as with Viritopia on both the design and installation elements. EOS Facades worked with AECOM structural engineers to form the 17 m tall supporting structure for the living wall.

Design features: 17-m tall supporting structure for the living wall which stretches three storeys of the internal atrium and provides support for the plants and mosses. Bespoke oversail bracketry and lattices were installed vertically up the 17-m height to assist growth.

Maintenance: future maintenance of the living wall is carried out via abseil rails incorporated in to the new rooflight feature at the top of the atrium.

Additional benefits:

- ***Education***: the wall aims to be educational and functional as well as ornamental. The design was based on an abstracted world map, with the plants used relating to species from different regions. It provides a link to the work of Cambridge Conservation Initiative (CCI);
- ***Workforce benefits***: it is reported that people working in an environment with plants can be 8 per cent more efficient and 12 per cent more productive and less stressed, and may have a 15 per cent increase in well-being compared to those who work in a space without natural features. Workspace design has direct effects on employee performance and well-being (Viritopia, no date, a);
- ***Air quality***: research has shown that 1 m^2 of vegetation cover generates the oxygen required by a person throughout the year while trapping 130 g of dust annually;
- ***Regulatory benefits***: living walls also help to achieve building standards in the United Kingdom such as BREEAM and WELL. The use of living walls can also help to secure planning permission (Viritopia, no date, b).

Source: Viritopia (2015).

1 Reference to commercial companies or products in this report does not imply endorsement by the United Nations or its Member States.

Flooding

River flooding

Adaptation options for built infrastructure, such as levees, dykes and modifications to river channels, are conventional solutions to managing river flood risk. While these measures can provide effective flood protection, they often have high maintenance costs and can lead to ecological degradation. NbS offer alternative approaches to reduce the severity and frequency of river flood risk, lowering the need for built flood protection infrastructure while supporting a much broader range of environmental and social benefits.

NbS can mitigate river flood risk by storing water in the landscape, reducing peak flows and preserving the natural capacity of river channels to convey water downstream (Dadson *et al.*, 2017; Chausson *et al.*, 2020; Buechel *et al.*, 2022). Wetlands, floodplains and ponds can function as natural storage reservoirs, holding excess water during storm events and releasing it gradually, reducing downstream flood peaks. At the catchment scale, NbS, such as the protection of forests and agroecology practices such as lower stocking densities and increased vegetation cover, can intercept rainfall, reduce soil compaction and support water infiltration into soils and groundwater, and reduce surface runoff, thus lowering the volume and rate at which water enters the river. Different ecosystems have different surface roughness values; ecosystems with greater surface roughness, such as forests and shrublands, can have a greater impact on lowering runoff rates, delaying the arrival of water into river channels and reducing peak flows.

NbS can also play a crucial role in preserving the long-term functionality of river systems and reducing requirements for maintenance in the form of river dredging. Riparian buffers, living fences or shelterbelts, and cover crops can stabilize soils and reduce erosion. This helps to prevent sedimentation of river channels and preserve storage capacity, enabling continued conveyance of water and reducing the risk that rivers will overtop their banks (WWAp, 2018). This is particularly important in waterways that receive high quantities of sediment from surrounding catchments (Dadson *et al.*, 2017).

However, as is typically the case with NbS, the effectiveness of NbS for river flood reduction is context-specific, and in some cases they may inadvertently increase flood risk. For example, forest restoration that slows water in one part of a catchment may lead to unintended consequences elsewhere, such as increased flood risk upstream as water flows slow down. Similarly, implementing NbS in tributary catchments may alter the timing of peak flows, and may unintentionally synchronize high flows in the main channel, intensifying downstream flooding (Dadson *et al.*, 2017). Evidence to date suggests that NbS are generally most effective for reducing flood impacts at smaller spatial scales (typically under 20 km^2) and for small to moderate flood events, such as those with a return period of up to 1-in-100 years (Ibid). There remains a limited evidence base regarding their effectiveness in mitigating high intensity floods or at large spatial scales underscoring the need for further research and long-term monitoring.

Countries within the ECE region are already implementing NbS for river flood risk reduction. For example, in Dushanbe, authorities are investing in hybrid infrastructure in flood-prone zones in response to rising spring flood risks exacerbated by climate change. Many of the city's river channels are currently constrained by concrete embankments, which limit natural flow and ecological function. As part of a broader strategy to improve urban biodiversity, flood resilience and water quality, the city is restoring river cross-sections and bed profiles and reconnecting rivers with floodplains. These interventions also support biodiversity and urban cooling through community-based green space conservation and biodiversity enhancement programmes (Barza, 2025). In another example, the Bic River Redevelopment Project aims to increase Chisinau's resilience to river flooding and future climate extremes. Frequent flood events are expected to worsen under climate change in the area. As the second follow-on investment under the Green City Action Plan, the city is financing a blend of structural and NbS interventions. These include partial reprofiling of the river channel and integrating flood water management measures, such as the rehabilitation of drainage networks, to manage stormwater runoff better and reduce exposure to flood hazards (Barza, 2025). More information on both of these actions within the EBRD Green City Action Plan may be found at EBRD (no date). See also case study 4.6 for a Canadian example of NbS for river flood reduction.

Box 4.3: Practical aspects to consider for river flooding

- **Space required:** a greater extent of forest has been linked to greater reductions in river flood flows (Buechel *et al.*, 2022). Infrastructure planners will need to be mindful of this when they plan new infrastructure projects in flood-prone regions that result in deforestation, and when they consider NbS options for river-flood reduction.
- **Consider sedimentation rates:** NbS can impact river floods through mechanisms that go beyond water storage and runoff regulation. Practitioners should not overlook NbS for soil stabilization, erosion control and sediment capture, particularly in rivers and streams that have a high rate of sediment delivery.
- **Soil type and permeability:** soil types and their permeability will impact hydrological flows, including whether water runs off the land into the rivers or infiltrates into soils and groundwater.
- **NbS location:** depending on the context, NbS may be more effective if they are in closer proximity to a flood-prone area and located upstream of a flood. However, in large catchments, extent may be more deterministic of flood-reduction benefits than location (Buechel *et al.*, 2022). Equally, practitioners should consider the local and wider context, as NbS implemented in one part of the catchment may cause floodwaters to back up and transfer risk to upstream locations.
- **Hydrology:** visualization of water flow directions using digital elevation models, geospatially locating flood-prone areas, and determining the upstream catchment of a flooded location can help to inform decisions on where to locate NbS.
- **Tributary rivers:** care must be taken in catchments that have tributary rivers, as tree planting in one tributary catchment may inadvertently increase flood risk in another. Care must be taken to consider location within the catchment and the timing of peak flows from tributaries to ensure that NbS do not inadvertently increase flooding through synchronization of flood peaks.
- **Flood return period:** NbS are generally considered more effective for lower return period floods (up to 1-in-100-year frequency), although evidence is lacking for larger floods.
- **Catchment size:** NbS are generally considered more effective at the scale of 10km^2 or less, although evidence in larger catchments is lacking.

Resources:

- The GRI tool developed by the University of Oxford (Russell *et al.*, 2025) project provides a global screening of NbS opportunity areas for infrastructure resilience in river catchments. These include maps of global tree suitability and estimated annual baseline economic damages from river flooding nearby within river catchments.
- The Hydrological Engineering Centre's River Analysis System (HEC-RAS) HEC-RAS is a free computer-based program for modelling water flows, sediment transport and water temperature or water quality (US Army Corps of Engineers, no date).
- HydroSHEDS provide global river networks (HydroRivers) and basins (HydroBasins) that can be used to inform catchment-based analysis (HydroSHEDS, no date).
- Open-source modelling software such as QGIS provides a suite of built-in tools such as GRASS that can support the delineation of water networks and basins.

Case study 4.6: Water Management Benefits of Prairie Pothole wetlands, Alberta, Canada

The Province of Alberta is vulnerable to floods that are exacerbated by wetland degradation. "Prairie pothole" wetlands are inland wetlands that are not typically connected to rivers or streams when water volumes are at average levels.

A pilot project assessed the value of these wetlands in the "White Zone", an expanse of land covering the lower third of Alberta and containing the Bow River and South Saskatchewan River Basins.

NbS: wetland restoration and wetland protection.

Why: flood reduction.

Capex: it was estimated that the full cost of restoration of the natural wetlands in the White Zone is US$10,000/ha, increasing to between US$19,000–23,284/ha in areas closest to Calgary.

Water storage: they can provide flood storage of 36.3 million per m^3.

Cost savings: it led to the avoidance of US$257 million of investment in engineered stormwater ponds.

Additional benefits: provision of clean water, a lower cost of water purification, habitat for wildlife, and settings for scientific research and education. They also provide a valuable carbon sink—the White Zone's wetlands have captured over 160,000 t of CO_2-equivalent since the 1960s. Access and proximity to wetlands have increased the average worth of a house by US$3,340–3,900, demonstrating benefits to property prices. Tourism linked to the wetlands was found to generate US$3.4 million in revenue for the province.

The value of the additional ecosystem benefits provided by the wetlands made a business case for stopping the drainage of wetlands and the encroachment of intact wetlands by residential, industrial and agricultural development.

Implementer: Alberta Province.

Source: Kapos *et al.* (2019).

Surface floods

NbS can play a key role in mitigating surface flooding, helping to protect infrastructure, reduce economic losses and safeguard human well-being and health. Water bodies, such as natural and constructed lakes and ponds, can store water alongside NbS such as wetlands and peatlands, while providing opportunities for walking, cycling, socializing and relaxation. Ecosystems intercept rainfall, support water infiltration into the soil, and reduce surface runoff through evapotranspiration, reducing water accumulation on surfaces and in depressional areas. Studies have demonstrated that ecosystems such as forests can reduce the risk of surface water flooding around railway tracks, helping to prevent earthworks from destabilizing during heavy rainfall events, and associated damage and disruption (Blackwood *et al.*, 2022).

In urban areas, NbS can be integrated into urban planning to reduce surface flood risk and relieve pressure on built stormwater management infrastructure (Chausson *et al.*, 2020; Dadson *et al.*, 2017). Small-scale interventions, such as green roofs, green walls, bioswales, rain gardens and planter boxes, can be integrated into dense city areas to absorb water, support infiltration into the ground and reduce the quantity and rate of water reaching urban drainage and sewer networks. Where watercourses, such as rivers and canals, intersect with urban areas, restoration of natural vegetation and channels can capture runoff and help convey water downstream more effectively.

Many cities in countries across Europe and North America are actively investing in projects that use NbS to mitigate flood risk. To date these have been known under different terms, such as Sustainable Urban Drainage Systems (SuDS), Low Impact Development (LID), Green Infrastructure, Water-Sensitive Urban Design and Sponge Cities (see case studies 4.7 and 4.8).

Box 4.4: Practical aspects to consider for surface floods

- **Applicability of the NbS to the context:** it is vital to evaluate the suitability of an NbS to the given context. For example, it has been reported that green roofs are considered suitable for roofs up to a slope of 30 per cent if paired with structural interventions such as strips to hold the substrate on which the vegetation grows. Equally, the structural capacity of the roof must be considered as roofs must be able to withstand the weight of the green roof and the additional volume of water.
- **Understand hydrological conditions:** this is critical to the design of bioretention areas such as detention ponds. Bioretention areas should always remain above the water table to ensure that groundwater does not intersect the filter bed and reduce infiltration capacity. It is recommended that a distance of at least 0.6 metres is maintained between the bottom of the excavated bioretention areas and the seasonally high groundwater table unless an impermeable liner is installed.
- **Flood return period:** NbS are generally more effective for lower return period floods and less effective for higher return period floods, as they are likely to reach a saturation point at which they no longer provide benefits (Acreman and Holden, 2013).
- **Hybrid options:** NbS may be paired with hybrid options where return periods are projected to be higher.

Relevant tools:

- There are tools that can help to estimate the potential value of NbS spatially, including the Urban Flood Risk Mitigation and Urban Stormwater Retention module in the Integrated Valuation of Ecosystem Services and Trade-offs (InVEST).

Case study 4.7: Sustainable Urban Drainage Systems in the United Kingdom

The United Kingdom has implemented various SuDS projects, including in 10 schools in a river catchment in North London. The SuDS functioned similarly to natural wetlands to reduce local flooding and supported biodiversity and provided additional benefits, including improved water quality in streams, learning opportunities, training and skills development.

Type of NbS: creation of wetlands.

Why: reduction of surface flooding.

Additional benefits: improved water quality, educational opportunities, improved skills.

Source: WWT (no date).

Case study 4.8: A sponge city in Mongolia

A notable example from beyond the ECE region is Ulaanbaatar, where authorities are pursuing a "sponge city" approach to address increasing flood risk due to climate change. The initiative aims to transform Ulaanbaatar into a city capable of absorbing and retaining water during intense rainfall events, reducing flash floods and recharging the city's aquifer.

Avoided costs: this approach is expected to reduce infrastructure costs by 15 per cent compared to conventional grey flood mitigation options and reduce maintenance costs.

In parallel, the city plans to expand green space, from 0.12 m^2 per person to 2.4 m^2 per person over four years, while promoting integrated water management and enhanced urban climate resilience through water retention. These multifunctional green spaces will not only reduce flooding but also deliver broader environmental and social benefits for the people who live there.

Type of NbS: various green spaces including floodable parks in case of heavy rainfall, green roofs, and rain gardens, bioswales and planter boxes to collect runoff from sidewalks, parking lots and streets, as well as the soft lining of bicycle and walking paths. These are combined with other measures such as downspout disconnection and permeable pavements.

Why: reduction of surface flooding.

Additional benefits: carbon sequestration, recreational areas.

Additional measures: reforestation and riparian buffers will also be implemented to address river flooding across the Tuul and Selbe river basins. Reforestation of 120 ha is expected to cost US$600,000, while green embankments will cost US$13 million for a total of 100 km.

Source: Barza (2025). More information on the EBRD Green City Action Plan may be found at EBRD (no date) and Municipality of Ulaanbaatar (2019).

Coastal floods

Infrastructure and communities located along the coastlines of the ECE countries are susceptible to coastal hazards, such as coastal flooding, erosion, sea level rise and storm surges. Built coastal defence infrastructure, such as seawalls and gabions, can support the protection of infrastructure and people. However, there are also opportunities to harness the protective benefits that NbS can provide for coastal hazard risk reduction (Narayan *et al.*, 2016; Tiggeloven *et al.*, 2022). Coastal ecosystems, such as salt marshes, seagrass meadows, coastal beaches and dunes, wetlands and artificial reefs, can help to protect coastlines from these hazards (Beck *et al.*, 2018; Menéndez *et al.*, 2020). Salt marshes can stabilize shorelines through sediment trapping and by reducing the velocity of waves—they are reported to reduce the heights of non-storm waves by 72 per cent (World Bank, 2021). Sandy and rocky shorelines and dunes can minimize coastal erosion caused by winds and waves during storms. Coastal wetlands can support storm surge mitigation by as much as 8–20 cm for every mile of continuous wetland (UNEP, 2014). Salt marshes can contribute to storm surge mitigation by increasing flow resistance, although this requires sufficient land availability as a width of 6–10 km has been recommended (World Bank, 2021; UNEP, 2023).

The protective services of NbS offer potential to ports and port cities. Located at the natural interface between land and water, they are subject to various coastal hazards. Integrating NbS, such as the restoration of mangroves or creation of artificial reefs, offers natural protection for ports against these coastal hazards (Taneja *et al.*, 2020; Liu *et al.*, 2025). At the same time, implementing NbS can significantly enhance the environmental credentials of sectors such as ports, while supporting biodiversity and improving the quality of life for communities. More information on the specific applicability of NbS to ports is provided in Chapter 6.

As countries look to embed resilience into new and upgraded infrastructure systems, consideration of NbS within the portfolio of options will be essential to ensure that the potential benefits that they can provide for protecting infrastructure and more broadly are considered within the cost-benefit analysis. Case study 4.9 provides an example of a project where salt marshes were constructed to provide protection against coastal flooding and habitat for biodiversity.

Box 4.5: Practical aspects to consider for coastal floods

- **Connectivity of different coastal ecosystems:** coastal ecosystems, such as mangroves, coral reefs and seagrass, function synergistically and can amplify the benefits of each other. Therefore, to ensure maximum benefits from one, practitioners should assess whether other ecosystems in the vicinity should be protected or restored.
- **NbS size:** the width (applicable to salt marshes, mangroves, dunes, beaches) and height (applicable to mangroves and dunes) of NbS are integral components of their effectiveness at reducing risk from coastal hazards.
- **Return period:** NbS are generally more effective for lower return period floods compared to higher return periods.
- **Space available:** given that wider NbS offer higher risk reduction benefits, practitioners will need to consider the amount of land available and factor this into the evaluation of potential effectiveness. For coastal NbS to adapt to sea level through inland expansion, sufficient space needs to be available. Existing land uses, such as infrastructure developments, can impair the ability of coastal ecosystems to adjust.
- **Soil type:** certain soil types are more conducive to coastal ecosystems. For example, the availability of silt and clay in the substrate can increase the stability of salt marshes and their ability to develop. Consulting key experts who have knowledge of coastal ecosystems will be a critical success factor.
- **Slope:** slope and soil properties can dictate what kind of NbS are feasible. E.g. For mangroves, salt marshes and other ecosystems, the slope and soil properties are essential for their stability and resilience.
- **Geographic applicability of the NbS:** not all coastal NbS are applicable to all regions. For example, mangroves are typically found in tropical locations and are not likely to be applicable to temperate locations.
- **Management:** restoration of NbS such as mangroves may require activities such as litter clearing to support their establishment.
- **Salinity:** coastal species, such as salt marshes and mangroves, typically have optimal salinity ranges. For example, for mangroves this salinity is 3–27 ppt (parts per thousand), while for salt marshes it is between 18–35ppt.
- **Hybrid options:** coastal NbS may be paired with built infrastructure, such as seawalls or dykes, to increase effectiveness.

Relevant tools:

- Tools exist that can help to spatially estimate the potential value of NbS in reducing risks from coastal hazards, including the Coastal Vulnerability module in the Integrated Valuation of Ecosystem Services and Trade-offs (InVEST), the Artificial Intelligence for Ecosystem Services (ARIES) and the Multiscale Integrated Models of Ecosystem Services (MIMES).
- For the United States of America, the coastal resilience mangrove explorer can be used to look at current and future mangrove potential (Coastal Resilience, no date).
- Beck *et al.* (2018) and Menéndez *et al.* (2020) provide datasets on global flooding with and without coral reefs and mangroves, respectively, which are available upon request.
- Other tools can be found in a report by the World Bank (2016).

Case Study 4.9: Salt marshes for flood defence in the Dutch Wadden Sea

Classified as semi-natural habitats, approximately 9,000 hectares of constructed salt marshes exist on the shores of the Netherlands and the barrier islands. In one location in the Netherlands where 25 km of salt marsh were built along a dyke, an evaluation found salt marsh construction to be more cost-effective than dyke heightening in instances where economic damage in the case of dyke breaching is small to moderate. Models showed that the construction of earthen breakwaters within the saltmarsh, above the area where sediment naturally accumulates, appears to be more effective than increasing the height of the dyke itself.

The Wadden Sea lies between the coasts of the Netherlands, Germany and Denmark and a string of barrier islands stretching 500 km separates it from the North Sea. Consisting of tidal mudflats and salt marshes, it is a crucial biologically productive ecosystem, of which several stretches have earned the title of UNESCO World Heritage Sites.

Salt marsh restoration has been evaluated as a more cost-effective approach to reduce coastal flooding impacts in the Wadden Sea region compared to the built defence option of dike heightening. A modelling-based study estimated that implementing a salt marsh zone on the seaward side of 600 km of dykes would greatly reduce the need for dyke reinforcement. It estimated that the salt marshes would lessen the need for dyke reinforcement from an estimated heightening of 0.5 metres over the whole 600 km needed by 2050 without the salt marshes, to a heightening of less than 0.25 metres over only 50 km of dykes with the presence of the salt marshes. This was contingent on the salt marshes keeping pace with sea level rise. Another study further found that foreshores vegetated with salt marsh significantly reduced the probability of dyke failure due to both wave overtopping and wave impact on revetements.

The restoration of salt marshes would also provide a critical habitat for salt-tolerant plant species, leading to biodiversity benefits, while reducing risks for local people.

NbS: salt marsh restoration.

Multi-stakeholder governance: the project is co-governed by three countries—the Netherlands, Germany and Denmark—through the Trilateral Wadden Sea Plan. At a local level, landowners work with local governmental bodies and nature conservation organizations to establish sustainable cattle grazing policies for the area.

Finance: The Wadden Programme runs these projects. It is a subsidiary of the Dutch Delta Programme, which is funded by the Dutch Government. Studies on the effects of the marshes were funded by the BE SAFE programme, which is part of the Netherlands Organization for Scientific Research.

Monitoring & Evaluation: extensive government funding has been provided to finance the monitoring and reporting of scientific data on the implementation of salt marsh restoration.

Source: NbSI (no date, b).

Water quality

Ensuring and maintaining water quality is a major challenge across the ECE region, with significant implications for human health, the environment and economic productivity. Pollution of water supplies arises from both point and diffuse sources, including agricultural runoff carrying nutrients and pathogens; sedimentation from unsustainable land management practices, ecosystem loss and degradation; leaching of heavy metals and persistent organic compounds from landfills and industrial activities past and present; pollutants from mining; untreated sewage disposal; industrial wastewater discharges; and sewer overflows during storm events in urban areas. These pressures can lead to waterborne diseases, chronic exposures to harmful chemicals, ecosystem degradation and increased costs for water treatment, impacting infrastructure functioning and the health of both people and the environment.

NbS can support water quality as an alternative or additional approach to conventional infrastructure (Haggis *et al.*, forthcoming), including within ECE countries (EU4Environment-Water and Data Consortium, 2024). By stabilizing soils and riverbanks, NbS such as riparian buffers, shrubs, floodplains and forests can reduce erosion and prevent sediments from entering water sources, lowering turbidity and pollutant loads, improving water quality and aquatic health, and reducing pathogen spread (Center for Agroforestry, 2013; Browder *et al.*, 2019). At the same time, they can provide habitat and a source of food to local wildlife and reduce heat stress on waterways through shade provision. Agroecological land management practices, such as cover crops, agroforestry and silvo-pasture, can improve soil stability and retention and reduce runoff of nutrients such as nitrogen and phosphorus, which can cause harmful algal blooms. Across Europe, land conversion to agriculture is responsible for more than two-thirds of overall soil loss, suggesting a significant need for mitigating agroecological approaches (Trémolet & Karres, 2020).

Natural and constructed wetlands and reed ponds can play a critical role in filtering and removing pollutants and toxins, including sediments, nutrients, heavy metals, oil and grease, protecting water quality in surface and groundwater supplies. Trees and hedgerows can filter and absorb pollution, particularly if they are designed as shelterbelts along busy roads, although the degree of removal that they can provide cannot substitute for reducing pollution at the source (Smith, Hafferty and Seddon, 2023). Phytocaps on landfills and mines can prevent leachate from filtering into the environment and contaminating local water systems, often more effectively than conventional clay caps (see Chapter 6). Urban NbS, such as green roofs and walls, rain gardens, bioswales, street trees and planter boxes, can reduce stormwater runoff and pressure on urban drainage networks, and help prevent the overflow of city sewer systems, reducing risks of urban water supply contamination.

Across catchments, forests can offer significant economic benefits to water quality. It is estimated that restoring upstream ecosystems in watersheds can support the regulation of water flows and reduce sediment loads sufficiently to save water treatment utilities across the largest cities globally approximately US$890 million annually in treatment costs. In contrast, the degradation and loss of natural ecosystems can result in costs to water utilities. Globally, watershed degradation is estimated to cost cities US$5.4 billion per year in increased water treatment costs, affecting the drinking water supply of more than 700 million people (Browder *et al.*, 2019). This also has implications for wider economic functioning, as water of sufficient quality is required for industrial functioning, and water treatment can incur high costs.

In Albania, fuelwood collection and unsustainable agricultural practices, particularly in the poorest regions that often lack economic opportunities, have left land eroded, degraded and unproductive for farming. A project on assisted natural regeneration of degraded lands restored 5,357 hectares of degraded land through initiatives that span 24 communes in over 100 villages across the country. By supporting natural regeneration of vegetation in the area, the initiative has helped decrease soil degradation, improve water quality and protect biodiversity. This project's framework also sought input from the communities involved, who were partially responsible for choosing sites for reforestation and participated in the implementation of programmes (Nature4Climate, no date, a).

In another example, the Gorla Maggiore water park in Milan, Italy, is a constructed wetland built on the banks of the Olona River and aims to protect against flooding but also to keep pollution in check. It includes (i) a pollutant removal area composed of a grid, a sedimentation tank and four vertical sub-surface flow constructed wetlands; (ii) a multipurpose area with a surface flow constructed wetland or pond with multiple roles; and (iii) a recreational park with restored riparian trees, green open space, walking and cycling paths. The Gorla water park was developed by the sponsorship of the Lombardia Regional Authority and co-funding by Fondazione Cariplo to implement their environmental quality objectives (Nature4Climate, no date, b).

Box 4.6: Practical aspects to consider for water quality

- **Consider trade-offs:** the use of pesticides and fertilizers on NbS such as parks should be considered as this may impact water quality. Implementation of NbS for providing benefits to water quality may offset benefits to water recharge.
- **Consider a broad range of options:** NbS can be used to reduce pollutants at their source (e.g., through stabilizing soils) or to assimilate pollutants that are already within water bodies. Implementation of multiple options may be the best solution to improve and maintain water quality, depending on the context.
- **Limits to effectiveness:** NbS may not be able to treat highly polluted waters, owing to limits in their treatment capacity. This should be considered during the planning phase.
- **Quantifying benefits:** monitor flows and flow rates of key pollutants such as phosphorus, nitrogen, organic carbon and sediment flows over time (e.g., tonnes per year) and how they change through the deployment of NbS. Tracking requirements for flocculants to bind sediments can also be considered as an indicator.
- **Collaboration between water users:** this may help to support NbS efforts, such as the restoration of ecosystems in catchments supplying water.

Drought

Droughts, which are becoming more frequent and severe under climate change across the region, have far-reaching social, environmental and economic impacts. These include food and water insecurity, losses in agriculture, increased mortality among humans and livestock, ecosystem degradation, and reduced economic productivity (Kapos *et al.*, 2019). In many parts of the ECE region, drought is associated with receding groundwater levels, reduced water quality and competition over water use.

NbS can play a role in reducing the severity and duration of drought impacts by storing water, promoting infiltration, protecting water quality and supporting water reuse. Wetlands, floodplains, ponds and lakes can store water during periods of high rainfall, releasing it slowly during dry periods. Deep-rooted trees and shrubs promote the percolation of water into soils, supporting the recharge of groundwater and aquifers. Improving soil health and vegetation cover can further increase the infiltration capacity of the landscape, retaining water in the ground and reducing the amount which runs off the surface (UN, 2018). In upland areas, improved grazing and livestock management can reduce soil compaction and improve both infiltration and soil water retention (Browder *et al.*, 2019).

The restoration of native vegetation around water bodies can provide shade that can potentially help reduce the evaporation and loss of surface water. At the same time, by preventing sediments from entering waterways, riparian vegetation and NbS within watersheds can safeguard the storage capacity of rivers, streams and reservoirs that supply water. Agroforestry systems can reduce water losses in agricultural areas by slowing wind speeds over fields, while providing shade to livestock and farm workers. Other agroecological practices, such as mulching, can support the retention of moisture in the soil and lower requirements for irrigation. The removal of non-native and invasive species and replanting with native, local, drought-tolerant species can further contribute to drought mitigation across ECE countries by lowering water requirements associated with vegetation.

NbS can also support water reuse and reduce pressure on national water supplies. Green roofs can capture rainfall that can be reused for non-drinking purposes, such as toilet flushing, providing benefits to sanitation. Constructed wetlands and reed beds can treat wastewater from sectors such as manufacturing and production, fossil fuel energy generation and airports, which can be reused within the sector for purposes such as cooling (Kesari *et al.*, 2021). Through the water quality benefits described in the section above, NbS can help to safeguard the quality of national water supplies during periods of water scarcity.

While NbS offer multiple benefits for drought, they may also involve trade-offs. For example, urban parks or allotments designed to cool cities and provide recreational space may require irrigation, increasing water demand during droughts (Choi *et al.*, 2021). Where living fences are used to regulate microclimates around crops and livestock, water use by trees may offset benefits. Riparian vegetation may reduce evaporative losses through shade provision, but will also require water to survive and function. Careful planning is needed to optimize the design of NbS and ensure that they do not offset water-saving objectives. NbS can be most effective when implemented in combination with grey infrastructure solutions. For example, agroecology can be integrated with sustainable practices, such as the use of drip irrigation in the case of agriculture, to reduce unnecessary water losses. Combining rainwater harvesting with natural filtration systems can increase water security, while ensuring that systems are resilient to long-term climate change.

Box 4.7: Practical aspects to consider for drought

- **Species selection:** ensuring species are adapted to drought conditions will be necessary to ensure that those implemented do not exacerbate drought issues. The use of native species is recommended, as non-native species may be less adapted to the local context.
- **Consider maintenance needs:** some NbS will require irrigation to establish and may require irrigation as part of regular maintenance strategies. These irrigation requirements should be carefully considered during the planning phase. Some NbS, such as green roofs, can be paired with water storage technologies, and water captured during periods of rainfall can be used for irrigation.
- **Take a systems perspective to drought planning:** the implementation of some NbS can support the capture and storage of water that can be subsequently re-used for other needs. For example, green roofs in buildings can capture water that can be reused for non-potable uses, such as toilet flushing, providing wider benefits such as for sanitation.
- **Hybrid options:** NbS such as green roofs can be paired with water storage infrastructure to capture water for reuse.
- **Quantifying benefits:** monitoring changes in water retention and infiltration can help to build an evidence base on the effectiveness of different NbS measures in various contexts.

Transboundary water management

Implementing NbS for water management requires a watershed approach, whereby decisions are made at the level of the whole basin. Many ECE countries share water resources with other countries. NbS offer potential for building resilience in shared landscapes such as the Amu Darya and Syr Darya river basins, where infrastructure and ecosystems cross national borders. These are the two main rivers that connect the Central Asian region, and they provide all or most of the water resources to the riparian countries. Cooperation and collaboration between upstream and downstream riparian countries will be key to sustainable water management for the transboundary watercourse.

In the Danube River basin, which runs through 19 countries, the International Commission for the Protection of the Danube River has developed a transboundary climate adaptation strategy. In certain parts of the basin, river restoration works are implemented through a public-private Living Danube partnership including Coca-Cola bottling company and WWF (ECE, 2019). Case study 4.10 provides an example of a transboundary collaboration between Canada and the United States of America.

Case study 4.10: Transboundary collaboration for health ecosystems and community engagement, Canada and the United States of America

The International Joint Commission (IJC) was established by the Boundary Water Treaty of 1909 between Canada and the United States of America and serves to resolve and prevent transboundary water disputes between the two countries.

Canada and the USA created the IJC in recognition that each country is affected by the other's actions in the lake and river systems along the border. They cooperate to manage these waters and protect them for present and future generations. The treaty provides general principles rather than detailed prescriptions for preventing and resolving disputes over waters shared between the two countries and for setting other transboundary issues.

IJC approval is required for specific proposals to construct a dam or diversion that would affect water levels and flows across the international boundary. If a project is approved, the IJC may impose conditions on its design or operation to protect the interests of both countries.

The IJC has two primary responsibilities: approving projects that affect water levels and flows across the boundary and investigating transboundary issues and recommending solutions. The IJC's recommendations and decisions take into account the needs of a wide range of water uses, including drinking water, commercial shipping, hydroelectric power generation, agriculture, ecosystem health, industry, fishing, recreational boating and shoreline property.

Source: IJC (no date) and WWAP (2015).

Landslides and mudflows

Landslides are increasing around the world, driven by extreme rainfall, deforestation, poor management practices, overgrazing, natural resource exploitation and the construction of infrastructure such as roads. Mountainous and sloped areas can be particularly vulnerable to landslides and mudflows in the ECE region, particularly in areas which experience high rainfall and include agricultural pressures or ecosystem degradation. Deforestation can significantly increase the frequency and magnitude of landslides, as tree roots can be critical for maintaining soil stability (Lehmann, von Ruette and Or, 2019). NbS, such as the protection and restoration of native, deep-rooted trees, shrubs and grasses, and specific agroecology practices, can help to stabilize slopes by reinforcing soils, improving drainage and reducing surface runoff (Chausson *et al.*, 2020; IPCC, 2019). When designed and maintained appropriately, these systems can serve as practical and cost-effective alternatives to grey infrastructure solutions, while providing additional benefits such as improved biodiversity and flood mitigation.

Vegetation contributes to slope stabilization through both mechanical and hydrological mechanisms. Mechanically, roots increase soil shear strength and bind soil particles together. Thick, deeper roots act like anchors that buttress the upslope soil mantle and provide structural reinforcement, while fine lateral roots weave through upper soil layers, adding cohesion and reducing erosion (Stokes *et al.*, 2014). In shallow soils, roots may penetrate the entire soil mantle, providing anchors into more stable layers while dense lateral roots stabilize soil surface layers against landslides. For NbS to effectively reduce shallow landslide risk, roots must cross the sheer surface, which may reach depths of up to two metres (Stokes *et al.*, 2014). Forests can also provide a physical barrier that can mitigate the impact of smaller landslides, debris flows and rockfalls. Trees and undergrowth help to slow or fragment moving material, reducing the runout distance and velocity of mass movements, and protecting critical infrastructure, people and ecosystems located below (Moos *et al.*, 2018).

Hydrologically, vegetation intercepts rainfall through its foliage, reducing the amount of water that percolates into the soil. Plant roots can help to minimize soil compaction and increase soil permeability and roughness, promoting greater infiltration and reducing surface runoff. Vegetation roots absorb water, decreasing pore water pressure and increasing slope stability, helping to prevent soil saturation and the slumping of earth materials. Forests can support greater slope stability over time by encouraging the development of cracks within the soil—as roots develop and soil moisture levels reduce following absorption this leads to increased space for water to percolate through the soil.

The effectiveness of NbS in stabilizing slopes can depend on several factors. Root depth and lateral spread are critical components. NbS are generally most applicable to shallow landslides, typically affecting soils less than 1–2 m in depth (Moos *et al.*, 2018). NbS are less effective for deeper landslides, where roots are unable to penetrate fully. NbS are considered effective on moderately steep slopes, but less effective on very steep slopes. For example, trees with deep tap roots are considered able to protect infrastructure from landslides arising from slopes less than 70°. In some cases, heavy trees on fragile or saturated slopes may contribute to slope instability, mainly where gaps in the forest canopy occur due to age (e.g., older forests thinning out), degraded condition because of poor management or pests (e.g., bark beetle outbreaks), or storm damage. Uprooted trees can destabilize slopes and soils further, especially after intense rainfall, high winds which transmit dynamic forces to soils, or on steep slopes. These risks must be factored into the design of NbS for mass-movement hazards.

Examples in the ECE region include protection forests in Switzerland (see case study 4.11), the application of NbS in Almaty, Kazakhstan, to manage mudflow risk through the expansion of blue and green urban infrastructure (see case study 4.12), and NbS for slope stabilization in Azerbaijan (see case study 4.13).

Case study 4.11: Protection forests in Switzerland

Switzerland offers an example of the deployment of NbS in slope stabilization strategies through its protection forests, which form a core component of disaster risk reduction in the Alps. These forests are protected and carefully managed to reduce the risk of multiple mass-movement hazards, including avalanches, landslides and rockfalls, which threaten infrastructure and settlements. The Swiss Government invests over US$120 million annually in the management of protection forests, ensuring a diverse mix of tree species and a balance of young and old trees, which is a key component of healthy NbS. These forests are managed over long timescales, typically 50–100 years, requiring long-lasting public and political commitment to protect and maintain them. Studies suggest that protection forests can cost 5–10 times less than built alternatives over time.

NbS: protection and management of forests.

Why: protection from mass-movement hazards: avalanches, landslides and rockfalls.

Funder: Swiss Government.

Management: managed by the Government forest office.

Strategies: the forests are managed over long timescales, typically 50–100 years; they ensure a diverse mix of old and young trees.

Additional benefits: local people use the forests for recreation and appreciate their aesthetic value compared to conventional barriers or rock nets.

Source: Sudmeier-Rieux *et al.* (2019).

Box 4.8: Practical aspects to consider for landslides and mudflows

- **Slope steepness:** planting trees on steep slopes (over 50°) can increase landslide risk.
- **Landslide cause:** NbS are typically less effective for earthquake-induced landslides compared to landslides triggered by rainfall or land-use change.
- **Built infrastructure planning:** where infrastructure cuts along slopes and deforestation occurs as a result, this can be a key trigger of landslides, and should be avoided where possible.
- **Root depth and distribution:** the effectiveness of NbS in mitigating landslides can depend on the extent and architecture of the root system. Deep-rooted species and roots that are more distributed can be more effective at binding soils and stabilizing roots than shallow roots (ADPC, 2020).
- **Species type and age:** selection of species that maximize benefits to biodiversity and people can achieve greater benefits. For example, while bamboo can be effective at stabilizing soils, it is fast growing and the introduction of bamboo in non-native locations can lead to poor biodiversity outcomes through it out-competing native tree species. In some countries, broom grass provides landslide mitigation benefits while offering co-benefits to local communities as it can be harvested in certain seasons.
- **NbS dimensions:** the structural characteristics of an NbS can influence their effectiveness, for example, forest gaps can limit the protective effect (UNEP, 2023).

Resources:

- Geospatial datasets exist that can form a starting point for considering NbS for landslides. For example, the Global Landslide Catalog (2019) shows landslides triggered by rainfall for the period 2007–2019.

Case study 4.12: Reducing mudflow risk in Alsace, France

In Alsace, mudslides occur following more frequent spring storms that bring intense rain. The region has strategically implemented hedges and adapted crop rotation. This initiative has had positive local acceptance, effectively reducing mudslide risk and improving water retention, with co-benefits including landscape diversification, new habitats for biodiversity and improved water quality.

NbS: creation of living fences; improved management of agricultural lands (agroecology).

Why: mudflow mitigation.

Wider benefits: diversified landscapes, habitat for biodiversity, improved water retention and water quality.

Source: EU4Environment (2023).

Case study 4.13: NbS for Slope Stabilization and Livelihood Diversification in Azerbaijan

In the mountainous regions of Azerbaijan, unsustainable land management, particularly high intensity livestock grazing, has led to widespread degradation of pastures. Vegetation loss and soil erosion have reduced productivity and biodiversity while significantly increasing the risk of landslides. These pressures are expected to intensify as a result of rising temperatures and more frequent extreme weather events.

In response, the Germany Agency for International Cooperation (GIZ), in collaboration with Azerbaijan's Ministry of Agriculture, implemented a comprehensive programme to combat the effects of pasture degradation on hillsides through improved management practices, erosion control and a landscape restoration programme focused on hillside stabilization. The project employed various NbS, including agroecology (terracing), afforestation and orchard establishment, to reduce soil erosion and restore ecological function. Fences were installed to prevent further degradation, and the steepest hills were reinforced with terraces planted with fruit trees, enhancing both slope stability and economic value for farmers.

To further reduce erosion, check-dams were constructed in eroded riverbeds to slow water flow and erosion rates. Degraded gullies were fenced for safety and replanted with native tree species to anchor the soil. Severely eroded grazing pastures were transitioned into hay meadows, which helped to increase vegetation cover and likely increased the area's carbon storage potential. These interventions collectively reduced erosion rates, mitigated vegetation loss and lowered landslide risk, while also improving habitat quality and supporting local biodiversity recovery.

NbS: improved pasture management including agroecology; landscape restoration including afforestation and orchard establishment.

Participatory approach: importantly, the programme took a participatory, community-based approach. A Community Management Group was established to oversee the implementation and monitoring of interventions. Members of the group were chosen through voting by municipality members. The group brought together diverse local stakeholders with experience in natural resource management. It coordinated with relevant government bodies, including the District Administration, the regional department of the Ministry of Ecology, the Property Committee and the Rayon Agriculture Department, and was empowered to approve activities, resolve conflicts and ensure community ownership.

Capacity building: the project also aimed to reduce economic dependence on grazing by promoting alternative, sustainable livelihoods. Support was provided to develop tree nurseries and orchards, beekeeping enterprises and hay production. Local experts trained community members in these practices, ensuring knowledge transfer and long-term capacity building.

Monitoring: socioeconomic and ecological outcomes are regularly monitored, enabling transparent evaluation and dissemination of results to neighbouring communities. This integrated approach demonstrates how NbS can deliver simultaneous benefits for disaster risk reduction, ecological restoration and rural development, while building resilience to future climate impacts.

Source: NbSI (no date, d); Ecoserve (no date); Koeppler (2020).

Soil health and erosion control

Intense precipitation and drought events that occur across ECE countries can exacerbate soil erosion, an issue compounded by unsustainable land management practices, ecosystem loss and degradation. Soil erosion can have significant impacts on infrastructure sectors, particularly those which rely predominantly on freshwater sources to function. Soil loss from areas upstream of reservoirs can result in high sediment yields in rivers, which are transported downstream by the flow of water, causing sedimentation of waterbodies and reservoirs, pollution of water, and sediment-driven wear-and-tear on built assets. Built infrastructure such as dykes and hydropower turbines are at risk from damage caused by scouring that results from the increased sediment yields in rivers (Stokes *et al.*, 2014). Soil erosion also has huge economic implications—it has been estimated that the current impact of soil erosion on the productivity of agriculture is US$8 billion globally (European Commission, 2024). Soil erosion results in the loss of topsoil and nutrients, which can lead to lower soil fertility, land productivity and crop yields, affecting the agricultural sector and food security, as well as regional food trading markets and the economies of ECE countries that rely on food production for their GDP (Sartori *et al.*, 2024).

NbS can support the mitigation of soil erosion, by stabilizing soils and capturing eroded soils before they enter watercourses. Vegetation within watersheds can reduce wind speeds, shield soils from wind and rain, and help to bind and stabilize soils, reducing the risk of erosion. Wetlands, floodplains and riparian vegetation function as barriers and can trap eroded sediments, preventing them from washing into rivers. This in turn can support water quality within nearby watercourses, reduce pollution, safeguard storage capacity of rivers and reservoirs, and reduce flood risk and damage to built assets. Case study 4.14 provides an example of a project in Moldova where pastures and forests have been restored to combat soil erosion.

Within the agricultural sector, agroecology practices can support wider soil health. For example, improved grazing management can reduce soil compaction and increase pore space, supporting infiltration of water, while cover crops can shield soil from rain and wind. In areas of water scarcity, practices such as mulching can enhance water retention within the soil, which can bind soils and prevent erosion. By reducing erosion rates, agroecology can help the retention of nutrients, such as phosphorus and nitrogen, within agricultural lands and play a role in improving soil productivity by increasing soil organic carbon content. Conservation tillage can increase soil fertility and improve crop yields by helping to bind harvest residues, organic matter and nutrients in the soil, and supporting the growth of soil microorganisms. Countries in the ECE region are beginning to apply these approaches. For example, Georgia has introduced agroforestry systems and living fences or shelterbelts to reduce wind-driven soil erosion (EU4Environment-Water and Data Consortium, 2024).

Protection and restoration of natural vegetation and the implementation of agroecology practices can also generate wider benefits for the ECE region, including by improving carbon sequestration and reducing the release of carbon dioxide from soils, supporting biodiversity and water regulation, and improving food security (Sartori *et al.*, 2024). By improving soil structure and supporting water retention in the soil, NbS can help to reduce dust in the air, which is an important factor in respiratory health, particularly in arid countries. Crop diversification can increase resilience to climate impacts and support the reduction of pests and disease outbreaks, and reduce the need for pesticides, which benefits both the environment and human health. Case study 4.15 provides an example of agroforestry practices which have been undertaken in the United Kingdom to both combat soil erosion and generate wider benefits.

Poor agricultural management practices and the loss of native vegetation can exacerbate soil erosion. However, the rates of soil erosion in Eastern Europe have fallen on average over the last three decades, partially as a result of the abandonment of agricultural croplands (ECE, 2022b). At the same time, examples from ECE countries show the benefits of implementing NbS measures to combat soil erosion. As countries in the ECE region look to reduce soil erosion rates further, there is both a need and an opportunity to integrate and scale NbS approaches as part of their adaptation strategies.

Box 4.9: Practical aspects to consider for soil erosion and health

- **Slope steepness:** slopes can be more prone to soil erosion than flatter areas, and steepness may be considered when assessing where to implement NbS.
- **Management practices:** the management of landscapes can be an important factor in soil compaction and erosion. For example, exposed soils are more susceptible to erosion than those stabilized with vegetation. Improving management practices should be a key consideration within the portfolio of NbS options.
- **Water and wind management:** as high rainfall, drought and wind can all impact soil erodibility, considering NbS for mitigating these impacts is recommended.

Case study 4.14: Combatting soil erosion in the Republic of Moldova

In the Republic of Moldova, 500 ha of public pastures were rehabilitated in Orhei National Park over three years, along with afforestation on 150 ha of eroded and unproductive land, to reduce soil erosion and capture and store carbon. This resulted in an increase in the average productivity of pastures by 2.5 times, from 2,04 t/ha (2014) to 4,59 t/ha, and an improvement in carbon accumulation by more than 200 per cent. This project involved 18 local communities which developed, with project support, Forest Management Plans covering 1,400 ha of communal forests and Pasture Management Plans covering 5,000 ha of pasture lands. The project also included capacity building—more than 100 representatives of local public authorities and entrepreneurs will train to understand the impacts of climate change on pastures and forests.

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NbS: restoration of public pastures; restoration of forests.

Why: soil erosion mitigation.

Key components: capacity building through training programmes; development of Forest Management Plans and Pasture Management Plans; communal forest management.

Timescale: 3 years.

Stakeholders included: 18 local communities, representatives of local public authorities and entrepreneurs.

Wider benefits: carbon sequestration, improved agricultural productivity.

Source: UNDP (2017).

Case study 4.15: Organic silvo-arable agroforestry on Whitehall Farm, United Kingdom

Soils at Whitehall Farm are particularly susceptible to wind erosion, a challenge that was exacerbated by the destabilized quality of the soil before the introduction of agroforestry principles. The tenants secured a 15-year tenancy, significantly longer than the traditional 3–4-year term, allowing ample time for their agroforestry investments and efforts on the 125-ha plot to succeed.

In 2000, Stephen and Lynn Briggs started planting rows of apple trees 27 m apart, leaving enough space for farm machinery to cultivate cereals in the alleys between them. The apple trees are intended to provide benefits to the farming system, including improved soil quality and greater resilience through crop diversity. Furthermore, the direction of the planted tree rows allows for optimized sun exposure during the day for all crops, extending harvesting possibilities throughout the year.

Silvo-arable agroforestry, the practice of planting trees between crops, has been largely successful on the farm, reducing soil erosion and increasing agrobiodiversity. Agroecology principles have also been embraced to attract wildlife including pollinators and pest predators; these included leaving 15 per cent of the area as habitat. Wildflower strips beneath trees attract pollinators and grassy flower-rich buffers around the fields protect the soil from being washed into watercourses. Ditches dug are left deliberately unkempt to provide habitat for wildlife. Seed mix strips are sown to feed farmland birds.

Diversified crop production and tree cover has reduced soil erosion and helped protect the farm from extreme weather risks. The sales of apples and apple juice and a recently opened farm shop have diversified the farms income stream, an important buffer should the principal cereal crop be affected by adverse weather. The farm is also used as a demonstration and education site, to encourage others to adopt agroforestry methods and teach interested visitors about sustainable agroforestry.

NbS: agroecology, in the form of agroforestry.

Governance: the project is governed by the farm owners with collaboration from the landowners allowing for extended leases to develop the agroforestry farming approach.

Finance: financing for the project was provided by the farmers implementing the agroforestry scheme on the basis of future income generation.

Monitoring & evaluation: a baseline botanical and bird survey was conducted on the property before the implementation of the intervention. Since then, continued monitoring has occurred through the Royal society for the protection of birds with a focus on farmland birds. It is unclear whether the effectiveness of the intervention in reducing soil erosion (e.g., reduced tonnes of soil per hectare) is being monitored.

Limitations: the land-tenure system associated with farming in the United Kingdom disincentivizes the implementation of long-term agricultural projects such as agroforestry. While the farm has secured a 15-year lease, longer term leases would allow for the farmers involved to plan with more stability.

Source: NbSI (no date, e).

Dust storms

Dust storms are common in some parts of the ECE region, particularly arid and semi-arid lands, including within Turkmenistan, Uzbekistan, Kyrgyzstan, Tajikistan, and Kazakhstan (Indoitu, Orlovsky & Orlovsky, 2012). Key trigger factors for the formation and intensity of dust storms are areas with (i) strong winds; (ii) surface materials that are susceptible to wind erosion and transport, such as areas of scarce vegetation or ecosystems that human activities have impacted; and (iii) unstable atmospheric conditions (Ibid). Desert areas are predisposed to dust storms; for example, in Uzbekistan and the Central Asian region more generally, the Kyzyl Kum and Kara Kum deserts are major sources of dust, and the Aral Sea bed is emerging as a significant source of dust. Dust storms can transport fine particles over long distances, including across country borders, posing impacts on air quality, visibility, agriculture, infrastructure and health within the region.

The implementation of NbS can help to mitigate dust storms and their impacts. Vegetation can act as a protective barrier for surfaces and reduce the mobilization of dust particles. Living fences, consisting of rows of trees or shrubs, can be planted around agricultural fields, infrastructure and other lands, to stabilize vulnerable soils and reduce dust emissions at their source, or act as windbreaks to reduce the impact of dust storms (Akramkhanov *et al.*, 2024). These methods are widely adopted in dust-prone countries to protect infrastructure such as roads from the deposition of sand. On agricultural lands, implementing sustainable agricultural practices through agroecology, such as crop rotation, agroforestry or no-till agriculture, can reduce soil erosion that serves as a source of wind-blown particles, while generating additional benefits in the form of improved long-term land productivity and economic benefits to local communities (Ibid). The restoration of lands prone to dust storms is essential to reduce the frequency and severity of impacts. The development of green belts, through the restoration of native trees and shrubs, can form a larger-scale strategy to combat dust storms. Case studies 4.16 and 4.17 provide two examples of NbS projects for dust storm mitigation from Uzbekistan.

Case study 4.16: Modelling the impact of NbS on dust storm mitigation in Uzbekistan

Uzbekistan is prone to increased dust concentrations in the atmosphere and sandstorms, particularly in the arid and semi-arid regions. The country is predominantly covered by large desert landscapes, including the Kyzyl Kum and Karakum deserts, where vegetation is sparse and there are extreme temperature fluctuations and seasonal weather patterns. These circumstances are compounded by desertification and climate-induced extreme weather events. A comprehensive study was undertaken to examine the impact of dust storms and vegetation scenarios in Uzbekistan.

How: high-resolution meteorological data and land cover datasets were used to simulate baseline conditions and assess the impact of vegetation changes on dust dynamics. Key data inputs included the ERA-5 reanalysis datasets for meteorological conditions and the MERRA-2 data for aerosol interactions. High-resolution land cover and soil texture datasets were integrated to refine simulations and enhance model accuracy.

The analysis focused on 2023 as a representative year and used recent atmospheric and vegetation datasets to increase their relevance and precision. While a multi-year approach would have been preferable, only one year was selected owing to the high computational cost and extensive time required for multiple annual simulations. The year 2023 was chosen as it represented a year characterized by increased dust activity and is a recent full year that could enable use of up-to-date atmospheric information along with the latest vegetation cover datasets and high-quality observations.

The study looked at the baseline and three different scenarios to assess different restoration approaches:

- Baseline control scenario: simulations were conducted for a domain covering the regional dust sources (not just the national country context);
- Scenario 1: assessed the contribution of external dust scenario by excluding dust sources within Uzbekistan, to allow analysis of only the impact of long-range transported dust from surrounding regions;
- Scenario 2: analysed the impact of uniform increases in vegetation cover on dust production and transport, assuming all desert and semi-desert regions are planted with vegetation at a given percentage;
- Scenario 3: similar to scenario 2 but assumed resources constraints and therefore assessed the impacts of targeted vegetation changes on select high-impact areas within Uzbekistan.

Findings: baseline simulations revealed significant dust loads across Uzbekistan. Analysis demonstrated that external dust sources contribute significantly to the overall dust burden, with long-range transport accounting for up to 80 per cent of dust concentrations in some areas, demonstrating the importance of regional cooperation to address the challenge.

Simulations showed that a uniform increase in vegetation cover across deserts and semi-deserts reduced dust emissions by up to 40 per cent in specific affected areas. Localized efforts mitigated dust emissions and used fewer resources compared to large-scale interventions. However, the scale of dust reduction was less than when vegetation cover was increased across all relevant areas. Vegetation changes targeting only high-impact areas yielded locally bound reductions in dust concentrations, highlighting the importance of prioritizing NbS locations carefully where resources to invest are limited.

On a monthly basis, the vegetation impact on dust concentration varied—the largest reductions were in January and February, decreasing in summer months.

The findings underscore the important role that NbS can play in mitigating dust storm impacts, improving air quality, and supporting sustainable land management. However, where atmospheric factors are large, such as regional wind patterns and external dust sources, large-scale changes in vegetation cover are likely to be required rather than targeted implementation.

The case study recommends national interventions focus on solutions such as forest-based initiatives, shelterbelt programmes, sustainable agricultural practices, and enhancing early warning systems.

Source: Akramkhanov *et al*. (2024).

Case study 4.17: Afforestation for dust storm mitigation, Uzbekistan

In November 2021, Uzbekistan experienced a severe dust storm. At its peak, the dust concentration in the air in Tashkent was reported as 30 times the level permitted by national authorities. Visibility was reduced to 100–200m and over 4,000 residents called emergency services with respiratory problems.

Much of the dust comes from the exposed dry seabed of the Aral Sea, which started to dry up in the 1960s as water was diverted to feed the region's expanding agricultural sector. In its place, a huge new desert appeared, which was polluted with pollutants from industry and agriculture. Each year, the dry hot winds pick up and transport more than 75 million tons of dust and toxic salts, poisoning the air, damaging fertile soil layers and reducing agricultural productivity.

In an effort to mitigate these impacts, the Government of Uzbekistan has carried out an intensive afforestation campaign in the region since 2018. By 2020, the State Forestry Committee of Uzbekistan had planted 500,000 hectares with saxual, a drought-resistant plant that helps protect the soil and reduce excess evaporation.

In November 2021, Uzbekistan's president launched a new initiative called "Yashil Makon" ("Green Nation"), which aims to plant 1 billion tree and shrub saplings across Uzbekistan over the following 5 years, increasing green areas of the country from 8 per cent to 30 per cent. The project aims to improve air and soil quality and increase climate resilience. It may help to avoid or reverse desertification in some parts of the country and will contribute to the country's national commitments under the Paris Agreement.

The initiative aimed to improve the overall management system in terms of selecting, planting and caring for trees by:

- Conducting extensive research and analysis of the soil-climatic features of the regions;
- Mapping the planting areas based on scientific approaches;
- Increasing the number of nurseries, localization of imported trees adaptable to the country's climate, taking into account soil fertility;
- Creating "green public parks" in the cities, districts and provinces;
- Improving the tree watering system, ensuring its effective functioning;
- Strengthening responsibility for damage and destruction of trees, further increasing public control in this direction;
- Establishing a digital "Register of Trees";
- A special state enterprise "Green Space" was established to ensure the practical implementation of the above tasks.

Important aspects for long-term future success: successful NbS require extensive planning, continuous commitment and long-term investment and management to achieve the desired outcomes.

Extensive planning: it is vital to consider what type of trees to plant, where, and how dense. In water-stressed countries like Uzbekistan, afforestation puts further pressure on water resources, so consideration of water use and water management of the initiative is essential.

Conducting a comprehensive feasibility study as part of planning can be a good starting point to help identify important ecological zones and planting targets, deciding which locations are suitable for trees, shrubs or grass, to resolve any land ownership issues, planning the watering infrastructure, setting up monitoring systems, and determining the best ways of capturing quantified outcomes.

Ensuring that tree planting is done in a way that benefits and involves local communities and provides biodiversity benefits is a critical component.

Efficient coordination system: this is needed to align the efforts of various stakeholders. Given that the phases of the initiative (e.g., support for seedling nurseries, planting, infrastructure development, maintenance, financing, monitoring) are managed by different institutions, there is a critical need to ensure that all actions are well synchronized and coordinated, and local communities can contribute.

Financing model: the Government's Green Nation Fund is the key funder. Investment and financing could be expanded to attract more non-governmental funds, such as international financing, private domestic financing, green bonds or blended finance, to ensure the complex needs of sustainable forest management are met.

Long-term maintenance: without a comprehensive vision for the care and management of trees, their viability and long-term success will be uncertain. To ensure success, nationwide efforts could be coordinated to ensure the seedlings are cared for and helped reach maturity.

Partners: The State Committee for Ecology and Environmental Protection, the Ministry of Finance, the State Forestry Committee, Uzhydromet, the Ministry of Water Resources, the Ministry for Support of Makhalla and Family, municipalities (province, district and city administrations), UNDP in Uzbekistan, UNECE and civil society organizations.

Source: UN (no date); Dimovska (2022).

Box 4.10: Practical aspects to consider for dust storms

- **Understand the contribution of both local and long-range dust transport:** efforts by any country to mitigate dust storms will need to consider the regional context, as dust storms impacting a given area can be caused by locally mobilized dust, or dust that has been transported from sources beyond national borders. Taking a broad-scale view, at national, regional and international levels, may be necessary for effective mitigation and management.
- **Consider the prevailing wind direction and wind speed when planning locations for NbS:** this is crucial as these factors determine where and how air masses and dust are distributed across regions, and where an NbS may be best placed to function as a protective barrier.
- **Regional collaboration:** the effective management of shared dust sources requires coordinated actions among neighbouring countries. Prioritizing cross-border cooperation and the sharing of expertise is essential to address the transboundary nature of dust storms, and ensuring shared resources and strategies are deployed effectively. This should include shared early warning systems for predicting dust storm patterns and impacts, supporting evidence-based decision-making.
- **Seasonal variation in effectiveness:** in case study 4.17, the effectiveness of NbS at mitigating dust storms was greater during cooler months, and lower during spring and summer. This seasonal variation in effectiveness needs to be factored into decisions.
- **Do not plant trees on areas where they are not native, where they come at the expense of other native ecosystems such as grasslands:** while green belts are advocated as a means of helping to address dust storms, these should not be at the expense of native vegetation, as this will likely lead to biodiversity disbenefits and lower resilience.
- **Invest in strengthening monitoring and forecasting capabilities to predict dust storm events:** in addition to NbS, advanced monitoring and dust forecasting systems, which leverage remote sensing and meteorological data to track the movement of dust storms and their intensity, can offer promising tools for improving the accuracy of predictions. Early warning systems, integrated with advanced atmospheric modelling, can help communities to prepare for and respond to dust storm events.

Resources and tools (Akramkhanov *et al.*, 2024):

- A detailed description of interventions that include vegetation cover approaches to prevent dust emissions can be found in **Zucca (2020)**.
- For more detailed guidance, a comprehensive list of over **150 good practices** tailored to various agroecological zones, along with an evaluation of 15 high-impact practices, can be found in **FAO (2023b)** and the **UNCCD SDS (Sand and Dust Storms) Toolbox**: https://www.unccd.int/land-and-life/sand-and-dust-storms/toolbox.
- The **SLM guide** by Harari *et al.* (2023) provides a framework that can help to guide collaboration across country borders.
- **RAMS/ICLAMS atmospheric modelling system** – this was used to analyse dust emissions and transport in case study 4.17. The model incorporates advanced aerosol parameterizations and vegetation schemes to simulate dust emissions, transport and deposition. It accounts for both local and long-range dust sources and captures atmospheric dynamics and the effects of landcover changes, such as the implementation of NbS.

Air pollution

Air pollution is a major problem for cities in the ECE region, originating from various sources, including fossil-fuel-based industry, transport, energy production, dust storms and, increasingly, wildfires. This poses problems for health across the region, with large impacts in terms of both short- and long-term adverse health effects, including mortality, morbidity, hospital admissions and associated healthcare costs. As countries across the region move towards decarbonization of their infrastructure systems and work to meet their targets under the Paris Agreement, there is an opportunity to integrate NbS as part of strategies to improve air quality.

NbS, such as forests, street trees, green walls and roofs, can absorb and filter harmful pollutants and intercept dust, whilst producing oxygen through the process of photosynthesis. In doing so, they can contribute to cleaner air. For example, it is suggested that urban parks can filter up to 85 per cent of local air pollution (Browder *et al.*, 2019). However, without proper planning, NbS may result in trade-offs—the presence of grasses, trees and flowers can increase the prevalence of pollen in the air, which may aggravate allergies such as hay fever and exacerbate respiratory illnesses, including asthma and bronchitis. This can be mitigated through careful design and species selection.

NbS can also help to mitigate the occurrence and severity of wildfires that are a factor in poor air quality. While wildfire is a component of the natural functioning of some ecosystems, improved management practices, such as controlled burning, can lessen the intensity at which fires burn (Chausson *et al.*, 2020). The protection of water-related NbS, such as peatlands, wetlands, rivers and lakes, can help to preserve natural firebreaks and provide refuge areas for local species. By incorporating NbS into wildfire management strategies, countries can help manage the air pollution and associated impacts on health that can arise from fire. Case studies 4.18 and 4.19 provide examples from Kazakhstan and the United States of America, respectively, both of which are undertaking actions to mitigate wildfire, while 4.20 provides examples from the United Kingdom where NbS have been implemented to improve air quality.

Box 4.11: Practical aspects to consider for air pollution

- **Species type:** consideration of species in areas susceptible to wildfire can help to reduce the risk that the NbS will exacerbate wildfire risk. Selection of fire-tolerant and native species rather than non-native or flammable species types is preferable in such locations.
- **Density:** tree density can be a risk factor for fire.
- **Planting:** optimal planting regimes to improve air quality may involve factors including crown architecture, leaf morphology, stomata abundance and opening. Leaf area size can positively correlate with pollutant trapping.
- **Management:** management of NbS such as trees and shrubs can be a key determinant of wildfire. For example, tree thinning can help to mitigate risks.
- **Consider disservices:** while in most cases NbS may provide air quality improvements, in some cases the presence of trees (e.g., within narrow streets) may worsen environmental quality by diminishing pollutant dispersion and increasing concentrations of pollutant particles at pedestrian level. Equally, practitioners should consider ecosystem disservices, for example the emission of Biogenic Volatile Organic Compounds (BVOC) and pollen which may cause asthma (Choi *et al.*, 2021).
- **Scale:** given that in narrow streets NbS such as trees may trap pollutants, practitioners are recommended to consider the scale at which they are working and the most appropriate NbS given the context.
- **Quantification of effectiveness:** metrics monitored may include tons per year and percentage reduction in pollutants against a baseline. For example, for the USA, the estimated value of removal of air pollutants using i-Tree is close to 17 million tons per year.

How?

- Satellite monitoring can be used to evaluate current fire risks and identify potential interventions (see Case study 4.18).
- Modelling approaches have been developed to calculate the possible contribution of new planting programmes in air pollution mitigation. The most widely used is the i-Tree model, developed by the United States Department of Agriculture. The model enables urban green infrastructure design with a particular focus on urban forest and its contribution to filter several air pollutants including O_3, $PM_{2.5}$, NO_X and SO_2. Specific modules are also available for CO_2 and BVOC emissions.

Source: European Commission (2020).

Case study 4.18: Wildfire management in Kazakhstan

UNDP and the Kazakh Government have expanded protected areas in the Altai-Sayan region by 328,000 ha and created a green corridor to link up previously separated protected areas within the region. In parallel, to reduce the region's increasing vulnerability to wildfires, a regional fire management system was established as part of the project and training in wildfire management was provided to local firefighters to reduce the extent of damage sustained when wildfires inevitably occur.

NbS: protection of ecosystems through protected areas.

Who: international organization and government.

Why: expand protected areas, connect disconnected protected areas, and wildfire management.

Key components: this project will likely require legislative changes to assign protected area status; capacity building through training; development of a regional fire management system.

Source: UNEP (2020).

Case study 4.19: Fire risk reduction in the San Carlos Apache Reservation, United States of America

The San Carlos Apache Reservation lies in an area which is prone to fires due to a combination of arid landscapes and dense woodlands. Historic fire management practices from the United States of America government have allowed the buildup of fuel loads within the forest and climate change has led to an increase of fire risk in the area. Many of Arizona's largest fires on record have happened in or near the San Carlos Apache Reservation, including the 2011 Wallow Fire, which was the state's most destructive. However, the San Carlos Apache Reservation faced less damage than the surrounding lands, due to the tribe's fire reduction strategies.

The U.S. Geological Survey (USGS) partnered with the San Carlos Apache Tribe in order to implement improved fire mitigation strategies combining indigenous management and satellite imagery.

Satellite imagery was implemented alongside indigenous fire management techniques to complement the Tribe's implementation of techniques to reduce fire intensity. The satellite images were able to highlight the best places within the reservation for the construction of firebreaks and the ideal locations on rivers to construct water detention installations. These implementations work together with the tribe's forestry interventions, such as tree thinning to return the tree densities to their pre-colonial baselines.

NbS: forest management.

Wider benefits: the reduction of fires in the region helps promote both habitat connectivity and habitat quality for species in the Reservation. The thinning of trees also supports the local Apache timber business. The thinned trees can be turned into slabs and sold to make furniture, supporting local livelihoods.

Governance: this project is governed by the San Carlos Apache Tribe who works with the USGS for additional capacity.

Finance: the project is financed by the USGS and the San Carlos Apache Tribe.

Monitoring and Evaluation: the USGS provides satellite monitoring of the site in order to evaluate current fire risks and highlight opportunities for interventions. The Apache foresters also monitor the forest to evaluate the density of trees within stands.

Source: NbSI (no date, f).

Case study 4.20: NbS for improved air quality, Scotland, United Kingdom

Green active travel routes: throughout Scotland the National Cycle Network (NCN) consists of a network of pathways over 12,000 miles long (4,000 of which is traffic-free), which have been reconstructed from old railways and canals. These pathways provide a great opportunity to employ NbS to improve air quality for users whilst promoting active travel. For example, a green active travel corridor established along the NCN7 allows pedestrians to travel from Paisley to Lochwinnoch and through to Glasgow with much lower exposure to air pollutants. It also supports the creation of biodiversity corridors and improved health benefits associated with green spaces.

Green screens: the impact of green screens on localized air quality was measured at St Andrews Church of England Primary School. The school implemented a green screen around the schoolgrounds, providing an attractive barrier which tackles poor air quality and reduces students' exposure to air pollution. The green screen, covered in climbers, was installed over a pre-existing 2-metre-high, 61-metre-long fence which surrounds the schoolgrounds. Air pollution levels were monitored before and after installation and it was found that the presence of the green screen decreased particulate matter concentrations up to 44 per cent in the school playground when wind was blowing from the road towards the school grounds.

Source: NatureScot (no date).

4.3 Broader adaptation benefits

Increased adaptability of NbS

Healthy, adaptively managed NbS can protect built infrastructure assets and people from climate impacts and also be more adaptable, flexible and resilient to climate change compared to conventional solutions (Seddon *et al.*, 2020). For example, coastal ecosystems, such as mangroves and dunes, can grow naturally through the accumulation of sediments, increasing their resilience to sea level rise, unlike conventional solutions such as seawalls (Menendez *et al.*, 2020; Tiggeloven *et al.*, 2022).

Resilient societies

Through the benefits that ecosystems can provide, such as reduced heat exposure, improved air quality and better mental health, NbS can help to empower communities and increase their mental and physical resilience to climate change. They can support the creation of decent jobs in local communities, ranging from low to highly skilled, supporting livelihoods within the region (ILO and IUCN, 2024). Through the integration of food trees, allotments and urban food growing in gardens and on green roofs, NbS can both support food security and livelihood diversification that can enhance societal resilience (IPCC, 2019; Blicharska *et al.*, 2016).

Resilient economies

NbS can contribute to the resilience of economies of ECE countries by protecting existing infrastructure from climate impacts, thereby reducing the extent of economic damage and economic losses that occur through damaged and disrupted infrastructure systems. In doing so, NbS can help preserve funding earmarked for new infrastructure development and upgrades, reducing the need to divert funds to repair existing infrastructure systems (UNEP, 2023). By substituting and complementing conventional infrastructure, there is potential for NbS to help reduce capital and operation requirements for infrastructure service provision, whilst supporting a multitude of wider benefits that would otherwise require separate funding, such as to create spaces for recreation and protect biodiversity. NbS may also appreciate in value over time, as the solution develops and provides services, unlike conventional built infrastructure. More research is needed to document the costs of NbS compared to conventional infrastructure systems in different contexts, to fully understand whether NbS are more economically viable than built infrastructure approaches.

As mentioned in previous sections, NbS can also improve soil health and food security of the ECE region and increase the productivity of agricultural lands. This can have significant economic implications for countries that depend heavily on agriculture. For example, in Uzbekistan, agriculture accounted for 25 per cent of GDP in 2020, the highest in the Central Asian region, and employs 20 per cent of people (IFAD, no date).

Resilient infrastructure systems

Section 4.2 has provided an overview of how NbS can be implemented to protect infrastructure from a range of climate hazards and increase the resilience of different sectors. However, infrastructure sectors are inherently interlinked and connected, functioning as an infrastructure system. Therefore, actions undertaken in one sector can have implications across other sectors (UNEP, 2023). For example, while the implementation of NbS such as green roofs, green walls and street trees in and around buildings can improve their insulation and reduce wear and tear on building facades, the benefits that they can have in terms of energy efficiency can have cascading benefits across other sectors. By reducing energy use in buildings, such as for heating or cooling, this can in turn reduce pressure on national electricity supplies, and help to safeguard electricity for use in other sectors, such as water and healthcare. Similarly, where NbS can support water re-use, such as in the case of green roofs or constructed wetlands, this can reduce pressure on national water supplies and safeguard water for other sectors. Equally, the protection and restoration of NbS such as forests can reduce the risk of hazards such as floods or landslides onto transport infrastructure, which can safeguard access routes to infrastructure in other sectors, such as to schools or hospitals.

These benefits can be magnified across borders where NbS are carefully planned and managed. For example, where watercourses flow through multiple countries, actions in upstream basins can impact water availability for sectors such as potable water, hydropower or water transport downstream. Collaboration between national governments and other relevant stakeholders within and across these countries is necessary to support the resilience of infrastructure systems at both national and regional scales. This is particularly important to ensure that actions taken in one country do not have adverse effects on others within the region.

Resilient health systems

When considered in their entirety, health systems in industrialized countries are responsible for 4–6 per cent of national GHG emissions, due to the complex range of activities they undertake, especially in the health care domain, involving use and disposal of material resources, transport, procurement, energy and water consumption (Pichler *et al.*, 2019). Health systems worldwide are also becoming more burdened by the demand to respond to increasing climate-related health impacts, especially during extreme weather events. Thus, evolving health systems have been facing the necessity to (i) become more resilient to cope with climate-induced pressures; and (ii) limit their large environmental footprint, which is bigger, for example, than the aviation sector. Priorities have been outlined by recent work coordinated by the WHO, through the Alliance for Transformative Action on Climate and Health (ATACH) (WHO, no date). NbS have a role to play towards this transition, for example by: promoting exposure to nature as a form of primary prevention and/or therapy for a number of conditions, including in mental health; improving supply chain sustainability, sourcing food, water and materials from NbS (e.g. agroforestry systems), reducing carbon footprints and supply chain risks; reducing hospitals' energy use with investment in green spaces and other green infrastructure to help cooling facilities.

Resilient workforces

Workforces are fundamental to the provision of infrastructure services, as they are integral to the operation and maintenance of infrastructure systems. Climate change poses huge risks to workforces across the world, through direct climate impacts and the health problems that occur as a result of warming temperatures. This, combined with rising cases of mental health problems, can impact employees across infrastructure sectors, posing risks to service provision. By improving the local environment, for example, through reduced heat, improved air quality and opportunities for exercise, NbS such as green roofs, gardens and green spaces can support physical health outcomes. Through opportunities for socializing, movement and aesthetic relief in the built environment, NbS can also generate wide-ranging mental health benefits, including reduced stress, relaxation and improved attention spans (UNEP, 2023). By integrating NbS into the development of infrastructure systems, such as offices, ports and retail centres, infrastructure practitioners can help to increase the resilience of workforces, reduce staff sickness and absences, and improve their ability to do their jobs (Yu *et al.*, 2020; Han and Hyun 2018).

Resilient ecosystems and biodiversity

The ability of NbS to provide services and benefits for societies, economies and the environment is underpinned by the health of ecosystems (Key *et al.*, 2022). Poorly managed ecosystems and those with low biodiversity will be more vulnerable to climate impacts, pests and disease, which can impact their persistence long-term (Haggis *et al.*, forthcoming). Through careful planning and stewarding, infrastructure practitioners can improve the health and resilience of ecosystems and NbS. For example, by using a diverse mix of native, locally adapted species and improved management actions such as weeding and invasive species removal, practitioners can help increase genetic diversity and improve the resilience of ecosystems to climate change, while supporting local wildlife. Strategic planning of NbS from local to national and supra-national scales can safeguard species diversity by supporting pollination and the safe movement of wildlife across the landscape, supporting resilience outcomes (UNEP, 2023).

Ensuring local benefits to people is also critical for the resilience of NbS. This can feed back into local acceptance, buy-in and support for NbS, improved stewardship of green and hybrid infrastructure, and increased chance of sustaining benefits long-term. To be most effective, NbS should be community-led and draw on traditional and local knowledge, be inclusive of the views of local people, and benefits should be equitably distributed (Cohen-Shacham *et al.*, 2016; EU4Environment-Water and Data Consortium, 2024).

4.4 Biodiversity conservation

Through deployment of NbS as part of sustainable infrastructure systems, ECE countries can help to reduce the impact of infrastructure on nature, and support projects which contribute to biodiversity conservation. The region is home to iconic species such as bears, lynx, wolves and American and European bison, as well as a wide variety of plant species. Practitioners can support the conservation of these species by preserving ecological corridors, such as networks of green spaces along linear infrastructure such as roads, railways and waterways, and supporting their movement across landscape through the creation of overpasses and underpasses to cross built infrastructure. Through investment in NbS, practitioners can also protect and increase habitat extents within the countries, which is a factor in the ability of ecosystems to support a diverse range of species.

Countries have an opportunity to design and invest in green spaces strategically to reduce ecological fragmentation and increase ecosystem connectivity across the region. For example, green walls, green roofs and green spaces such as bioswales, rain gardens, cemeteries and allotments, can provide a refuge for birds, insects and wildlife in cities and urban areas, where available land is limited and expensive (European Commission, 2024). Through careful planning, these smaller areas of green space can be connected to larger areas such as urban parks, and surrounding forests and grasslands, facilitating the movement of wildlife and pollinators, and helping to maintain and preserve genetic diversity. Replacement of built fences and walls with hedgerows, living fences and agroforestry systems can equally improve the movement and diversity of species, while improving aesthetic appeal and regulation of water, air and temperature (UNEP, 2023).

A transition to sustainable infrastructure approaches can help to reduce the negative impacts that built infrastructure and human activities can have on natural ecosystems and biodiversity. The adoption of NbS approaches where possible, through the substitution of built assets with nature-based options, and through the addition of nature to complement and protect built infrastructure, can play an integral role in supporting countries to transition to approaches which support positive outcomes for biodiversity.

5. Human health co-benefits of NbS

Key messages

- NbS contribute to improved physical and mental health by reducing exposure to environmental hazards and enhancing access to green spaces.
- NbS help mitigate urban heat islands, improve air and water quality, and reduce noise pollution—factors closely linked to cardiovascular and respiratory health.
- Access to nature is associated with lower stress levels, increased physical activity and improved mental well-being.
- NbS can help reduce health inequalities, especially in underserved urban areas, by providing equitable access to healthy environments.
- There is growing evidence that integrating health considerations into NbS planning enhances their effectiveness and public support.

Practical tips

- Design NbS to promote physical activity—e.g., walking trails, green corridors and recreational parks.
- Include diverse vegetation to improve air filtration and reduce allergen exposure.
- Target NbS in areas with high health burdens, such as neighbourhoods with poor air quality or limited access to green space.
- Engage health authorities and encourage collaboration between health ministries and local health services to align NbS with health promotion strategies.
- Monitor health outcomes of NbS interventions to build evidence and guide future investments.

This chapter reviews current evidence on the human health benefits of NbS and presents actionable guidance for public health professionals and policymakers. Drawing on recent research, international frameworks and examples across the region, it explores how NbS contribute to improved air quality, mental and physical well-being, climate resilience, sustainable food systems and health equity. The findings highlight that NbS reduce disease burden, enhance quality of life and offer cost-effective solutions to multiple environmental health threats.

To ensure that all populations benefit, the report emphasizes inclusive planning, targeted investments in vulnerable communities, and integration of NbS into cross-sectoral strategies. Key recommendations include aligning health and climate goals with NbS deployment, expanding urban green and blue spaces, supporting biodiversity-friendly agriculture, and establishing governance mechanisms for equitable implementation.

NbS are not an optional enhancement to traditional infrastructure, rather they are essential to building resilient, healthy and inclusive societies. With adequate support, monitoring and integration into policy, NbS can be transformational for public health in the ECE region and beyond.

5.1 Context

Public health in the 21st century faces unprecedented challenges, involving a complex mix of global and local risk factors. Climate change, biodiversity loss and environmental pollution contribute to rising rates of non-communicable diseases, mental health disorders and health inequalities. This is exacerbated by socio-demographic factors, notably urbanization and ageing populations. Together, these pose a substantial threat to public health, potentially capable of undoing the important progress made in the last several decades, especially when it comes to the most vulnerable groups. In response, policy actors across Europe and Central Asia are seeking integrated approaches that promote human health while addressing ecological degradation and climate threats.

NbS have emerged as a compelling response to this need. By harnessing natural processes and ecosystems, NbS address environmental and health risks at their source, thus implementing primary prevention strategies, or even so-called primordial prevention—by far the most effective public health strategy. As discussed throughout the report, examples of NbS include urban greening to reduce air pollution, wetland restoration to prevent flooding and agroecology to improve food security. These interventions offer co-benefits for physical and mental health, climate adaptation and social well-being. NbS also tend to subsume on a broad and comprehensive model of health, in line with the WHO definition: "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity."

The evidence base for NbS has expanded rapidly, yet implementation remains fragmented and awareness of the concept in health circles is not yet pervasive. Health considerations are often absent from environmental planning, while urban health strategies may overlook nature's role in disease prevention and psychosocial well-being. It seems important, therefore, to bridge these gaps by consolidating interdisciplinary knowledge and identifying policy pathways for embedding NbS in public health agendas. More intense collaboration is desirable between health, environment and planning sectors, building on systemic thinking and guiding action that benefits people and nature alike.

5.2 Nature and health: benefits and co-benefits

Human health and nature are fundamentally interconnected. Ecosystems provide the foundations of human life, including clean air and water, nutrient cycling, temperature regulation and disease buffering. Natural environments are also an essential setting for a healthy state of mind and balance. As such, nature can therefore be regarded as a critical part of the "health infrastructure". NbS enhance natural services, contribute directly to physical health, favour psycho-social well-being and strengthen the natural capital of the population.

Evidence has been growing in recent years that corroborates the intuitive notion that nature is beneficial for health. Exposure to natural environments is associated with improved mental health, reduced stress, lower incidence of cardiovascular disease, improved respiratory function and increased life satisfaction (Bosch & Sang, 2017; Banwell *et al.*, 2024). Mechanisms by which green spaces support health include:

- Biophysical processes: reduced pollution, lower ambient temperatures, improved air quality
- Behavioural pathways: increased physical activity, social interaction and nature-connectedness
- Psychophysiological effects: stress reduction, improved mood, cognitive restoration.

Blue spaces—rivers, lakes, wetlands and coasts—also offer therapeutic benefits. Regular contact with water environments is linked to enhanced psychological well-being, especially when combined with green elements such as riverside parks or wetland restoration projects.

Biodiversity, often overlooked in health planning, plays a crucial role. Diverse microbiomes in natural settings support immune system development whilst biologically rich ecosystems are more resilient to zoonotic disease emergence (IPBES, 2019; Brondízio *et al.*, 2019). Additionally, healthy natural ecosystems contribute to food security, mental resilience, and cultural identity.

A 2021 WHO review found that access to green space is associated with a 12 per cent lower risk of all-cause mortality (WHO Regional Office for Europe, 2021). A review by the European Environment Agency (2022) corroborated these findings, reporting consistently lower prevalence of obesity and hypertension in populations living in greener urban environments. Mental health benefits are among the most robust findings, with reductions in depression, anxiety and perceived stress observed across all age groups.

The potential of NbS to contribute to health equity is especially important. Vulnerable populations—such as low-income communities, migrants, the elderly and children—often experience disproportionate environmental burdens and reduced access to health-promoting natural spaces. Well-designed NbS can reduce this disparity by improving living conditions and providing accessible opportunities for rest, exercise and social engagement.

In sum, the co-benefits of nature for human health are multifaceted and mutually reinforcing. Realizing their potential requires not only ecological restoration but also a recognition of the complex patterns of environmental and social health determinants, operating at various levels, from individual to family, from community through to the global scale. Such an approach can ultimately embed nature as a core element of public health strategy.

5.3 Green and blue spaces in cities

Urbanization has dramatically reshaped landscapes across the world, often leading to diminished access to natural environments, fragmented ecosystems and reduced biodiversity. As more people live in cities, urban green and blue spaces, such as parks, forests, riverbanks, wetlands and coastal zones are essential components of healthy urban environments.

Green and blue infrastructure in cities supports human health in several ways. First, it provides places for physical activity, rest and recreation. Access to parks and greenways facilitates walking, cycling and outdoor play, contributing to cardiovascular fitness, lower obesity rates and improved musculoskeletal health. Second, these spaces encourage social interaction, reducing isolation and fostering community cohesion—key factors in mental well-being and resilience.

Blue spaces—rivers, lakes, fountains and canals—offer additional psychological and aesthetic benefits. Research has shown that living near or regularly visiting blue spaces is associated with reduced stress and enhanced life satisfaction. Combining both green and blue elements (e.g., riverside parks or restored wetlands) amplifies these benefits (Banwell *et al.*, 2024).

Beyond their recreational value, green and blue spaces deliver critical ecosystem services. Trees reduce air pollution by capturing particulate matter and absorbing nitrogen dioxide. Green roofs and vertical gardens insulate buildings and manage rainwater. Naturalized riverbanks enhance flood resilience and protect drinking water sources. These environmental improvements contribute to long-term health protection, especially in the face of climate change. Case study 5.1 provides an example of how a former uranium plant has been transformed into a community nature reserve, providing multiple benefits to communities in the area including reduced pollution and improved recreational opportunities.

Design quality and accessibility are essential: green and blue spaces must be safe, accessible and inclusive. Barriers such as distance, poor maintenance, lack of facilities, or perceptions of insecurity can limit use—particularly among older adults, women and people with disabilities. Effective planning must integrate universal design principles, diverse vegetation, shaded seating, water features and culturally appropriate spaces.

To maximize public health benefits, urban NbS should be treated as essential infrastructure, on par with transport, housing and sanitation. Integrated urban planning that aligns transport, green infrastructure and health priorities can transform cities into health-promoting environments. The WHO's Urban Health Initiative and the European Commission's Green City Accord offer guiding principles. Initiatives like the "15-minute city", supported by the European Green Deal, and nature-inclusive design demonstrate how cities can embed health-promoting NbS into daily life.

Expanding green and blue spaces is not just about beautification—it is about public health equity, climate adaptation and long-term resilience.

Case study 5.1: Conversion of World War II factory into wetland preserve, United States of America

The Fernald Preserve represents a former World War II uranium plant reimagined and revitalized as a community nature reserve which supports native biodiversity.

The 1,050-acre former industrial site has been cleaned of its pollution and transformed into a mosaic of created habitats through reintroducing native plant and grass species. Included in this are 385 acres of grassland (including tallgrass prairies and savannas), upland forests, lakes, riparian corridors, and one of the most extensive human-caused wetlands in Ohio. The intervention also included creating 7 miles of hiking trails to increase access to the natural site for the local community. Continued management of the site occurs with a significant focus on improving ground and surface water quality. Interventions also take place to limit erosion and the presence of invasive species.

The site previously produced high-purity uranium metal products for the American military during World War II. After it was decommissioned in 1989, efforts shifted to clean up and restore the environment surrounding the site. It took until 2006 for the project to have successfully cleaned and restored the landscape. At the time it was one of the largest environmental cleanup operations undertaken in the history of the United States of America.

It has been heralded as one of the most successful "reuse" projects undertaken in the US. Transformed from a source of emissions, it is likely a net sink of carbon as a nature reserve. The created habitats are important for many local species; more than 250 bird species have been recorded at the site, with more than 100 species of birds found to have nested within the Fernald Preserve.

The cleaning and regeneration have helped reduce the risk of uranium pollution affecting nearby communities and instead provided them with additional access to outdoor greenspace.

NbS: various, including restoration of grassland, forests, lakes, riparian corridors.

Governance: The US Department of Energy's Office of Legacy Management governs the project. The office is in charge of restoring and managing decommissioned sites previously utilized by the agency.

Finance: The project is financed by the US Department of Energy and took $4.4 billion dollars for the initial remediation and restoration.

Monitoring: the site is continually monitored by the Office of Legacy Management which checks that both the restoration and pollution clean-up remedies remain effective.

Limitations: the project has not yet been able to remove all pollution impacts from the groundwater in the aquifer below the site. Uranium remains the primary pollutant, but further clean-up efforts are underway.

Source: NbSI (no date, g).

5.4 Improved air quality and other urban co-benefits

Air pollution is one of the most significant environmental health threats in the WHO European Region, causing an estimated 300,000 premature deaths annually (WHO Regional Office for Europe, 2021). Fine particulate matter ($PM_{2.5}$), nitrogen dioxide (NO_2), and ozone (O_3) are particularly harmful, leading to premature mortality, cardiovascular disease, stroke, respiratory illness and cancer. Vulnerable groups—such as children, older adults and individuals with chronic conditions—are disproportionately affected.

NbS can play a vital role in reducing urban air pollution, mitigating concentrations by enhancing vegetative cover. Trees, shrubs and green walls can trap particulate matter on leaf surfaces and absorb gaseous pollutants through stomatal openings. Well-designed green infrastructure—such as roadside tree buffers, urban forests and vegetated barriers—reduces pollutant concentrations at the street level. This is especially important near schools, healthcare facilities and residential areas adjacent to high-traffic corridors.

Quantitative assessments show substantial benefits. For instance, increasing tree canopy by 30 per cent in urban areas can reduce $PM_{2.5}$ concentrations by up to 20 per cent (Nowak *et al.*, 2014). In Milan and London, green walls have been found to cut nitrogen dioxide levels by 15–25 per cent in high-exposure zones (Pugh *et al.*, 2012, as cited in Laurel & Raymund, 2025). These reductions translate to fewer asthma attacks, reduced hospital admissions, lower healthcare costs and improved quality of life. Economic gains are also achieved through reduced absenteeism from work and decreased pressure on the health systems.

Beyond air purification, NbS provide additional urban co-benefits that enhance physical and mental health. Vegetation buffers reduce noise pollution, which is linked to sleep disturbances, hypertension and cognitive decline. Cooler microclimates lower heat stress, while attractive landscapes support active mobility—encouraging walking and cycling rather than car use. This shift not only improves cardiovascular health but also reduces emissions, reinforcing the air quality cycle.

NbS also contribute to road safety. Street trees calm traffic by creating visual friction, reducing driving speed and pedestrian injury risk. Moreover, green infrastructure increases real estate value, economic activity and social cohesion—factors that indirectly support community well-being.

To maximize these co-benefits, NbS must be part of integrated urban strategies. Alignment with emission reduction policies, sustainable transport plans and land-use regulations ensures that greening interventions support wider public health and climate goals. The Zero Pollution Action Plan and Urban Greening Plans promoted by the European Commission offer practical models for scaling NbS in cities across the region.

At the national level, Amazon announced a 20 million grant for NbS in Europe, as part of its Right Now Climate Fund. One of its first projects—the initiative Parco Italia—aims to plant 22 million trees (one tree per city resident) across 14 metropolitan areas in Italy. These trees will be planted "in synergy with the urban forestry activities already active" in these areas. These projects are connected to the EU funding for recovery after COVID (Nature4Climate, no date, c). More information may be found at Amazon (2021).

5.5 Reduction in heat-related illnesses and extreme events

Climate change is intensifying extreme weather events globally; Europe and Central Asia are no exception, and they include highly vulnerable areas and ecosystems, such as coastal areas, glaciers and mountain ranges, and dry land. In terms of human health impact, heatwaves have emerged as one of the most lethal extreme weather events, and their frequency and severity are projected to increase. The summer of 2003 resulted in more than 70,000 excess deaths in Europe (Robine *et al.*, 2008); it was the first year when excess mortality was reliably measured and reported, but this impact had likely been occurring long earlier. Heat-related illnesses—including heat exhaustion, heat stroke and cardiovascular complications—disproportionately affect older adults, children, people with disabilities and those with pre-existing conditions. Urban areas are particularly vulnerable due to the urban heat island (UHI) effect, where built surfaces absorb, retain and radiate heat.

NbS offer effective, cost-efficient, scalable strategies for reducing heat-related health risks. Urban vegetation cools the environment through evapotranspiration and shading. Studies in Madrid, Paris and Vienna have shown that greening interventions in heat-prone neighbourhoods can reduce local temperatures by 2–4°C and decrease excess mortality during heat events (Iungman *et al.*, 2023); green roofs reduce rooftop temperatures by up to 30°C (E3S Web of Conferences, 2024) and green corridors channel cool air through dense cityscapes. These effects reduce the physiological burden of heat on the human body, especially during heatwaves. In addition, NbS help reduce energy demand for air conditioning, thereby cutting greenhouse gas emissions and urban pollution—creating a positive feedback loop for climate mitigation and public health. WHO recommends the inclusion of green spaces in urban heat health action plans (WHO Regional Office for Europe, 2008).

Beyond heat, NbS can also mitigate other climate-related hazards such as flooding, drought and landslides. Restored wetlands and permeable surfaces absorb stormwater, reducing runoff and the severity of flood peaks. Urban forests enhance soil stability and reduce erosion. These interventions support health by preventing injuries, infrastructure damage, displacement and post-disaster disease outbreaks.

Effective implementation requires climate-informed spatial planning, cross-sectoral coordination and citizen engagement. For example, integrating climate vulnerability assessments into urban planning can identify priority zones for greening. Green infrastructure should be treated as essential health-protective infrastructure—not as an aesthetic luxury.

Integrating NbS into climate adaptation planning requires spatial mapping of vulnerabilities, cross-sectoral governance and long-term investment. The IUCN Global Standard and EU Adaptation Strategy provide useful frameworks for mainstreaming NbS into disaster risk reduction (DRR) and health resilience planning (IUCN, 2020).

As Sudmeier-Rieux *et al.* (2025) note, the evidence base for NbS in DRR is rapidly expanding, but implementation depends on institutional coordination, local knowledge and inclusive design.

NbS provide a resilient, scalable approach to protect human health from the escalating impacts of climate change. Their integration into climate adaptation and disaster risk reduction strategies is not only prudent but necessary.

5.6 Healthier, more sustainable and resilient food systems

NbS are also relevant to food systems, offering transformative potential for both planetary and human health. Agricultural NbS, such as agroecology, regenerative farming, permaculture and landscape restoration, promote biodiversity, improve soil health and reduce the environmental footprint of food production. At the same time, they support access to and adoption of healthier, more resilient and sustainable diets.

Industrial food systems contribute significantly to environmental degradation and public health burdens. They are major drivers of greenhouse gas emissions, antimicrobial resistance (AMR), deforestation, water pollution and soil depletion, particularly through meat and dairy production. Meanwhile, highly processed, calorie-rich diets linked to these systems contribute to rising rates of obesity, diabetes, cardiovascular disease and micronutrient deficiencies across the region.

NbS offer a pathway toward resilient food systems. By enhancing soil fertility through composting, crop rotation and cover cropping, agroecological practices reduce the need for synthetic inputs and increase yields in the long term, producing health co-benefits. Diversification of crop and animal production by incorporating tree crops, fruits and other plants alongside staple crops can diversify food sources, income streams and help to build the resilience of food production (FAO, 2023a). Equally, floating gardens and the fertile soils of floodplains can support cultivation in some water-prone areas. NbS such as agroforestry, which integrates trees and biodiversity into agricultural landscapes, can contribute to carbon sequestration and habitat connectivity, and reduce GHG emissions embedded within the food system by reducing the distance over which food must travel (World Bank, 2021). These practices support food security while restoring ecosystem services.

Local food production, such as urban agriculture and community-supported farms, can enhance dietary diversity, reduce reliance on long food supply chains, support sustainable local food markets, help to stabilize food prices and affordability for consumers, and strengthen food security for local communities across the ECE region during periods of economic stress, climate shocks or supply chain disruptions (FAO, 2023a; ECE, 2024). It also improves food literacy and community engagement. In urban areas, rooftop gardens on office and residential buildings, edible landscapes and greenhouses can provide fresh produce, reduce food deserts and reconnect residents with seasonal eating, while benefiting biodiversity. By promoting familiarity with food production and awareness of the detrimental impacts of ultra-processed food, these practices are also likely to result in increased consumption of plant-based diets at the expense of meat, thus entailing both environmental and health benefits.

At the same time, NbS can provide co-benefits which amplify health outcomes. For example, community gardens and allotments can support social interaction, strengthen community bonds, provide opportunities for exercise and skill building and regulate the local microclimate. Urban food growing can support cultural heritage through the cultivation of indigenous species and reconnect people to food growing (ECE, 2024). Food trees in urban areas can enhance the visual appeal of urban spaces, create more attractive and liveable neighbourhoods, which can in turn attract businesses, visitors and support local investment. Together, this can lead to improved mental health and physical health outcomes for people (European Commission, 2024).

Importantly, NbS also support antimicrobial stewardship. AMR has been recognized as a serious challenge to global health, with almost 5 million of deaths estimated for 2019 and increasing figures (Antimicrobial Resistance Collaborators, 2022; Laximinarayan *et al.*, 2022). Reducing dependence on antibiotics in livestock farming and promoting plant-based, minimally processed diets can help mitigate AMR. The EAT-Lancet Commission recommends dietary shifts toward more whole grains, legumes, vegetables and fruits—goals that align with the outputs of biodiversity-friendly agricultural systems (Willett *et al.*, 2019).

Policy instruments to promote healthier, sustainable diets through NbS include school meal programmes based on organic local produce, subsidies for agroecological farming, and environmental criteria in public procurement. Health authorities can play a proactive role by promoting food environments that align with sustainability and nutrition goals. For example, in Leipzig, Germany, between 2007 and 2011, around 10 per cent of allotment gardens provided fresh horticultural produce to local foodbanks, supported through a social project funded by the city.

The implementation of non-food-based NbS throughout the ECE region can contribute to improved food systems and food-related health. One of the most critical ecological services for agriculture is pollination. NbS that protect and restore habitats, such as grasslands, hedgerows and forest edges, help to maintain pollinator diversity, which is essential for food production. It is estimated that 35 per cent of global food crops depend on pollinators (UNEP, 2023), highlighting the need to preserve and improve pollinator-friendly ecosystems within agricultural landscapes.

Ultimately, transforming food systems through NbS represents an invaluable approach to address the interconnected challenges of malnutrition, environmental degradation and inequity. These solutions offer co-benefits that support the long-term resilience of both ecosystems and human populations. Health authorities have a proactive role to play in aligning food, environment and health agendas. As Visca *et al.* (2024) argue, NbS must be part of a broader shift toward resilient, regenerative food systems.

5.7 Enhanced mental health and well-being

Mental and physical well-being are foundational components of public health. Besides the numerous benefits mentioned above on physical health, NbS offer powerful tools to enhance the psychosocial health dimension by supporting stress reduction, mood regulation, physical activity and restorative experiences.

Research consistently shows that exposure to natural environments reduces psychological distress and improves subjective well-being. Mechanisms include attention restoration, physiological relaxation and neuroendocrine modulation. These observations are consistent with the finding that time spent in green spaces is linked to lower levels of cortisol, reduced symptoms of depression and anxiety, and enhanced cognitive function.

Even short-term contact with nature—such as walking through a park, viewing green landscapes from a window, or interacting with indoor plants—has measurable benefits. A 2022 systematic review across 21 countries found that spending at least 120 minutes per week in nature was associated with significantly higher levels of well-being, regardless of age, income, or health status (White *et al.*, 2019).

NbS also promote physical health by creating environments that facilitate movement. Parks, trails, greenways and community gardens encourage walking, running, cycling and other forms of non-motorized activity. This supports cardiovascular fitness, musculoskeletal health and metabolic regulation. Among older adults, regular contact with nature has been associated with improved mobility and lower risk of frailty.

The workplace and education settings benefit as well. Green infrastructure in and around schools improves attention and academic performance in children. In healthcare facilities, access to natural light and views of greenery has been linked to faster patient recovery, reduced need for pain medication and greater satisfaction.

Crucially, NbS support social cohesion. Shared green spaces serve as venues for community events, intergenerational interaction and cultural expression. These social dimensions buffer loneliness and contribute to a sense of belonging which are factors that are increasingly recognized as protective for mental health.

These benefits are most impactful when NbS are designed inclusively by addressing access for people with disabilities, children and the elderly. Public health professionals should advocate for access to restorative nature as a right, integrated into housing, education, workplace and care policies.

For example, doctors in four Canadian provinces—British Columbia, Saskatchewan, Manitoba and Ontario—are prescribing time spent in nature. This includes providing patients with a pass giving a year's access to the country's national parks, marine conservation areas and historic sites. In the United States of America, the Park Rx America platform allows doctors to issue nature prescriptions to thousands of parks across the country (World Economic Forum, 2022). More information can be found at PaRX (no date).

5.8 Equity in access to nature

While the health benefits of NbS are well-documented, their distribution across populations is often unequal. In many cities and regions, socioeconomically disadvantaged groups, ethnic minorities, older adults, people with disabilities and children face structural barriers to accessing green and blue spaces. This inequity can reinforce existing health disparities and limit the population-wide beneficial impact of NbS in terms of health and well-being. Without explicit equity considerations, green investments can even lead to green gentrification, where environmental improvements raise property values and displace vulnerable populations.

Factors influencing unequal access include geographic segregation, income-related housing disparities, underinvestment in marginalized neighbourhoods and lack of inclusive design. Studies show that low-income communities frequently have fewer parks, poorer-quality green infrastructure and greater exposure to environmental hazards such as air pollution and noise. These same communities often bear a disproportionate burden of chronic disease and mental health issues.

Promoting equity in NbS requires intentional policy, planning, and resource allocation. Key actions include:

- Prioritizing greening initiatives in underserved areas through targeted investment.
- Ensuring universal design standards that accommodate people of all ages and abilities.
- Engaging communities in co-creation processes to ensure relevance, trust and ownership.
- Incorporating safety, accessibility and cultural relevance into green space planning.
- Monitoring distributional impacts through disaggregated data and equity indicators.

Frameworks such as the Urban Agenda for the EU and WHO's Health Equity in All Policies advocate for these principles. Case examples from cities like Copenhagen, Ljubljana and Barcelona demonstrate how NbS can be deployed to support environmental justice, social inclusion and community resilience.

Furthermore, implementation of the "3-30-300 rule" (ECE, 2021) can support ECE countries in transitioning to greener, healthier cities which are more resilient to climate impacts. Proposed by the Nature Based Solutions Institute, it is a tree-focused guideline which recommends:

- **3** – Everyone should be able to see at least 3 mature trees from their home and place of work or study
- **30** – There should be a 30 per cent tree canopy cover in each neighbourhood
- **300** – The maximum distance to the nearest high-quality public green space should be 300 metres.

The 3-30-300 targets have been developed based on evidence that links distance from home and workplaces and tree canopy cover density to the many benefits of green space. However, as with any NbS, the most appropriate targets for a given city within the ECE region should be set based on consideration of the local context, particularly given the large diversity of cities within the ECE region. In many cases, other NbS, such as integrating networks of bioswales, planter boxes, street trees, urban parks, allotments, cemeteries, green roofs and walls can provide similar or greater benefits, particularly given that a diversity of accessible NbS can support a range of recreational and relaxation activities, such as jogging, yoga, the provision of mental relief in the built environment.

Moreover, equitable access must be protected over time. Urban regeneration and green gentrification can lead to displacement if affordability and tenure security are not addressed. Cross-sectoral governance involving housing, health, planning and civil society is essential to create nature-inclusive cities that benefit everyone, not just the privileged.

Nature is a public good. Ensuring fair access to its benefits is a matter of human rights, public health and democratic governance.

Figure 5.1: The 3-30-300 rule for greener, healthier and more resilient cities

Source: ECE (2021).

5.9 NbS for hospitals and other healthcare infrastructure

While NbS can result in many co-benefits that can improve health outcomes, as discussed above, NbS can also be strategically integrated into built health infrastructure. Healthcare is considered an infrastructure sector, encompassing hospitals, medical clinics, nursing care facilities, residential care centres and dental practices. The integration of NbS into healthcare systems across ECE countries can yield significant benefits, from improved mental and physical health outcomes and enhanced patient and staff experiences to economic savings and infrastructure resilience. Investing in NbS is a key strategy for improving public health and reducing pressure on health services, especially in the face of climate change.

Incorporating views of greenery from patient rooms, with street trees, green walls and gardens in hospital design, has been linked to faster patient recovery times and reduced length of hospital stays. Nature-based therapy has been shown to provide preventative medical benefits, helping individuals manage chronic stress, anxiety and physical pain (Jo *et al.*, 2019). Therapeutic gardens and access to green space can reduce patient stress, improve mood and enhance staff well-being by creating restorative environments in hospital break areas and waiting rooms. For elderly patients, particularly those undergoing rehabilitation, nature-based interventions offer gentle, accessible routes to recovery and improved quality of life. Rooftop gardens, a type of intensive green roof, can serve as a source of fresh produce for hospital kitchens, contributing to healthier diets, food sustainability and security.

Poor mental health can impose a significant cost on national economies, associated with healthcare treatments, pharmaceuticals, paid and unpaid (e.g., family members) caregiving, lost workplace productivity and antisocial behaviour. Investing in NbS as part of health strategies can support economic outcomes in these areas. For example, urban green spaces, including parks, street trees and green roofs, play a critical role in reducing urban heat stress and mitigating air pollution across the region. It was reported that urban trees in 10 of the world's megacities are estimated to generate US$482 million annually in health costs savings through pollution reduction. Similarly, access to green space in the United Kingdom is projected to save the National Health Service (NHS) £2.1 billion in treatment costs. If NbS are scaled across the region, ECE countries could potentially experience similar economic benefits through savings on healthcare expenditure. Case study 5.2 provides an example of "Green Social Prescribing" from the United Kingdom.

Case study 5.2: Cross-government Green Social Prescribing Programme, United Kingdom

A two-year £5.77 million cross-government Green Social Prescribing Programme was launched in April 2021. It set out to test how to embed green social prescribing in mental health pathways and across integrated care systems to improve mental health and tackle health inequalities. It provided valuable learning to help health and care systems, providers and local communities develop green social prescribing to:

- Improve mental health outcomes;
- Reduce health inequalities;
- Reduce demand on the health and social care system;
- Develop good practice in making green social activities more resilient and accessible;
- Demonstrate how to spread and scale green social prescribing across integrated care systems.

Funding: the programme was supported by the Treasury Shared Outcomes Fund with additional funds from NHS England, Sport England and the National Academy for Social Prescribing (NASP).

Governance: The project was managed by the Department for Environment, Food and Rural Affairs with support of national partners: the Department of Health and Social Care, the Department for Levelling Up, Housing and Communities, Natural England, Sport England and NASP. NHS England managed the test and learn site delivery project.

Test and learn sites: There were seven test and learn sites which tested the ways in which connecting people with nature can improve poor mental health and which explored and brought together opportunities for communities to get involved in their natural environment. The sites were in areas that were disproportionately affected by COVID-19 and contain communities disadvantaged by health inequalities. This included people living in deprived areas, those with mental health conditions and/or people from specific ethnic minority communities.

Findings:

- Over 8,500 people have been referred to a green social prescribing activity during April 2021–March 2023;
- Interim findings showed positive improvements in mental health and wellbeing and strong engagement in communities experiencing elevated levels of social inequalities that affect health and well-being;
- 85 per cent uptake of green social prescriptions when offered;
- Green networks were established in all sites;
- Green social prescribing continues to be delivered in all seven sites, demonstrating a lasting impact.

Resources:

The learning from the programme has been captured in a Green Social Prescribing toolkit (National Academy for Social Prescribing, no date) designed to help communities, organizations and health professionals who are looking to set up green social prescribing programmes that connect with local health systems. The toolkit includes details of the project including:

- Information about specific projects involved in the pilot;
- Templates and guidelines for getting started and good practice;
- Links to evaluation and research;
- Links to other useful resources.

Source: NHS (no date).

Box 5.1: Practical resource

- The European Centre for Environment and Human Health's **Nature on Prescription Handbook** highlights the therapeutic potential of NbS activities such as gardening, walking groups, conservation volunteering and simple appreciation of nature (Fullam *et al.*, 2021).

6. Nature-based solutions and sustainable transport, energy, water and waste infrastructure

Key messages

- NbS can deliver infrastructure services directly or enhance existing grey infrastructure, improving operational efficiency and service provision.
- Sector-specific applications of NbS are feasible and beneficial across transport, energy, water, waste management and health infrastructure.
- NbS can reduce operational costs, extend asset lifespans and provide co-benefits such as habitat for biodiversity, climate mitigation and improved public health outcomes.
- Strategic integration of NbS into infrastructure planning from the outset is essential to maximize benefits, minimize trade-offs and avoid retrofitting challenges.
- NbS can support workforce well-being across sectors including healthcare and transport, by improving environmental conditions and mental health.

Practical tips

- Embed NbS in early-stage infrastructure planning to optimize design and cost-effectiveness and avoid retrofitting challenges.
- Use NbS such as green roofs and walls in urban infrastructure to provide co-benefits such as reduced heat stress, improved air quality and enhanced energy efficiency.
- Restore upstream ecosystems to protect water quality and reduce sedimentation in hydropower, potable water and water transport systems.
- Apply phytocapping and constructed wetlands for landfill and industrial wastewater treatment, offering low-cost, low-energy alternatives.
- Integrate NbS into transport corridors to reduce ecological fragmentation and improve safety.
- Incorporate NbS into workplace infrastructure, such as shaded areas for outdoor workers and therapeutic gardens in healthcare settings, to improve employee well-being and productivity.

Previous chapters have discussed how the scaling of NbS in ECE countries can generate a broad range of benefits. This includes supporting integrated progress on national climate change policy agendas through strengthening the incorporation of NbS in NDCs and NAPs, and generating environmental and health benefits, including protecting infrastructure systems from a broad range of climate impacts. This chapter focuses on the integration of NbS into key infrastructure sectors in the ECE region, notably transport infrastructure (water, road and rail); energy (hydropower, solar power, fossil fuels and biomass, and transmission); water (potable water, wastewater); waste management; and healthcare and social care infrastructure.

Evidence demonstrates that NbS can support the provision of services across these sectors by delivering infrastructure services directly, thereby substituting for built assets either partially or entirely, or enhancing the provision of infrastructure services, thereby complementing the built asset. NbS can deliver infrastructure services in the water and healthcare sectors, and improve the provision of services in transport, energy and waste management sectors. Scaling NbS strategically into these sectors has the potential to improve the provision of infrastructure services across the ECE region and, at the same time, support the provision of environmental and health benefits discussed in the previous chapters. Achieving these potential benefits requires decision-makers to embed NbS into infrastructure planning processes from the start of the infrastructure project lifecycle, and channel some of the investments earmarked for built infrastructure into NbS.

6.1 Transport

NbS benefits for water transport

Water transport infrastructure, which consists of grey infrastructure including ports, harbours, canals, inland rivers and shipping lanes at sea, is increasingly recognized as a domain where the integration of NbS can both benefit the sector and generate multiple co-benefits.

NbS can support the operational efficiency and resilience of navigation systems. For example, riparian vegetation along water courses and ecosystems within watersheds can be restored, protected and managed sustainably to limit soil erosion and sedimentation of navigation channels and ports that can impact water transport, reducing the need for dredging (Paalvast, 2012; Hijdra *et al.*, 2021; Almstrom *et al.*, 2022). NbS can support tranquillity of waters and reduce the impact of waves on riverbanks from passing boats. The use of living harbour wall systems can protect the harbour from wear and tear, and extend grey infrastructure lifespans (Perkol-Finkel, 2018). Beyond the provision of infrastructure benefits, NbS can also contribute to the long-term sustainability of the water sector, including ports and waterways, while delivering broader environmental and public health outcomes.

Increasing the sustainability of ports

Ports, as key transport infrastructure, are commonly recognized as critical enablers of international trade in global networks. Their pivotal role within international supply chains poses increasing challenges in terms of operational efficiency and environmental sustainability, primarily due to the increasing demand for port services, driven by the growth in global trade and related maritime transport traffic. Relatedly, increasing competitive pressures are forcing port managers and operators to find new ways to improve efficiency and service quality jointly guaranteeing adequate economic and financial performances. In this context, more attention is being awarded to drivers for improving ports' sustainability.

Port managers, through investments in "green solutions" (i.e., initiatives aimed at environmental protection and, more broadly, at ensuring the sustainability of maritime and port logistics activities), can improve port sustainability by reducing carbon emissions, improving efficiency and restoring natural ecosystems, thus enabling the development of effective "Green Ports". "Smart Ports" (i.e., ports that invest in and employ advanced technologies to develop innovative solutions capable of generating value for the entire ecosystem, by enhancing logistical processes and port-related activities) provide complementary, innovative solutions for monitoring operations, optimizing resources and enhancing overall system resilience. NbS can form a cornerstone for implementing green and smart port strategies—they can mitigate erosion and pollution of ports, manage noise from port operations, while offering climate regulation and biodiversity benefits by restoring natural coastal ecosystems. When developed alongside conventional port infrastructure, they can help to mitigate threats related to biodiversity loss and increase the resilience of port infrastructure to climate risks (Châles er al, 2023). NbS can be harnessed to address some of the most pressing environmental threats affecting port infrastructure and surrounding areas, such as water security and coastal hazards. They can greatly contribute to port infrastructure sustainability, while mitigating climate change and safeguarding biodiversity and community well-being.

NbS can provide a range of social benefits, as they improve the quality of the urban and coastal environment, strengthen the social acceptability of infrastructure interventions, and promote the active involvement of local communities in the design of more resilient and liveable spaces. These solutions can facilitate a substantial improvement in the spatial and functional integration between the port and surrounding locations, supporting initiatives for the regeneration of port-adjacent areas, the creation of green spaces accessible to the community, and the enhancement of the landscape value of port and hinterland infrastructure.

Equally, they can enhance the environmental credentials of ports. NbS hold immense value, as they can reinforce the positive perception and public support of the port and create opportunities for public participation and the development of a shared and participatory ecological transition process. NbS both synergically increase the positive effects generated by sustainable "green" and "smart" interventions and become key enablers for facilitating social acceptance and the creation of shared value in the port context. Combining NbS with technical solutions through Smart Port strategies can create a model for sustainable port development—examples of these technical solutions are discussed in Chapter 7. Grounding on the work of Sicomo (2022), a taxonomy of NbS available for port infrastructure is provided in Table 6.1.

Table 6.1: Strategies for sustainable ports, with examples that implement or support the implementation of NbS and hybrid approaches (aligned with Table 1.1)

Category	Description	Example
Marine and Coastal Protection	**Natural and hybrid coastal structures that function as natural break waters, attenuate wave energy, reduce shoreline erosion, and protect coastal infrastructure while enhancing ecological value.**	Shellfish reef creation
		Coral reef restoration
		Creation of perched beaches with submerged breakwaters
		Vegetated natural islands (e.g., wetland restoration)
		Hybrid tidal parks for coastal access and wave buffering, may include protection of ecosystems such as salt marshes or mangroves
Vegetated Habitats and Ecological Resilience	**Creation or restoration of vegetated ecosystems that offer natural barriers, improve air and water quality, support biodiversity, and provide recreational opportunities.**	Constructed and restored wetlands
		Salt marsh restoration
		Seagrass meadow restoration (e.g., *Posidonia*)
		Mangrove restoration
		Riparian buffer protection to maintain vegetated riverbanks
		Seabed topographic reconfiguration
Hybrid Infrastructures and Active Substrates	**Integration of nature into engineered solutions, such as eco-designed surfaces or floating structures, which support marine life colonization and improve ecosystem services.**	Eco-engineered revetments and ripraps, may include creation of artificial reefs
		Biologically active coatings
		Creation of floating and suspended marine habitats
		Substrate restoration for chemical/physical habitat improvement, may include seagrass beds
Urban Water and Climate Risk Management	**Green-blue infrastructure in urban areas designed to manage flood risks, retain stormwater, and regulate hydraulic pressure, contributing to climate resilience and liveability.**	Floodable green zones and buffer areas
		Secondary water channels and overflow basins, may include nature-based detention basins
		Flow optimization structures (e.g., weirs, nature-based berms)
		Sediment consolidation for adaptive reuse
Ecological Restoration and Ecosystem Reconnection	**Measures aimed at reconnecting fragmented habitats, restoring transitional zones (e.g., estuaries), and enabling migration routes for aquatic and terrestrial species.**	Ecological corridors between marine and inland waters
		Openings in seawalls for species migration (wildlife pass)
		Salinity gradient restoration (can support conditions for mangrove restoration, etc.)
		Land-sea transitional buffer zones
Sustainable Sediment Management	**Techniques for the ecological reuse of dredged materials, such as fine sediment placement and clay maturation, to stabilize environments and recreate coastal habitats.**	Strategic placement of fine dredged sediments
		Clay maturation and overlay for coastal reinforcement
		Reuse of dredged material for levees and agricultural support

Source: adapted from Sicomo (2022).

Within the scope of the recent report by the World Bank (2025) (see Practical Resources, below), in Table 6.2 below, actions conducive to NbS are classified according to the opportunities and entry points through which they respond to port-related challenges. In particular, examples of different actions that can support the development of NbS are grouped into four distinct "NbS Families". The table provides a concise description of each family, together with a detailed overview of the specific NbS included within each category. Further information on the relevance and effectiveness of NbS in addressing different port challenges along with their potential societal co-benefits can be found in the World Bank (2025) report.

Table 6.2: Families of NbS which can support strategic NbS planning within the port subsector

NbS family	Description	Actions to maximize ecosystem benefits and minimize impacts on the environment
Working with coastal systems	**This family focuses on the interaction between ports and their surrounding (coastal) environment. Working with coastal systems can lead to reduced sedimentation issues within the port and create more favourable conditions for vessels. In general terms, this family considers large-scale solutions that require a system-based approach during the initial stages of port development, such as selecting the optimal location for a port or terminal that leverages natural processes instead of opposing them.**	Consider port siting and layout Sustainable sediment management Restoring estuarine or riverine ecosystems
Wave and coastal dynamic attenuation	**Wave disturbances both outside and inside the port basin can impact port efficiency and operations. Therefore, a family of NBS designed to dampen and protect against waves is logical. Various ecosystems and natural formations can attenuate waves. NBS in this category, such as vegetated features, living shorelines, and reefs can reduce wave energy, dampen wave reflection within a port basin, decrease wave dominated sediment transport, and/or protect against storm impacts.**	Sandy foreshores Ecologically enhanced breakwaters Mangroves Salt marshes Reefs
Beneficial reuse of sediments	**Capital dredging and maintenance dredging are common activities in ports, making this a widely applicable category. Dredging is primarily conducted to maintain sufficient water depth, but it also results in the collection of large quantities of dredged sediments. Traditionally, these sediments are dumped offshore. However, this family of NBS can advocate for a more circular approach and offer new opportunities for effectively reusing dredged sediments for various purposes, such as wetland restoration, strategic placement to reduce dredging needs, and enhancing coastal protection systems.**	Foreshore and land reclamation Construction material Restoration, rehabilitation, and creation of habitats
Enhancing hard structures	**Quay walls, revetments, and breakwaters are essential types of hard infrastructure for every port. However, their design can incorporate the creation of micro-habitat features and increase their environmental outcomes. Quay walls, for example, are challenging to replace with NBS. However, it is possible to enhance these hard structures to make them more suitable for marine life by making small additions or adjustments, such as tide pools and other ecological enhancements that can support micro-ecosystems and biodiversity. This, in turn, improves the license to operate for port governance and development.**	Enhanced quay walls and revetments Hanging and floating structures Habitat creation units

Source: adapted from World Bank (2025).

It should finally be emphasized that NbS can be synergistically integrated within the broader so-called "green strategies" (i.e. initiatives aimed at reducing environmental impacts and fostering sustainable development), thereby enhancing their overall effectiveness and co-benefits. Figure 6.1 illustrates the degree of synergy between NbS and each green strategy (Satta *et al.*, 2025).

Figure 6.1: Synergies between green strategies and NbS in ports

	Synergy with NbS	Description
Digitalization and IC platforms	● (orange)	Environmental monitoring support and NbS management
Energy efficiency	● (orange)	Microclimate improved by urban greenery, natural cooling
Renewable energy production	● (green)	Several direct pointsof contact with NbS solutions
Policies and interventions	● (green)	Environmental policies can promote NbS
Bunkering and storage facilities for alternative fuels	● (red)	Technical infrastructure not linked to natural resources
Plants and infrastructure for energy supply	● (red)	Hard infrastructure without NbS binding
Land-use conversion	● (green)	Re-naturalization of port areas, green belts, wetlands
Research and development	● (green)	R&D supports NbS testing and monitoring

Box 6.1: Practical tips for the water transport sector

- **Avoid locating ports within areas of high biodiversity:** this includes avoiding Marine Protected Areas and Key Biodiversity Areas, planning navigation channels to minimize impacts on habitats that can occur from ship movement and maintenance dredging (WEF, 2025).
- **Systematically consider NbS options to enhance hard infrastructure when designing ports:** NbS, such as artificial reefs can provide benefits to both ports and biodiversity, for example by reducing erosion of built infrastructure assets whilst providing habitat for local species. Mangroves and salt marshes can buffer wave energy if strategically located near ports.
- **Consider land-based NbS options in addition to marine options for enhancing port services:** terrestrial ecosystems can provide benefits including helping to mitigate the influx of sediments into navigation channels by stabilizing soils and sediments at their source. This can reduce requirements for maintenance to preserve navigation lanes.
- **Improve green space to generate wider social, environmental and economic benefits:** for example, restoring unused land and establishing buffer zones around the perimeter of the port consisting of native vegetation can provide a natural barrier against noise and water pollution (WEF, 2025); green roofs and walls can help to manage runoff while providing aesthetic appeal to workers and pedestrians using the space. Modifying quay walls and revetments with NbS such as floating habitats can help to support marine life.
- **Consider reuse of dredged materials:** dredged materials can be applied for wetland restoration, land reclamation or construction to promote circular resource use.
- **Consider species types:** it is important to select native and locally adapted species. This is particularly important in areas experiencing water scarcity to reduce water use for irrigation which may put pressure on local water resources (WEF, 2025)
- **Integrate NbS with Smart Port technologies:** combine ecological and digital solutions to optimize operations, monitor impacts and boost climate resilience.

Resources:

- **Nature-Based Solutions for Ports: An Overview of NbS Implementation in Practice – Opportunities and Challenges**," published by the World Bank in collaboration with EcoShape (World Bank, 2025). This provides a comprehensive overview of the potential role that NbS may play in port environments. The report aims to illustrate how NbS can be systematically integrated into port planning, design and operational processes to tackle sectoral challenges, while at the same time strengthening climate resilience and generating a broad range of co-benefits.
- "**Nature Positive: Role of the Port Sector: Insight Report**" published by the World Economic Forum (WEF, 2025) provides information including how to plan port areas to minimize impacts on nature and on how to actively protect and restore nature, including relevant case studies.

NbS benefits for rail: railway tracks, railway stations

Railways and roads play a critical role in enabling the movement of people and goods, thereby supporting economic activity and access to basic services such as healthcare and education. These sectors typically rely on grey infrastructure for service provision, but there is growing potential to integrate NbS to enhance service reliability, reduce costs and mitigate adverse environmental and health impacts. It is projected that 335,000 km of rail track will be needed by 2050 compared to 2010 levels (IEA, 2013).

Managing vegetation along railway lines is a key opportunity for deploying NbS. Specifically, in naturally treeless landscapes, vegetation such as grasslands and shrublands can be protected, restored or managed to reduce the risk of leaves and branches from taller vegetation falling onto tracks, which can disrupt services (Varley, 2018). Using native, low-lying vegetation helps to reduce maintenance requirements and costs associated with vegetation control and enhances the reliability of rail operations by minimizing service disruptions. At the same time, development of ecological corridors can protect rail infrastructure from hazards such as flooding and snowfall, reduce landslide risk and help to increase the lifespan of built assets (Kapos *et al.*, 2019; UNEP, 2023).

Wildlife overpasses and underpasses offer another important application of NbS in both rail and road infrastructure networks. These structures enable safe wildlife movement across transport corridors, reducing animal-vehicle collisions, damage to trains and vehicles, and risks to human safety (ADB, 2019). Overpasses are often paired with wildlife barrier fencing to guide animals towards the crossing and prevent them from accessing the engineered transport infrastructure. Studies from around the world, including the ECE region, have shown that these structures can significantly reduce mammal deaths and collisions. Design considerations, such as the level of vegetation cover at the entrance point have been shown to determine wildlife use of crossings, supporting a wide range of species, from rodents and rabbits to ungulates, carnivores and bears. For example, one study found that more animals successfully returned through overpasses and underpasses with 100 per cent vegetation cover at entrances (55–100 per cent of animals), compared to those with 50 per cent cover (20–76 per cent of animals), or no cover (0–66 per cent of animals).

Integrating NbS into the design and maintenance of linear transport systems can reduce long-term maintenance costs and extend the lifespan of grey infrastructure assets. The greening of railways and highways can help with noise reduction, better visual integration, and function as ecological corridors to facilitate wildlife movement and preserve genetic diversity across the region, supporting environmental health (European Commission, 2024; Blackwood *et al.*, 2022). Strategically planning grey and green infrastructure together allows for reduced environmental impact, improved service continuity, and resilience against potential climate and animal risks. Several integrated initiatives across the ECE region now demonstrate the potential cross-border NbS, showing how NbS can be designed to benefit both rail and road infrastructure. The following section on road networks illustrates this with the TRANSGREEN project in the Danube-Carpathian Region (see Case study 6.3).

Box 6.2: Practical considerations for rail

- **Avoid rail development that cuts through areas of rich biodiversity:** where possible, plan the development of rail infrastructure to avoid key ecological areas.
- **Ecosystem connectivity:** where rail do cut across key ecological areas, development of overpasses and underpasses to connect these landscapes can increase benefits to both rail and wildlife through reduced collision risk and benefits to biodiversity.
- **Restore, protect and manage NbS along rail networks:** native vegetation alongside railway tracks can provide benefits including noise reduction and aesthetic appeal.

NbS benefits for road: paved and unpaved roads, service stations

The global demand for transport infrastructure is rising, with an estimated 25 million km of new roads expected to be built by 2050 over 2010 lengths (IEA, 2013). At the same time, many existing networks are increasingly vulnerable to climate impacts and environmental loss and degradation. NbS offer promising approaches to enhance road infrastructure while providing environmental and social benefits.

NbS can be integrated into road planning and design to reduce maintenance needs, mitigate environmental risks and extend the lifespan of built road infrastructure. As with rail networks, wildlife overpasses and underpasses can be created to maintain ecological connectivity and facilitate the safe movement of wildlife whilst increasing road safety. In the road sector, overpasses should be designed with vegetation that can withstand exposure to vehicle emissions. In addition, street trees can be planted and managed to enhance road safety by visually narrowing roads, which encourages slower driving, increases driver attentiveness and buffers pedestrians from vehicles, reducing collision risk (Greater Manchester Combined Authority, 2019). The creation of urban NbS, such as rain gardens, bioswales and planter boxes along pavements can be used strategically to block people from stepping into busy roads or prevent street crossings at dangerous points (Kustar *et al.*, 2024). This can reduce traffic accidents that can disrupt traffic flows, leading to enhanced quality and reliability of mobility via roads and improving pedestrian safety (Zhu *et al.*, 2022). In countries that experience snowfall, establishing living snow fences and hedgerows can support transport flows by improving driver visibility and road surface conditions, and can provide added benefits of lowering costs of road maintenance and reducing accidents that can be caused by blowing snow (Wyatt *et al.*, 2012).

NbS can also support sustainable mobility which can lead to added environmental and health benefits. For example, urban parks can be integrated with pedestrian paths and cycling lanes to promote walking and cycling as alternatives to car use and as an active transport option. In encouraging alternative modes of transport, NbS can help to reduce traffic and lead to additional benefits including reduced air pollution and GHG emissions (due to fewer cars on the road), encouraging physical activity, improving urban cooling and increasing habitat for biodiversity (Newell *et al.*, 2022).

Box 6.3: Practical considerations for roads

- **Avoid road development that cuts through areas of rich biodiversity:** where possible, plan the development of road infrastructure to avoid key ecological areas.
- **Ecosystem connectivity:** where roads do cut across key ecological areas, development of overpasses and underpasses to connect these landscapes can increase benefits to both rail and wildlife through reduced collision risk and benefits to biodiversity.
- **Consider how NbS can support road safety:** through strategic placement of planter boxes, bioswales, and other NbS, planners can help to separate pedestrians and vehicles and reduce traffic accidents.
- **Size and location:** sufficient distance is required from fire hydrants and bus stops to comply with regulations and enable maintenance of NbS, tree branches must not obscure driver views, practitioners may need to consider tree pit size in relation to sidewalk width (Messier, Margulies & Wilson, 2025).

Case study 6.1: Cycling infrastructure in Kyiv, Ukraine

In Kyiv, the number of cyclists increased by 2.5 times during the COVID-19 lockdown. To build on this momentum, the city plans to expand its cycling infrastructure, including by adding more bicycle lanes and expanding the "Nextbike" bicycle rental network. Integrating this infrastructure with urban parks and urban green spaces, such as bioswales, rain gardens and detention basins, could support mental health and well-being while increasing the uptake of cycling across the city.

Type of NbS: management / creation of urban parks, bioswales, rain gardens, detention basins.

Why: health benefits of exercise, air quality, and exposure to green space.

Who: city of Kyiv.

Components: integration of active travel networks with green spaces.

Source: OECD (2021b).

Case study 6.2: TRANSGREEN project in Czechia, Hungary, Romania, Slovakia and Ukraine

Built road and rail infrastructure can also be designed to minimize impacts on the natural environment. The network of highways and railways that connect key areas of Central and Eastern Europe to the rest of the continent is being planned for development. The TRANSGREEN project demonstrates how NbS can be mainstreamed into large-scale road and rail infrastructure planning across several countries within the ECE region. Operating in Czechia, Hungary, Romania, Slovakia and Ukraine, the project aims to take an integrated approach to develop environmentally friendly and safe transport corridors across the Carpathian Mountains, a region rich in biodiversity and protected ecosystems, including Natura 2000 sites.

A central focus is protecting uninterrupted ecological corridors to facilitate the movement of species most at risk from linear transport infrastructure, such as brown bears, wolves, lynx and herbivores. The initiative includes four pilot projects where NbS are integrated into planning, construction and monitoring: the Tîrgu Mureș–Iași motorway (Romania), the Curtici (Radna)-Deva railway (Romania), the Miskolc (Hungary)–Košice (Slovakia)–Uzhgorod (Ukraine) motorway and the Beskydy motorway (Czechia–Slovakia).

Type of NbS: protection of ecological corridors through improved infrastructure planning

Stakeholders: various. TRANSGREEN brings together a broad range of stakeholders, including motorway companies, conservationists, environmental organizations, national and regional authorities, international organizations, economists, engineers, ecologists, and academic and research institutions to co-design transport infrastructure that minimizes ecosystem fragmentation.

Project partners:

- Austria: WWF International Danube-Carpathian Programme (project lead), Secretariat of the Carpathian Convention;
- Czechia – Friends of the Earth Czech Republic (Olomouc branch), Nature Conservation Agency, Transport Research Centre;
- Hungary: CEEweb for Biodiversity;
- Romania: Association "Milvus Group", WWF Romania;
- Slovakia: National Motorway Company, State Nature Conservancy of the Slovak Republic, SPECTRA—Centre of Excellence of EU—Slovak University of Technology in Bratislava.

Associated project partners:

- Austria: Ministry for Transport, Innovation and Technology;
- Czechia: Ministry of the Environment;
- Hungary: National Infrastructure Developing Private Company Ltd;
- Poland: Ministry of Infrastructure and Construction;
- Romania: Ministry of the Environment, Ministry of Transport;
- Slovenia: Ministry of Infrastructure;
- Ukraine: Ministry of Natural Resources, Transcarpathian Regional State Administration – Department of Ecology and Natural Resources.

Funding: co-funded by the European Union (ERDF) through the Interreg Danube Transnational Programme (DTP), Priority 3 – Better connected and energy responsible Danube region.

Why: safe movement of wildlife, reduced collision risk, reduced habitat fragmentation. Specific objective to support environmentally-friendly and safe transport systems and balanced accessibility of urban and rural areas.

Source: WWF (no date). More information is available from the Interreg Danube Transnational Programme (no date).

6.2 NbS benefits for energy

While grey infrastructure solutions will continue to have a fundamental role in the delivery of energy services, NbS can complement built infrastructure to enhance service provision and support the provision of electricity at lower cost.

NbS for hydropower

Hydropower infrastructure encompasses built assets including dams, reservoirs, turbines and power plants, all of which depend on steady flows of clean water to function efficiently. NbS, such as the restoration of upstream forests and riparian vegetation, can enhance performance in several ways. By stabilizing soils and reducing erosion, NbS help to maintain the quality and quantity of water entering reservoirs, limiting sedimentation and reducing the need for costly maintenance and downtime for dredging (Stickler *et al.*, 2013; Kaura *et al.*, 2019; Guo *et al.*, 2007). This preserves storage capacity and reduces wear and tear on turbines caused by high turbidity, extending the lifespan of built assets and improving the efficiency of energy generation (Browder *et al.*, 2019). Managing upstream vegetation and agricultural lands can also be more cost-effective than engineering-based solutions, ultimately reducing costs for consumers. In contrast, the degradation and loss of upstream ecosystems can increase siltation and pollution from nutrients, chemicals and soils, disrupt water flow timing and degrade water quality, posing risks to the reliability and productivity of hydropower systems.

However, the integration of NbS for benefits to hydropower must be carefully planned with consideration of the local context. In water-scarce regions, reforestation of previously deforested areas may lead to negative trade-offs for hydropower by reducing water availability. Choosing locally adapted and native species specific to the context will be important to maximize benefits and manage these potential trade-offs.

Box 6.4: Practical considerations for hydropower

- **Hydrological context:** the reforestation of deforested lands with trees can exacerbate issues of water scarcity in drought-stricken regions as trees use water to grow.
- **Species type:** native species that are adapted to the local conditions may reduce potential trade-offs with water availability.
- **Maintenance:** healthy, well-maintained NbS will provide more effective service provision, including stabilization of soils and regulation of water flows. Practitioners should develop well-planned maintenance schedules and allocate sufficient budget to maintenance across the project lifecycle.
- **Evaluate the benefits of existing native ecosystems prior to infrastructure development:** forests upstream of hydropower can provide many benefits to service delivery. As the restoration of degraded forests can take many years, even decades, protecting existing ecosystems will be more effective in the short term.
- **Consider sediment flows:** NbS offer potential to safeguard the storage capacity of hydropower by reducing soil erosion and capturing sediments. Rivers with high sediment loads may be considered priority areas for NbS.

Relevant tools:

- There are tools that can help to spatially estimate the potential value of NbS, including the Reservoir Hydropower Production (Water Yield) module in the Integrated Valuation of Ecosystem Services and Trade-offs (InVEST).

NbS for solar power

The solar energy sector includes both ground- and rooftop-mounted solar panels. NbS can play a role in enhancing the efficiency and sustainability of solar power generation when developed through careful design and planning strategies.

In rooftop solar applications, green roofs offer several synergistic benefits when paired with solar panels. They can function as a substrate and anchor panels to keep them in place. The evapotranspiration of the vegetation can moderate rooftop temperatures, providing a cooling mechanism which can increase the energy efficiency of solar panels by up to 20 per cent in some cases (Enzi *et al.*, 2017).

Case study 6.3: Green roofs and photovoltaics in Zurich, Switzerland

A study from Zurich, Switzerland, found that green roofs boosted annual photovoltaic (PV) energy yield by 1.8 per cent, while integrated "cool roofs" which combined greenery and PV increased yield by 3.4 per cent for flat rooftops. These combined PV-green roof systems offer additional benefits for residents and the environment, including through helping to protect buildings from weather impacts, enhancing roof lifespans, and improving overall building energy performance.

Green roofs lower surface temperatures and boost PV efficiency through increased albedo which reduces the amount of absorbed solar radiation, and through evapotranspiration, referred to as evaporative cooling, which reduces heat. This can increase the yield of rooftop PV, whose functioning is temperature dependent.

This study measured the benefits through use of a model: a rooftop energy balance model linked with a physically-based solar energy model (the System Advisor Model, SAM), which quantified energy yield of PV installations based on different roofing configurations. Roof surface temperatures were first estimated and then integrated into a revised version of the SAM model to simulate energy yield.

Type of NbS: creation of green roofs.

Why: improved efficiency of rooftop-mounted solar panels.

Quantification of benefits: benefits were measured through modelling approaches.

Wider benefits: improved energy efficiency of buildings; enhanced lifespan of built infrastructure; protection of buildings from weather (e.g., wind, rain, dust).

Who: this was an academic research project (see source).

Source: Cavadini and Cook (2021).

For ground-mounted solar, water management is a critical component of solar farm design. Good drainage is necessary to protect electrical infrastructure and allow access for maintenance vehicles. Even relatively level sites can experience waterlogging due to small topographic variations. Open drainage systems are often preferable to sub-surface drainage systems, making NbS, such as bioswales and created balancing ponds effective options, offering both water control and habitat provision. Solar parks will often feature a stable water management system, providing rich wetland habitats that can be readily incorporated into solar farms, and which can increase energy efficiency of solar power generation, through the temperature regulating services that ecosystems provide. When properly designed and implemented during the construction phase, such drainage systems are cost-effective and can be integrated into broader habitat enhancement programmes to boost positive outcomes for the environment and biodiversity. These systems must be designed to ensure that overflowing water drains away safely from solar panels once storage capacity is reached.

Some studies suggest that ground-mounted systems typically involve minimal ground disturbance (less than 5 per cent), with panels set on posts, leaving much of the land accessible for vegetation and complementary uses such as wildlife conservation or agriculture. Integrating solar with agriculture, a concept known as agrivoltaics, offers an opportunity to align clean energy production with land management if carefully designed and planned in coordination with stakeholders. Livestock, particularly sheep, can help maintain vegetation under and around solar panels, reducing the need for mechanical maintenance in the form of mowing. Sheep can reach areas under panels that lawnmowers struggle to trim, whilst benefitting from heat abatement from the shade of solar panels. In the United Kingdom, a 1GW project in Nottinghamshire plans to share its 4,000 acres with a flock of almost 4,000 sheep, which is expected to climb to 9,000 sheep once lambing begins. It is considered to have the potential to save £5 million in mowing costs across its 40-year lifespan.

Case study 6.4: Agrivoltaics in the United States of America

In the United States of America, approximately 80,000 sheep graze around 100,000 acres of solar installations across 500 solar power sites in 27 states (Casey, 2025). Their grazing helps to prevent grasses and weeds from growing to heights where they can interfere with solar panels or block sunlight from reaching them. Weed control can be a major challenge for solar operations, as weeds can obstruct the panels, reducing energy production, and overgrowth can damage panels. By eliminating the need for mechanized lawn mowers or chemical herbicides, solar grazing can reduce maintenance costs. For example, in Arizona, desert tumbleweeds can be a major issue for solar farms, but they are high-protein food sources for sheep. The practice is not only cost-effective as a form of maintenance for solar farms, but also offers an important income source for farmers, with around 200 sheep needed per 100 acres and payments made per grazing session. Farmers are typically paid US$1 per acre each time they visit a site, usually two or three times a year.

In cases where sheep grazing and solar farms co-exist on a more permanent basis, this can provide benefits in terms of maximizing the use of land by enabling multiple uses to coexist on land areas, rather than choosing between farmland and solar power.

The use of sheep instead of mechanized maintenance provides further benefits. For example, they provide a source of natural fertilization; as they graze, their manure helps to distribute organic matter across the land, which enriches the soil with nutrients that can support healthy plant growth. As they move around, they trample old plant matter into the earth, helping seeds to germinate, encouraging native plant growth, and supporting a habitat for insects, birds and small mammals. At the same time, panels can provide shelter for sheep, from rain, wind and direct sun.

Type of NbS: agricultural management.

Why: to maintain the area around ground-mounted solar, providing more effective and lower cost maintenance compared to mechanized machinery.

Wider benefits: additional income for farmers, improved soil quality, habitat for biodiversity, shade for sheep from wind, rain, sun.

Considerations: NbS must result in biodiversity benefits. Therefore, maintenance of solar panels should be done to improve biodiversity and preserve space for habitat.

Source: Casey (2025); American Lamb Board (no date); Harvey (2025).

It is unclear whether sheep grazing can offer carbon benefits. For example, while it has been reported that grazed soils under solar panels can store up to 80 per cent more carbon (Harvey, 2025), and sheep grazing can reduce emissions associated with mechanized lawnmowers, sheep are also a source of emissions, therefore studies are required to assess whether they provide net benefits or are sources of GHG.

The integration of sheep with ground-based solar farms can provide additional environmental co-benefits. If sheep are managed with low stocking densities and seasonal grazing breaks, they can support an increase in species richness and abundance compared to mowed grass areas, providing benefits to wildflowers, invertebrates, ground-nesting birds and small mammals. Seasonal breaks during spring and summer may be necessary to support biodiversity outcomes. Grassland managed with grazing typically has a higher carbon sequestration potential than that which is mowed, though this can offset benefits through the release of other GHGs such as methane. Solar farms located on previously degraded farmland can support a fallow period for the land to regenerate over the 25–30-year operational lifespan of the panels. Once the panels are removed, the land can be returned to agriculture in an improved condition. At the same time, the protection and restoration of wild spaces amongst solar panels can provide habitat to insects including pollinators, providing wider benefits, including for food production (Semeraro *et al.*, 2018).

Solar panels can also create microclimates by casting shade and altering patterns of rainfall on the ground. Evidence from the United Kingdom suggests that areas under panels experience lower ground temperatures and light levels, along with altered moisture conditions, compared to adjacent fields. This has prompted growing interest in the integration of crop systems with solar, where crops are grown in the shaded microclimates created by panels. This dual-use model has the potential to produce both food and energy from the same land area.

However, locating solar on agricultural or other lands of value requires caution and careful assessment of costs and benefits. The siting of solar farms on high-quality agricultural land can result in significant trade-offs for food production. Equally, siting solar farms in high-value natural locations may also raise issues. For example, in Oxfordshire, United Kingdom, a large solar farm planned for development has raised concerns, including the visual effect on the landscape, public access to opportunities for recreation, and impacts on the historic environment. Avoiding fertile soils and productive lands, and involving local stakeholders in planning are essential to minimize the trade-offs that solar deployment may result in. Solar farms are generally better suited to low-productivity lands, and care should be taken to avoid installing them on prime agricultural areas with highly fertile soils, where competition with food production may have economic costs for the livelihoods of farmers and for food security of local communities, offsetting the benefits that they provide.

Case study 6.5: EIB Riga Forest Peatland and Solar PV example, Latvia

SIA Rigas Mezi, the municipal forest management company of Riga City, is developing a project to transform degraded peatlands in the proximity of Riga. They are aiming to combine the re-naturalization of these former peatland extraction areas with the installation of large-scale solar PV parks, totalling approximately 200MW, across a 300ha area.

Type of NbS: peatland restoration (combined with solar PV).

Purpose: SIA Rigas Mezi owns more than 60,000 hectares of forest, much of which is on drained peatlands. They aim to explore how to manage these areas effectively. The project demonstrates an example of planning a landscape for restoration whereby part of the land is used for renewable energy generation, and the rest optimized for biodiversity and carbon sequestration through a sustainable development framework.

Who: The solar PV promoter is the SIA Rigas Mezi forest company, which is owned by the city of Riga. This creates a public-private partnership between the forest company and the public sector, which is the majority shareholder.

Funding: The partnership thus generates extra revenue streams for the restoration activities. The solar PV company is leasing the land. Part of the funding generated through the lease is to be used to restore the peatlands. They are additionally looking to monetize the project through carbon credits complying with strict environmental standards.

Benefits: degraded peatlands are prevalent in the Baltics, where prolonged peat extraction for fuel has left behind barren landscapes. Restoring these habitats would re-establish their ecosystem, enabling them to function as carbon sinks and attract biodiversity.

Source: Mayerhofer (2025).

Box 6.5: Practical considerations for solar power

- **Land fertility:** highly productive agricultural lands are not recommended for ground-based solar development owing to the trade-offs with food production and the livelihoods of farmers. Siting solar farms in areas of previously degraded land can support a fallow period that can help the land to regenerate over the operational lifespan of the panels.
- **Drainage:** consider NbS to capture runoff from ground-based solar. These should be designed so that water flows away from the solar site when capacity is reached.
- **Measurable biodiversity benefits:** as with all NbS, by definition they must result in biodiversity benefits. Where agrivoltaics are deployed or nature-based drainage solutions used, practitioners must ensure that biodiversity benefits are a key project outcome.

Resources:

- Organizations like the American Solar Grazing Associate (ASGA) are helping to formalize best practices and connect farmers directly with solar site operators.
- Agrisolar Handbook (SolarPower Europe, 2024).

NbS for fossil fuels and biomass

Constructed wetlands can enhance aspects of energy generation across sectors, including coal, oil, gas and biomass, through their ability to treat wastewater streams that can be subsequently reused (Vyamazal, 2022). These systems use a mix of vegetation, soils and aquatic organisms to filter and treat contaminants in water flows, often at lower cost and energy use compared to conventional built water treatment options.

In the coal sector, constructed treatment wetlands have been used alongside settling ponds to remove pollutants from coal slurry. Reed plants help to filter out nitrogen, ammonia and heavy metals. These systems have also been applied to Underground Coal Gasification (UCG), enabling water recycling and reuse. Constructed wetlands have also been deployed for oil and gas operations.

Box 6.6: Practical considerations for fossil fuels and biomass

- **NbS tolerance to temperature fluctuations:** some ECE countries experience large fluctuations in temperature. It has been reported that in some contexts where constructed wetlands have been piloted, they have failed due to their inability to withstand these fluctuations. Understanding the resilience of constructed wetland species to such extremes and variations in temperature will be necessary for effective service provision.
- **Available space:** constructed treatment wetlands typically require large areas to be effective solutions for water treatment at scale. This needs to be considered in any planning processes to ensure that there is a sufficient area available. As with any NbS, evaluation of costs and benefits will be necessary to determine the best use for large areas.
- **Species relevance for wastewater treatment:** evaluation of the best species for treating wastewaters from fossil fuel and biomass can help to ensure that the solution is effective at service provision and is not negatively impacted by the wastewater.

Case study 6.6: Constructed wetlands in Poland

A study in Poland demonstrated the efficacy of vertical subsurface flow constructed wetlands in treating wastewater from underground coal gasification (UCG) processes. The system achieved significant reductions in pollutants such as phenols, BTEX compounds (a group of four volatile organic compounds: benzene, toluene, ethylbenzene and xylenes), cyanides, heavy metals and ammonia. Toxicity levels decreased by up to 99 per cent within 50 days, demonstrating the potential of constructed wetlands for remediating complex industrial effluents.

Toxicity was assessed in the raw wastewater samples and effluents from the wetlands. This was conducted using a Microtox test using the Microtox M500 toxicity analyser, in line with relevant standards for water quality. The degree of treatment, also known as the percentage of reduction, characterizes the efficiency of wastewater treatment plants and is standardized for key pollutants such as biochemical oxygen demand, chemical oxygen demand, nitrogen and phosphorus compounds. Relevant national and international legal acts, such as the European Union Council Directives, regulate the minimum degree of pollutant removal for treated municipal wastewater discharged into water or the ground.

Type of NbS: Creation of constructed wetlands.

Why: Wastewater treatment from underground coal gasification.

Benefits: Reduction of pollutants, and reduced toxicity by 90 per cent within 50 days; water made available for non-potable reuse; low-cost technology. The results indicated that the constructed wetlands were an effective technology to clean up the post-processing wastewater from UCG.

Considerations: The appropriate design and operating parameters of the constructed wetland system were essential for achieving satisfactory pollutant removal rate. In environmental monitoring, it is desirable to consider combining the use of traditional physicochemical parameters with ecotoxicity tests to ensure environmental safety.

Source: Jalowiecki *et al.* (2024).

NbS for energy transmission

Energy transmission networks, including overhead power lines, pylons, underground cables and undersea pipelines, play a vital role in delivering energy to people across the ECE region. However, maintaining these networks and minimizing wear and tear during day-to-day operations can be resource intensive. NbS offer a potential opportunity to both enhance these aspects of energy transmission and generate wider benefits for the environment and societal health.

A common challenge for overground energy transmission is managing vegetation, particularly tall trees that may interfere with overhead cables and pylons. Current approaches typically involve removing existing vegetation and undertaking frequent mechanical and manual cutting. These methods can be costly, time-intensive, can unintentionally exacerbate the problem by dispersing seeds, and can lead to loss of ecological connectivity and native biodiversity that is removed in the process.

NbS can provide a more effective and environmentally sound alternative for non-tree-based landscapes. By restoring or managing low-lying habitats, such as peatlands, grasslands or pasture, transmission corridors can be maintained in ways that are compatible with electrical safety, due to their naturally low vegetation height, and supportive of biodiversity. These habitats can preserve ecological connectivity across the landscape, attract pollinators, safeguard native species, enhance the landscape's aesthetic appeal and provide opportunities for local farmers. In some cases, planting thorny shrubs along the edges of corridors can also serve as a passive security measure, helping deter encroachment. NbS can also play a role in increasing public acceptance of energy transmission projects by providing benefits to local communities. These may include aesthetic appeal, improved air quality and recreation opportunities.

Case study 6.7: LIFE ELIA project, in Belgium and France

A prominent example of this approach in the ECE region is the LIFE ELIA project, which demonstrated how electricity transmission corridors can be transformed into biodiversity-rich ecological spaces while reducing maintenance requirements and costs. Between 2011 and 2017, the project restored approximately 130 km of ecosystems along transmission lines in Belgium and France. These included peatlands, grasslands and other habitats with naturally low vegetation. The initiative showed that NbS could break even within 3 to 12 years and become between 1.4 and 3.9 times cheaper than conventional vegetation management over a 30-year period. Additional benefits included increased pollinators, improved carbon storage, and enhanced amenity and aesthetic value for local communities.

However, while the LIFE ELIA project provides a strong demonstration of the potential for NbS in energy transmission corridors, care must be taken to ensure that these approaches are applied in ecologically appropriate contexts. In some cases, parts of the project were implemented in forested landscapes. While management of existing degraded clearings can provide benefits compared to the baseline state, removal of native forest to create open non-native habitats is not considered an NbS, as it can result in significant biodiversity loss. To align with NbS principles, interventions must avoid harm to native ecosystems and generate benefits for both people and biodiversity.

NbS type: various: protection of low-lying ecosystems; restoration of low-lying ecosystems; agroecology.

Why: to maintain the safety of overhead energy transmission infrastructure and reduce maintenance requirements.

Benefits: low-cost solution compared to traditional vegetation periods; habitat for biodiversity and pollinators; carbon sequestration; recreational space for communities; and improved relations with authorities and local communities, including increased acceptance of overhead lines.

Return on investment: 3 to 13 years.

Cost: it was a 6.5-year project of €3 million, co-financed by:

- European Union (LIFE programme): 36 per cent;
- ELIA (Belgian Transmission System Operator: 24 per cent;
- RTE (French Transmission System Operator): 15 per cent;
- The Walloon Region: 25 per cent.

Started in 2011, the project was led by a team of seven people spread across two NGOs: Solon asbl and CARAH.

Partners: ELIA, RTE, SOLON, CARAH, National Forestry Office (ONF), Department of Nature and Forests (DNF).

Considerations: to be considered an NbS, the implementation of a solution must not come at the expense of native vegetation. Therefore, where native forests are replaced with low-lying non-native vegetation, it would not be considered a viable solution. Longer timeframes may be required to measure benefits. This project broke even after 3–12 years and was cheaper when assessed over a 30–year period.

Source: LIFE ELIA (no date) and LIFE Elia-RTE (2018).

For offshore transmission, artificial oyster reefs have been suggested to offer potential benefits to underwater cables. They can colonize underwater transmission infrastructure, providing a barrier that can protect cables from scour, reducing wear-and-tear and helping to preserve their functioning. This, in turn, has potential to reduce operational requirements associated with the maintenance of underwater cables. The use of artificial reefs has been documented for Belgian wind farms that have been operational for 10 years.

Box 6.7: Practical considerations for energy transmission

- **Native habitat:** understanding what the native habitat is will be essential to ensuring a solution is an NbS and can result in biodiversity benefits. Replacing native forests with non-native low-lying vegetation is not considered an NbS, as it will lower biodiversity compared to that of the native habitat. Low-lying native ecosystems, such as wetlands, grasslands and rivers may provide better candidates for overhead transmission infrastructure.
- **Local biodiversity:** the siting of overhead electricity pylons is likely to degrade the local ecosystem. Where possible, care should be taken to avoid biologically rich areas to minimize impacts to biodiversity.
- **Longer timeframes to assess benefits:** as highlighted in the case study above, assessing costs and benefits over longer timeframes can help to make the investment case. The EU ELIA project was assessed to be more cost-effective than traditional management practices when assessed over a 30-year timeframe.

6.3 NbS benefits for water

A sufficient supply of freshwater that meets quality standards is essential for the functioning of societies, through meeting basic needs for domestic water use, including drinking, sanitation and cooking, for agricultural use and food provision, including water for crops and livestock, and for sectors such as health and manufacturing and production.

NbS for potable water

Built infrastructure assets, such as water reservoirs, storage ponds, treatment plants and pipelines, play an integral role in meeting potable water-related development needs and supporting health and well-being across countries. However, NbS have the potential to substitute for built assets and deliver some of the services of the potable water sector (Haggis *et al.*, forthcoming). Through improved ecosystem and land-use management, and the protection and restoration of ecosystems such as forests, wetlands and riparian buffers, NbS can help to reduce requirements for grey infrastructure, and support water services whilst generating a wealth of wider environmental and health benefits through carbon sequestration, air purification, opportunities for recreation, eco-tourism and stress relief (Browder *et al.*, 2019).

NbS can support the provision of potable water supplies including through enhanced infiltration into soils which can help to recharge groundwater supplies and aquifers, by storing water in natural and created ponds, wetlands and floodplains, and by regulating water flows and water quality in rivers (Blicharska *et al.*, 2019; Trémolet and Karres, 2020). Healthy ecosystems located upstream of potable water reservoirs can help to regulate peak flows and reduce requirements for water discharges from dams.

Sedimentation and turbidity of watercourses is a big challenge in water management and can result in costly damage to water reservoirs through wear and tear on built assets and lost storage capacity (Kapos *et al.*, 2019). Water utilities often address these challenges through dredging and desilting and use inputs such as flocculants to help reduce turbidity. However, NbS can be developed to address these issues at their source. For example, the implementation of agroecology practices and forest management can help to stabilize soils and reduce soil erosion, while restoration of riparian buffers and floodplains can capture soils before they enter the river (Trémolet and Karres, 2020). This can reduce the frequency at which dredging is required and reduce water treatment needs and associated costs (Browder *et al.*, 2019). For example, one study reported that a 10 per cent reduction in sediment can result in a reduction of 2.6 per cent in operation and maintenance costs for water providers, while another identified similar cost savings, whereby reducing sediment in water by 1 per cent lowered water treatment costs by 0.19 per cent (Trémolet & Karres, 2020).

In cities and urban areas, NbS such as green roofs and rainwater harvesting systems can be integrated into buildings to capture rainwater for domestic use, which can help to relieve pressure on urban water supplies (Enzi *et al.*, 2017). This offers additional benefits, such as contributing to flood reduction during times of intense rainfall, supporting local heat reduction, helping to shield building roofs from wind and dust, reducing associated wear and tear, and providing small patches of urban green space which can contribute to ecosystem connectivity. In coastal areas, NbS can help to preserve freshwater supplies by acting as a protective buffer and reducing saline intrusion, reducing requirements for desalination treatment (Kapos *et al.*, 2019). For example, in the Netherlands, dunes play a vital role in providing freshwater in coastal areas from underlying aquifers, by acting as natural filters and purifying rainwater. However, the extent to which this can be scaled across coastal areas is questionable because water abstraction from the aquifer can lead to replacement by saltwater, offsetting benefits.

Trade-offs can occur relatively easily within the water sector and between different objectives. For example, the creation and management of urban parks may support water quality in cities, but can require water for irrigation, leading to trade-offs with water quantity. Equally, wetlands can support the provision of water quality benefits and regulate water flows, but can also release GHGs such as methane and nitrous oxide under anaerobic conditions. These have 84 and 298 times higher global warming potential than CO_2, respectively, and both contribute to ozone depletion. These trade-offs need to be assessed and managed as part of the decision-making process.

Case study 6.8: City-level watershed protection in the United States of America

In the late 1990s, New York City commenced a plan to protect its source water supply. It avoided the need to build a US$8–10 billion water treatment facility by investing in NbS across the 2,000 square-mile upstream watershed. Approximately 90 per cent of the city's water is provided by three protected watersheds, which have 75 per cent forest cover and where farmers implement improved agroecology practices under New York City's Working Forest Pollution Prevention programme. The anticipated cost of the conventional treatment plant was US$6 billion to build and US$250 million annually to maintain. In contrast, the NbS was estimated at US$1.5 billion. This also resulted in an injection of US$100 million into the rural economy by providing supplemental income to farmers and forest landowners, paying local contractors to install septic systems and set up stormwater protection measures, and by promoting ecotourism.

Similarly, in Portland, Maine, the protection of forested areas saved water treatment infrastructure costs of US$97–155 million over two decades.

NbS type: restoration of forests; agroecology

Why: improved water quality and reduced water treatment requirements

Benefits: avoided costs of built infrastructure. Investing in NbS avoided the need to build a new water treatment plant. Also reduced costs of water treatment.

Source: Browder *et al.* (2019); Hallegatte *et al.* (2019); UNEP *et al.* (2014).

Case study 6.9: Darkwoods Forest Carbon Project, Canada

The Nature Conservancy of Canada facilitated the purchase of 54,792 hectares of land after a private sale threatened to turn the area of boreal forest into subdivisions and timber extraction zones. Prior to TNC's purchase, the Darkwoods Forest was managed for timber production. TNC purchased the forest for long-term conservation and improvement of ecological function, for climate benefits, biodiversity benefits, water benefits, and other ecosystem services benefits, while retaining substantial net benefits for local communities.

The Darkwoods Forest plays a critical role in maintaining freshwater ecosystems across the province, including 17 watersheds and 50 lakes. The project achieves a significant level of water benefits that improve water quality, quantity, timing of flows, and important aquatic habitat improvements through the retention and management of riparian habitat, watershed-level forests and ecosystems, and road and access management.

Large-scale construction and logging operations in the region would threaten those ecosystems, including a number of endangered species. The project's protected land creates a wildlife corridor between fragmented habitats, along with restoring water quality and degraded land in the region.

The project achieves net GHG emissions reductions through avoided emissions due to conventional logging in the baseline scenario, along with additional carbon sequestration by protecting forests.

Benefits to communities include through allowing low impact backcountry recreation and wildland amenity values, and aesthetic values. The project also participates in various scientific research projects related to key habitat, mapping, threatened species, and other elements related to biodiversity and water.

Type of NbS: protection of forests, watershed ecosystems and riparian vegetation.

Why: the forest was at risk of deforestation for construction and logging operations but play a critical role in freshwater supply and the provision of multiple other benefits.

Benefits: protected water supply and quality across watersheds and lakes; benefitted various endangered species; preserved a wildlife corridor to connect fragmented habitats, carbon sequestration, community access for recreation, visual appeal.

Who: The Nature Conservancy of Canada.

Time: the project was signed as a 100-year project.

Monitoring: Various assessments were conducted, including a baseline assessment, carbon monitoring, biodiversity and water management and monitoring. A management plan is updated every 5 years.

Source: Nature4Climate (no date, d); Ostrom Climate Solutions & TNC (2024).

NbS for wastewater

As populations grow and industrial and agricultural activities intensify across the region, the challenge of wastewater treatment is becoming increasingly complex. Emerging contaminants and growing volumes and types of wastewater pose risks to both environmental and human health. Engineered assets, such as wastewater treatment plants and pipeline infrastructure, are essential tools for effectively and safely managing wastewater. However, a significant portion of wastewater continues to be discharged untreated into the environment. While traditional infrastructure plays a central role in preventing pollution, NbS can substitute for engineered assets and reduce the burden on built wastewater treatment infrastructure.

Pollution from untreated or inadequately treated wastewater can accumulate in the environment, degrading water quality, harming biodiversity and posing risks to public health and well-being. NbS, such as constructed wetlands, can offer more cost-effective alternatives in treating certain contaminants, including for single households, blocks of houses, residential neighbourhoods, commercial areas and small industries (Stefanakis, 2019), and provide co-benefits such as carbon sequestration, habitat and resilience to hazards such as floods.

Case study 6.10: Constructed wetlands at London Heathrow Airport, United Kingdom

London Heathrow airport has piloted the use of constructed wetlands, encompassing reed beds and floating reed platforms, to treat stormwater runoff and wastewater from the airport. The initiative, called Mayfield Farm Treatment System, includes 80,000 planted reeds, demonstrating the potential of NbS in urban contexts.

The treatment system receives effluent collected from the Southern Catchment of Heathrow Airport, a total of 290 ha. During winter operations, weather-related de-icing activity results in large shifts in the flow and concentrations in airport runoff. The biological treatment of used de-icing fluids is challenging because it involves the treatment of a cold and nutrient-deficient wastewater that has variable flow and strength.

A pilot project that consisted of a non-aerated HSSF (horizontal sub-surface flow) wetland system was constructed in 2001. It had a design treatment capacity of approximately 374 kg/day cBOD5 at 40l/s. Upon its success, it was upgraded to an aerated HSSF wetland system which were constructed in 2011 and had a design treatment capacity of 2073kg/day cBOD5 at 80l/s. In actuality they operated at much higher loading rates, up to 12,187kg/day during the 2012–2013 de-icing system. The optimization of the HSSF wetland system led to a dramatic improvement in overall treatment capacity without having to increase the wetland treatment area.

The increased treatment capacity of Mayfield Farm was achieved by retrofitting aeration technology into the existing infrastructure whilst maintaining its flow path configuration. It cannot, however, be assumed that this would be the ideal configuration for all airports when designing a new wetland treatment system. Effective dosing of nutrients throughout the treatment process was required given the de-icing run-off is nutrient deficient; this is required to establish and maintain effective quantities of treatment bacteria for the treatment process.

Type of NbS: creation of constructed wetlands.

Why: to treat wastewaters associated with airport operations (anti-icing fluid).

Wider benefits: the reedbeds are home to warblers, buntings, moths and dragonflies. The outflow pond is home to news and other amphibians, warblers and wintering Water Rail. They have attempted to get the rare Water Avens plant to grow, with some initial success.

Who: British Airport Authorities (BAA) commissioned the constructed wetland project.

Considerations: the location of the treatment works in relation to the runways and runway approaches, available land space, and upstream recovery processes all play a role in the design and configurations of wetlands for treating de-icing fluids at airports. Since wetlands for de-icing treatment in the United Kingdom are event-driven, they behave very differently than systems operating under steady-state conditions such as those operating at Buffalo Niagara International Airport, demonstrating the need for context-specific design.

Cost: £2.6 million (for the 2011 project).

Size: 2.1 hectares, 12 bed aerated horizontal system, balancing ponds, aeration lagoons, rafted reed beds.

Source: Heathrow (no date); Murphy *et al.* (2015); Guymer (no date); Global Wetland Technology (no date).

Constructed wetlands, built at the farm or small catchment scale, can help mitigate the effects of agricultural diffuse load and remove different pollutants from drainage water. They also reduce the impacts of floods by retaining large volumes of water and discharging it slowly. Water retained and treated by constructed wetlands can be used for non-potable uses by humans, farm livestock and wildlife during drought (Kesari *et al.*, 2021). Constructed wetlands also increase biodiversity by providing suitable habitats for plants and animals, as well as having recreational values (EIP-AGRI Focus Group, 2022). Wetlands function as natural filtration systems, removing pollutants from agricultural runoff and wastewater. They are especially effective for filtering out nitrates and phosphorus, improving water quality and reducing risks of waterborne diseases, which is critical for public health.

Constructed wetlands can provide services using no or low energy consumption, depending on the slope. They can treat a variety of wastewater streams, including from agriculture, landfill, mining and industry. There are lower investment costs for small wastewater treatment plants, and low operation costs in particular when gravity is used. However, their feasibility will depend on the context. Constructed wetlands can require relatively large spatial areas, annual cutting of vegetation and removal of weeds, especially during the first years. There can be challenges finding available local plants with suitable characteristics and locally adapted materials (e.g., sands, gravels) for the filter. The fluctuating temperatures of ECE countries poses a challenge to biologically-based technologies—for example, in Armenia, the use of reed beds to treat effluent failed due to the cold temperatures, which lowered treatment performance. In Europe, construction costs for constructed wetlands are considered to be in the same range as conventional technical treatment plants, not taking the area requirement into account (Langergraber, 2013), however some large wastewater treatment plants can have high investment costs (EU4Environment, 2023). However, operation and maintenance costs are lower for constructed wetlands due to less energy demand and technical devices used, and usually decrease with increasing size of the plant (Langergraber, 2013). Case study 6.11 below illustrates how investment in conventional infrastructure provides opportunities to embed funding streams for smaller-scale and pilot NbS projects.

Box 6.8: Practical considerations for wastewater

- **NbS tolerance to temperature fluctuations:** some ECE countries experience large fluctuations in temperatures. It has been reported that in some contexts where constructed wetlands have been piloted, these have failed due to their inability to withstand these fluctuations. Understanding the resilience of constructed wetland species to such extremes and variations in temperature will be necessary for effective service provision.
- **Available space:** constructed treatment wetlands typically require large areas to be effective solutions for water treatment at scale. This needs to be considered in planning processes to ensure that there is a sufficient area available. As with any NbS, evaluation of costs and benefits will be necessary to determine the best use for large areas.
- **Species relevance for wastewater treatment:** evaluation of the best species for treating wastewaters from fossil fuel and biomass can help to ensure that the solution is effective at service provision and is not negatively impacted by the wastewater.
- **Feasibility:** opportunities for using constructed wetlands for treating wastewaters from industry may depend on the type of pollutant and the quantity. Built wastewater treatment assets may still be required for more toxic substances to ensure that constructed wetlands are not contaminated (WWAP, 2018; UNEP, 2023).
- **Time:** where NbS are used, some species may require longer retention types to filter the pollutants (WWAP, 2018; UNEP, 2023).

Case study 6.11: NAWAMED (Nature-based Solutions for Domestic Water Reuse in Mediterranean Countries), Italy

In Italy, domestic water use can be reduced by using constructed wetlands. The NAWAMED aims to lower domestic water use by installing new green and low-cost treatment technologies for wastewater recovery. NAWAMED serves as an example of a holistic approach for innovative nature-based urban transformation. An example is the installation of a constructed wetland plant in the province of Latino (Lazio) in order to solve sanitation challenges.

The Italian project is part of a broader-scale Mediterranean project that runs across Italy, Tunisia, Jordan, Malta and Lebanon. Broader project information is outlined below:

NbS type: created constructed wetlands and green walls.

Purpose: the broader project aims to demonstrate technical and economic feasibility of NbS and low-cost solutions such as green walls to treat non-conventional water resources in schools, universities, public facilities and a refugee camp. Recovered wastewater or storm water will be used for different purposes, such as toilet flushing or irrigation, reducing pressure on potable water supplies.

Expected achievements:

- 8 pilot installations for greywater or rainwater treatment and reuse, including living green walls and constructed wetlands treating flows from a public building, parking area and refugee camp;
- 30 per cent reduction in water consumption at pilot site level;
- 9,000 m^3/year of non-conventional water to be reused at urban or domestic level;
- 15 technical visits to pilot sites;
- 10 training workshops organized for technical staff and decision-makers;
- 1 Mediterranean Policy Document to foster the inclusion of water demand management and non-conventional water resources measures in national policy frameworks.

Project duration: 2019–2023.

Financial data: €3.2 million total budget: EU contribution – €2.9 million; 10 per cent project co-financing.

Benefits: low-cost, water reuse lowers domestic water needs.

Source: Nature4Climate (no date, e); ENI CBCMED (no date).

6.4 NbS for waste management

The quantity of solid waste is increasing across the ECE region, leading to growing pressure on existing waste management infrastructure. Engineered approaches, such as solid waste treatment plants, recycling plants, landfills, incinerators, composting facilities and anaerobic digesters, remain central to the sector. However, NbS can enhance the functioning of the sector, particularly in landfill closure and leachate treatment.

The closure of modern landfills typically involves capping the waste with clay layers to prevent water infiltration, control leachate flows and reduce emissions of gases and odours (Khapre *et al.*, 2019). However, traditional clay capping systems tend to degrade over time, as they can crack and lose integrity, leading to percolation of water into waste and contamination of surrounding soils and water bodies. Phytocapping offers an NbS alternative to clay caps. It uses vegetation and natural soil processes to prevent water infiltration through the interception of rainfall by plant canopies, storage of water in the soil, and evapotranspiration by vegetation (Lamb *et al.*, 2014). Evapotranspiration typically accounts for more than 60 per cent of the precipitation that falls on vegetated landfill caps and is essential for preventing deep drainage into the landfill.

Studies show that, when site-specific conditions are considered in the planning and design phase, phytocaps are at least as effective as clay caps at reducing water percolation into waste. They offer additional benefits including increased cap stability, reduced erosion of capping materials, lower gas and odour emissions, and reduced wind-blown dust and water run-off, leading to improved air quality and reduced environmental contamination. Beyond this, phytocaps have a longer lifespan than clay caps, and lower maintenance and construction costs (35–72 per cent cheaper than clay). The selection of phytocaps over clay caps by solid waste practitioners can both benefit the sector and provide multiple environmental benefits. They support vegetation, such as grasslands, trees and shrubs, which helps restore native biodiversity and ecosystem functioning, such as the provision of pollination, habitat for wildlife and natural heritage value. Re-naturalized landfills have also been shown to lead to health benefits including improved mood through opportunities for walking and recreation, and can provide buffers against dust and the harmful effects of urbanization (Geniole *et al.*, 2016).

In addition to landfill capping, NbS such as constructed wetlands are increasingly used to treat landfill leachate, which typically contains high concentrations of organic matter, nutrients, heavy metals, salts and other pollutants (Kumar and Choudhary, 2018). Constructed wetlands offer a low-cost, effective solution to reduce reliance on engineered treatment systems. They can achieve substantial pollutant removal rates including biochemical oxygen demand (BOD) by 72.2 per cent, chemical oxygen demand (COD) by 56.2 per cent, phosphate (PO4) by 61.0 per cent, total Kjeldahl nitrogen (TKN) by 64.9 per cent, total nitrogen (TN) by 67.3 per cent, ammonia-nitrogen by 68.9 per cent and total suspended solids (TSS) by ~51.8 per cent ± 29 per cent (Bakhshoodeh *et al.*, 2020). Vertical flow constructed wetlands are particularly effective in removing heavy metals, showing average removal of 92.4 per cent for cadmium (Cd), 90.0 per cent for chromium (Cr), 93.3 per cent for nickel (Ni), 84.1 per cent for lead (Pb), 89.3 per cent for zinc (Zn), 93.6 per cent for iron (Fe) and 77.1 per cent for manganese (Mn) (Ibid). These systems could be especially valuable in the ECE region for retrofitting existing landfill sites, improving compliance with water quality standards, and enhancing ecosystem services in both peri-urban and rural areas.

Box 6.9: Practical considerations for waste management

- **Native vegetation:** special attention should be paid to the use of native plants for phytocaps to ensure biodiversity benefits and maximize the resilience and effectiveness of the solution. Native plants can develop into a self-sustaining ecosystem, with reduced need for maintenance using fertilizers, pesticides and irrigation (Rubin, 2006). Plants can be selected based on the design of the landfill surface, depth of plant roots, irrigation and drainage requirements, environmental condition, long-term maintenance requirements, and cost.
- **Proper design and planning:** for landfills, a primary concern in planting NbS on landfill surfaces is ensuring the integrity of the containment system, particularly the potential for roots to penetrate and physically damage the cap, thereby creating entry points for water, or to open cracks in the protective barrier by excessive moisture reduction. If properly designed and implemented, surface integrity can be maintained while supporting various plants, particularly as studies show that roots can grow laterally once they reach the clay cap (Rubin, 2006).
- **Optimal moisture conditions:** water logging and drought stress are major factors that can limit NbS for landfill and can occur at different times of year. Trees and shrubs can help to mitigate water logging through water absorption and use. Landfills in arid environments pose additional challenges for phytocapping as they must be stabilized with sparse vegetation. Various options are available, including adding compost blankets or other organic amendments to the soil to increase water-holding capacity and fertility, shaping the ground to collect and retain water, and using native species (Rubin, 2006). Monitoring of moisture is essential.
- **Terrain and slope:** the shape of landfill which often consists of a mound and steep slopes can impair plant establishment. Site-specific amendments can be used on steeper slopes to help hold seeds and prevent soils from drying out.
- **Suitability:** the use of a phytocap and choice of species will depend upon the local conditions. For example, the peat cap that is used in case study 6.12 requires conditions for developing peat to be present, which includes that the soils are kept in a wet condition.

- **Space required:** where constructed wetlands are deployed, these may require more space than conventional treatment technologies, therefore practitioners will need to determine whether sufficient space is available to reach the desired treatment capacity.
- **Effectiveness validation:** the effectiveness of pollutant removal by constructed wetlands may vary depending on the type of constructed wetland, species and pollutant type. These will need to be carefully considered as part of the assessment process. Equally, for phytocaps, validating the choice of natural cap requires a good understanding of the processes involved, particularly at the boundary layer between the landfill and the ecosystem. The question of whether the solution is capable of absorbing the range of contaminants is relevant.
- **NbS tolerance to temperature fluctuations:** some ECE countries experience large fluctuations in temperatures. It has been reported that in some contexts where constructed wetlands have been piloted, these have failed due to their inability to withstand these fluctuations. Understanding the resilience of constructed wetland species to such extremes and variations in temperature will be necessary for effective service provision.
- **Evaluation of costs and benefits over long timeframes:** some constructed wetlands have higher upfront costs and lower maintenance costs, and therefore their treatment cost per unit of wastewater is expected to decrease over time. Assessing costs and benefits over longer timeframes can help to make the business case for NbS compared to conventional solutions.
- **Provide adequate soil quality and depth:** for phytocaps, these factors affect the feasibility of planting and to reduce risk that trees are uprooted by windthrow (Rubin, 2006).
- **Active management:** active management may be required for phytocaps while they develop, as discussed in case study 6.12. Eventually, once that cap has developed, less management is required compared to conventional caps.
- **Allow sufficient time for phytocaps to develop:** an important aspect of the development of phytocaps is time. In the case of Volgermeerpolder in case study 6.12, a period of at least 30 years was expected.
- **Landfill gas:** these can create a hostile environment that can impact NbS due to lack of oxygen in the root zone. This may need to be addressed, such as through gas collection systems or use of methanotrophic bacteria which can consume landfill gas (Rubin, 2006).
- **Phytocap maintenance:** will be required generally during the first 5 years, and include activities such as control of invasive species, re-seeding and irrigation (Rubin, 2006). Longer-term maintenance to address invasive species and remove any plants affected by windthrow, disease, drought, frost, etc.

Resources:

- More information on phytocapping, in the context of the United States of America (but applicable more broadly) can be found at Rubin (2006).

Case study 6.12: Natural Capping of the landfill Volgermeerpolder, the Netherlands

The Volgermeer is an area of approximately 105 ha, located 5 km north of the city of Amsterdam in a marshy polder with shallow groundwater, open water and peaty soils. In the 20th century the Volgermeerpolder was used as a dump site for domestic and industrial waste. This included large amounts of chemical waste, making it one of the most heavily contaminated areas in Western Europe.

In the 1970s, discussion began about the risk of uncontrollable spreading of toxic waste into the environment. After closure, the site was isolated in order to prevent the spreading of pollution. Over a period of 30 years, the quality of the groundwater surrounding the Volgermeerpolder was monitored. It was found that the waste did not pollute the groundwater in the surrounding polder system, which consisted of peat meadows. It was concluded that the peat efficiently functioned as a natural barrier and prevented the spreading of contaminants. This triggered the question as to whether the same material could effectively be used for capping.

After the discovery that peat functioned as a natural barrier, it was decided that for remediating the Volgermeerpolder it would be sufficient to only cover the landfill, and that complete isolation of the landfill or placement of a leachate-interception system was not necessary. In 2001 the consortium ACV—Advies Combinatie Volgermeerpolder—started remedial planning and design for the Volgermeerpolder. The cap construction started in 2005 by covering the landfill with several surface sealing layers of soil and HDPE (high-density polyethylene) foil and was completed in 2010. The capping is now in the management phase.

The HDPE foil used to cover the landfill will normally have to be replaced after some time due to leaks in the foil. To avoid this expensive operation, ACV developed the "natural cap", which involves a gradual functional replacement of the standard cover (soil and synthetic foil) by a natural layer of peat that develops over time. This is based on the notion that the lifespan of the initial synthetic foil (30–100 years) will allow the natural peat layer to develop. In the Volgermeerpolder, the foil will not be removed because its function is taken over by the developing peat layer. To start the peat development, swamp-like conditions were created on top of the cover in paddy-fields, which facilitate water storage and water level control.

Active management was used, to maintain the correct conditions for peat to form. For example, to maintain wet conditions across the year, water balances were made, and buffer paddy fields were created where rainfall is stored. Water from these buffers can be used to maintain the minimum water levels for peat development by actively pumping water.

The phytocap provides additional benefits in terms of carbon storage and supports local biodiversity through the provision of habitat, including acting as a corridor for grass snakes.

NbS type: phytocap creation or restoration of natural ecosystems.

Why: to cover a landfill and reduce local pollutants.

Benefits: reduced built infrastructure components, reduced pollution, carbon sequestration, habitat for biodiversity, restoration of ecological corridors, lower cost, longer lifespan of cap solution.

Source, and further information: EcoShape (no date).

7. Measuring the effectiveness of nature-based solutions

Key messages

- Robust monitoring is essential to demonstrate the effectiveness of NbS, inform planning and investment decisions, and build a compelling evidence base for scaling.
- Many NbS projects lack long-term monitoring and, where it exists, it often focuses on short-term outputs rather than long-term outcomes.
- Standardized indicators are needed to compare NbS performance across sectors and contexts, and to align with global frameworks like the SDGs, Paris Agreement and Kunming-Montreal Global Biodiversity Framework.
- Monitoring should cover environmental, health, social, economic and governance dimensions, including biodiversity, climate mitigation, public health equity, and cost-effectiveness.
- Participatory governance and cross-sectoral coordination are critical to ensure inclusive, context-relevant monitoring and adaptive management.

Practical tips

- Use outcome-oriented indicators rather than just output metrics.
- Establish baseline assessments before implementation to enable meaningful comparisons and track progress.
- Monitor across the full lifecycle of NbS projects—from design and implementation to long-term maintenance and evaluation.
- Disaggregate data by income, gender, age and ability to assess equity in access and benefits.
- Leverage existing tools and frameworks, such as IUCN Global Standard for NbS, EU Handbook for Evaluating NbS Impact, UNEP's NbS Toolbox, Urban Forest Compass and Urban Nature Index, and Ecosystem Services Valuation Database.
- Engage communities and stakeholders in monitoring to ensure relevance, build ownership and support long-term stewardship.

The previous chapters demonstrate the potential benefits that NbS can provide. To inform planning and investment decisions, including which NbS options are best suited to address a given service need in a particular country or context, and compare these alongside other NbS, hybrid (green-grey) and built infrastructure options, data on the costs and benefits of NbS are needed, including their effectiveness at service provision. This chapter discusses the importance of monitoring the effectiveness of NbS benefits and provides an overview of existing monitoring tools and frameworks.

7.1 Importance of measuring NbS effectiveness

Measuring the effectiveness of NbS outcomes is essential to build a robust evidence base, inform infrastructure planning and decision-making, attract funding, inform policy and ultimately scale up NbS deployment. Given that NbS can take time to develop and provide benefits, long-term monitoring of outcomes is critical to capturing their full impact. However, many projects still lack robust monitoring components and, where monitoring does take place, it is often limited to the short term (often less than five years).

Monitoring should span the entire project lifecycle, from initial design and implementation through to long-term maintenance and evaluation. This includes tracking financial costs, ecosystem health and long-term environmental, social and economic impacts. Using standardized indicators and metrics is essential to enabling comparison of outcomes across different NbS types, sectors and geographical contexts, particularly given that the effectiveness of these solutions may vary depending on the context. The indicators monitored should also align with national and international goals, to support countries as they track their progress towards agendas such as the Sustainable Development Goals, Kunming-Montreal GBF and Paris Agreement.

Indicators are central to demonstrating the effectiveness of NbS in supporting ecosystem services to meet the primary intended need for which the NbS was deployed, and wider co-benefits. Commonly reported indicators include the number of trees planted, hectares of ecosystems restored, protected or under improved management, and stakeholder participation metrics, such as the number of farmers engaged in a project. While useful, these tend to reflect outputs rather than outcomes, often at the request of project funders. To fully assess impact, outcome-oriented indicators, such as reductions in flood peaks flows, improvements in air and water quality, decreased soil erosion, or improved mental well-being of residents, are essential, yet often underreported. Evaluating NbS should be done in a way that enables comparative assessment of their performance relative to conventional grey infrastructure, as well as the additional co-benefits that can demonstrate the multifunctionality of NbS and help to make the case for investment in nature-based approaches.

A baseline assessment will often be required to measure outcomes in relation to the baseline context, including the extent and condition of the ecosystem. This should be broad enough to understand the ecological state, drivers of ecosystem loss, and opportunities for improvement.

Implementing robust monitoring systems presents several challenges. These include the need for long-term funding, access to ecosystems, including those on private land, and the availability of trained workforces and technologies. Expertise in field data collection, statistical analysis, programming and data management and information sharing is often required, along with suitable technologies for measuring and analysing outcomes (ECE/FAO, no date).

There is an overarching need to develop and implement appropriate and standardized indicators, and methods and systems for monitoring and information management, including through the application of new technologies, to fill data gaps for improved decision-making and ensure timely availability of information. The following sections provide information on those that are already in use.

7.2 Environmental impact

NbS can support multiple benefits for the environment and biodiversity, including improved ecosystem health, biodiversity conservation, climate mitigation and pollution reduction. Measuring these environmental impacts is essential to evaluate the effectiveness of NbS in relation to conventional infrastructure, and to inform planning, policy and investment decisions.

Ecosystem and biodiversity metrics

Biodiversity underpins ecosystem function and resilience (Key *et al.*, 2022). NbS can contribute to biodiversity by supporting native species, enhancing structural diversity and improving connectivity between habitats. As defined in the IUCN Global Standard for NbS (2020), at a minimum, the NbS should include the following for each management target related to conservation and restoration of biological diversity and ecological integrity:

- Specific measurable variable(s) associated with the management target (e.g., number of species / ha, percentage canopy cover)
- Action (e.g., increase, decrease, maintain)
- Quantity (e.g., 50 per cent)
- Time-period (e.g., 5 years).

Examples of relevant biodiversity indicators include:

- *Habitat extent and diversity*: area and diversity of ecosystems (e.g., forests, wetlands, grasslands).
- *Ecosystem connectivity and fragmentation*: degree of connectivity between habitat patches, which is important for ensuring the movement of species, genes and overall resilience of the NbS.
- *Species richness and abundance*: native species supported by the NbS.
- *Functional and structural diversity*: including canopy cover, urban vs peri-urban areas, size of parks and green spaces.

The UN Urban Forest Compass, developed by ECE, provides a standard structure to assess and compare urban forest canopy cover, diversity, connectivity, structure and management among cities nationally and internationally.

Environmental performance metrics

NbS can also support measurable improvements in air, water and soil quality, temperature regulation, water flows and availability. Relevant indicators include:

- *Air quality*: reduction in pollutant concentrations (e.g. $PM_{2.5}$, NO_2) and frequency of exceeding air quality standards (ECE/FAO, no date), related to NbS interventions such as urban parks and street trees.
- *Urban temperature regulation*: surface and ambient air temperature reductions in areas near to NbS. Metrics can include average °C change accounting for NbS extent and proximity.
- *Flood mitigation*: peak river flow attenuation according to NbS interventions, such as percentage catchment forest cover.
- *Water quality and storage*: water storage and reuse (e.g., m^3 retained per m^2 of green roof); treatment throughput, effluent quality and nutrient removal in NbS-based water and wastewater treatment systems (e.g., constructed wetlands).
- *Soil health and erosion*: indicators such as increased soil retention, reduced erosion rates and nutrient runoff can be linked to sedimentation and dredging requirements in sectors such as hydropower, water transport and potable water.
- Other examples include the measuring of storm water runoff reduction for water utility companies, funded by the Environment Impact Bond by the DC Water in the United States of America (DC, Water is Life, no date).

Climate mitigation metrics

NbS can support climate mitigation by storing carbon and reducing energy demand. Relevant indicators include:

- *Carbon sequestration:* measurements of carbon stocks in above- and below-ground biomass and soils. Monitoring changes over time supports national and global GHG accounting under the Paris Agreement.
- *Energy performance*: energy inputs required to operate NbS (e.g., pumps for constructed wetlands) can be compared to conventional infrastructure options. Where NbS, such as green roofs, walls and street trees are integrated into cities, monitoring of building energy consumption can help track the benefits that NbS brings for insulating buildings and reducing heating and cooling requirements.

Land and space requirements

NbS often require more physical space than grey alternatives, which can be a challenge in urban or spatially constrained contexts. Metrics such as land area per unit of service delivered (e.g., hectares of wetland per volume of water treated, m^2 of green space per degree of cooling, or per cent of catchment forested) can help decision-makers assess feasibility and trade-offs in different contexts. While larger space requirements can be a barrier in denser urban areas, the multifunctionality of NbS and ability to provide services such as habitat, recreational opportunities and climate mitigation simultaneously, can minimize this trade-off in some cases.

Climate resilience

To assess the baseline of climate resilience and build a rationale for NbS integration, there is some standardization of resilience benefits, with emerging initiatives for standardized resilience risk assessment and frameworks such as:

- Global Infrastructure Risk Model and Resilience Index: GIRI (GIRI, n.d.)
- Physical Climate Risk Appraisal Methodology (PCRAM) (IIGCC, n.d)
- FAST-Infra Label (FAST-infra, n.d).

GIRI, created by the Coalition for Disaster Resilient Infrastructure (CDRI) and UNDP, is the first performance indicator for resilience per country, enabling the assessment and ranking of countries based on their resilience levels. The investing community has begun efforts to integrate climate physical risk assessment into investment decision-making through the initiative known as the Physical Climate Risk Appraisal Methodology (PCRAM). PCRAM factors in physical climate risks, such as floods, heatwaves and storms, and support investors to identify resilience investment opportunities according to financial materiality. The FAST-Infra Label Framework, developed by a multi-stakeholder working group led by the Global Infrastructure Facility (GIF), provides self-assessment tools for infrastructure on four key dimensions: environment, social, governance, and adaptation and resilience. These initiatives are promising; however, it is still far from mainstreaming climate resilience in business decision-making.

7.3 Health and well-being

NbS can provide measurable public health benefits through improved environmental quality, access to nature and climate resilience. These health benefits have direct implications for individuals, but also for the economy through their influence on workforce productivity and well-being. Monitoring health outcomes helps to demonstrate the full value of NbS and support public health planning. Relevant indicators are presented in Table 7.1.

Table 7.1: Health and well-being indicators

Issue	Possible indicators
Physical health	• *Respiratory and cardiovascular health*: improvements in air quality associated with NbS can lead to reductions in respiratory diseases such as asthma and heart disease. Tracking indicators such as the number and severity of cases, hospital admissions, or emergency visits can support monitoring on these benefits. • *Temperature-related illnesses*: NbS can reduce exposure to extreme heat, lowering risks of heat stroke and heat-related mortality. Metrics may include the percentage of population with access to heat-mitigating NbS, number of heatwave-related cases, heat-related deaths or hospital admissions. • *Physical activity and obesity*: accessible and safe green spaces can promote physical activity. Monitoring may include obesity prevalence changes over time, frequency of park use, and data on physical activity levels.
Mental health	*Stress reduction*: nature has been linked to lower levels of anxiety, depression and stress. Metrics may include self-reported or general practitioner (GP)-reported mental health; use of green spaces for relaxation or social interaction; and prescriptions for mental health medication as a proxy indicator.
Workforce health	Workforce health impacts can be tracked through analysis of absenteeism rates, number of sick days taken and self-reported well-being, particularly in relation to respiratory, heat-related or mental health conditions. Workplaces may gather data through workplace surveys, including on whether employees are reporting improved well-being or reduced stress, and burnout.
Equity in access	Measuring who benefits from these outcomes is essential. Indicators may include the number and percentage of residents with access to NbS spaces, disaggregated by income level (e.g., low-income, high-income). Other health outcomes as described above can be disaggregated by income, age, gender and able/disabled populations.

7.4 Social and economic benefits

Measuring the social and economic benefits of NbS is essential to demonstrate their value relative to conventional infrastructure. Robust monitoring of these benefits supports more holistic decision-making and helps to ensure that NbS generate inclusive outcomes.

Employment

Mainstreaming NbS within infrastructure systems is likely to impact employment patterns. In some sectors, NbS may reduce the need for conventional built infrastructure and associated labour, but increase nature-based job opportunities (ILO, 2024). For example, watershed restoration can reduce the need for built water treatment infrastructure, reducing construction and water treatment jobs, but increasing jobs in ecosystem restoration, maintenance and monitoring. Hybrid infrastructure solutions may generate even more employment by creating NbS jobs alongside conventional built infrastructure jobs. Measuring job creation and labour changes associated with NbS can facilitate understanding of their economic impacts. Metrics could include the number of jobs created or transformed, disaggregated by gender to enable monitoring of benefits to women, and account for the quality of employment—jobs generated through NbS should be safe, equitable and well-compensated, aligned with the International Labour Organization's standards for decent work (ILO, 2024).

Capital and maintenance costs

Comprehensive accounting of NbS costs is vital to assess cost-effectiveness and support comparisons with nature-based and built infrastructure alternatives. Capital cost estimates should be comparable to conventional infrastructure, and include aspects such as costs of labour, site preparation, materials, land acquisition or leasing, and equipment needs. Understanding how these financial aspects vary will be important for understanding the financial viability of NbS projects in different contexts. For example, while NbS may require lower costs of materials where the intervention is to protect an existing ecosystem, they may have higher land costs due to the larger space requirements that some NbS need.

Maintenance and monitoring costs are also integral components of decision-making and therefore important to measure as projects evolve. Maintenance costs may include expenses related to pruning, weeding, irrigation, clearing litter, removing invasive species, and the costs of staffing and transport (UNEP, 2023). Monitoring costs may include expenses relating to staff training, technology purchases, or licensing required for data access and monitoring. Reporting on maintenance and monitoring frequency and intensity is necessary to estimate total costs and compare long-term affordability relative to grey infrastructure and will be essential for ensuring the necessary finance is available to fund these aspects.

Broader economic benefits

NbS can generate wide-ranging economic returns, for example through increased property prices, and amenity value which attracts visitors, leading to enhanced local spending and tourism. For example, urban green spaces can support air quality and urban heat island mitigation and simultaneously increase restaurant patronage by as much as 50 per cent (UNEP, 2023). Parks and nature reserves can provide valuable opportunities for recreation and exercise and can also increase property prices by up to 20 per cent (Kapos *et al.*, 2019; UNEP, 2023). Well managed green spaces can attract businesses to the area, leading to improved economic investment and local services (GMCA, 2019). NbS can also attract tourists to the area—countries with biodiversity hotspots can experience faster growth in tourism investments (Blicharska *et al.*, 2016). However, such benefits must be carefully managed to avoid overuse or degradation of natural resources. Monitoring indicators such as tourist numbers, local business revenues and changes in property values can help to quantify these broader economic benefits that NbS can support.

Avoided economic damages and losses

By protecting infrastructure and associated services from climate impacts, NbS can help to avoid economic damages and economic losses that would otherwise occur when infrastructure networks are damaged and disrupted. Some studies are already accounting for these benefits. For example, mangroves are estimated to reduce annual expected flood damages to property by US$11.31 billion in the United States of America, based on a global study (Menendez *et al.*, 2020).

Where avoided annual economic damages and losses are quantified, these can be directly compared to the performance of conventional infrastructure adaptation options. These values reflect the direct costs of repairing or replacing damaged infrastructure assets, and the wider indirect economic losses that occur from service disruption, such as power outages. Ensuring these hazard mitigation outcomes are monitored in relevant projects can further help to build an evidence base and inform future decisions on NbS investments.

7.5 Policy and governance

Effective measurement of NbS requires supportive policy frameworks and governance systems. Strengthening these frameworks is essential to ensure that NbS are not only implemented, but that they are also systematically monitored and evaluated over time, enabling adaptive management and the development of a robust evidence base that can inform future decisions. This includes the development of standardized indicators on the costs and benefits of NbS, with a strong focus on outcomes, which can be mainstreamed across sectors, institutions and geographies.

National and local policy alignment

NbS monitoring should be aligned with national and subnational development priorities, including climate adaptation and mitigation strategies, biodiversity targets and sustainable infrastructure planning. Monitoring data should inform and be integrated into existing systems for reporting progress towards the SDGs, Kunming-Montreal GBF, and Paris Agreement through instruments such as NDCs, NAPs and NBSAPs.

Legal and regulatory frameworks can formalize the requirement to monitor NbS performance over time. Stable funding mechanisms are also necessary to support monitoring activities, from baseline assessments to regular long-term evaluation. In the ECE region, Environmental Performance Reviews offer a critical opportunity to assess how ecosystems have changed over past decades and can inform baseline assessments and future targets for NbS that can be integrated into monitoring frameworks. For larger infrastructure projects, governments and funders can require NbS monitoring and reporting as part of project approval processes.

Participatory governance

Inclusive governance processes are essential to ensure that monitoring systems reflect local needs and priorities, embed traditional and indigenous knowledge, and involve a broad range of stakeholders, for example:

- *Community-based monitoring*: local and indigenous communities can play a vital role in data collection and stewarding NbS long-term. Securing local buy-in for NbS is key for the resilience and longevity of NbS long-term, as it can feed back into improved local governance. Policy frameworks should actively support and embed community participation in monitoring efforts.
- *Cross-sectoral coordination*: the costs and benefits of NbS are likely to be distributed across sectors, requiring collaboration across sectors including water, energy, transport, agriculture and health. Effective monitoring requires collaboration amongst diverse stakeholders, including NGOs, academic institutions, farmers, private sector actors and government ministries. Establishing coordinating platforms and working groups can help align data collection and sharing.

Box 7.1: Resources to support the monitoring and evaluation of NbS projects

- The ECE Environmental Monitoring and Assessment Programme assists countries in their monitoring and assessment efforts through **Revised Guidelines for Environmental Indicators** (ECE, 2023e) and the first of their kind **Guidelines for national biodiversity monitoring systems** (ECE, 2023f).
- ECE monitors biodiversity through **biodiversity-related forest indicators** (Forest data, n.d.) in the pan-European region. A **Joint pan-European Data Collection platform** has been developed to provide comprehensive information on forests and the environmental, economic, and social dimensions of sustainable forest management in the region (FAO, 2020). To help upgrade forest biodiversity monitoring systems, ECE developed **Guidelines for the Development of a Criteria and Indicator Set for Sustainable Forest Management** (FAO, 2019) and contributes to the "**European Forest Biodiversity Indicators at a Glance**" (Forest Europe, 2023).
- The **EU Handbook for Evaluating the Impact of NbS** (European Commission, 2021) provides a practical impact assessment framework covering twelve societal challenge areas (e.g., climate resilience, health, biodiversity, economic opportunities). It includes methods and indicators to support robust impact evaluations and evidence-based policy. It aims to support practitioners in developing robust impact evaluation frameworks for NbS and support the development of an evidence base regarding impacts.
- The **IUCN Global Standard for Nature-based Solutions** is a globally recognized framework for the verification, design, and scaling of NbS. It consists of eight criteria and 28 indicators, supported by **guidance documents** and a **monitoring checklist** to track outcomes across environmental, social and economic domains. It is accompanied by in-depth guidance which includes the scientific background for NbS and guidance on the criteria and indicators (IUCN, 2020b).
- The UNEP Climate Finance Unit developed the **Positive Impact Indicators Directory** (UNEP, no date, d) together with the impact-focused financial community. This has been designed to help harmonize monitoring and reporting across a range of environmental and social impact areas: biodiversity, sustainable production, climate action and sustainable livelihoods.
- GI-VAL (Green Infrastructure Valuation Toolkit). This has been developed in the context of the United Kingdom, designed to help quantify and communicate the diverse benefits of green infrastructure. It provides a robust framework for assessing and demonstrating the impact of green investments (Mersey Forest, no date).
- NbSI **Monitoring Outcomes Tool**: provides a guide on relevant metrics for measuring biodiversity outcomes and a monitoring tool which includes links to various metrics that can be monitored (NbSI, no date, i).

There are various tools and frameworks that can support NbS projects across the lifecycle and the measuring of NbS outcomes. These can be found in Annex 5.

7.6 Further considerations

NbS are receiving increasing attention and recognition for the benefits they can bring to ecological and social systems. International agendas increasingly include NbS among the practical and effective actions that can support defined climate and biodiversity targets. However, there is a lack of data and processes for monitoring, reporting and verifying the effectiveness of NbS solutions, which can hinder their adoption and diffusion. The absence of structured forms of performance monitoring constitutes a barrier to accessing funding mechanisms for the implementation of these projects. Without solid and verifiable data, it is difficult for investors, financial institutions and policy makers to conduct adequate due diligence processes. This prevents proper capital planning, accurate risk assessment and, more generally, the integration of NbS into traditional financial mechanisms. To overcome these obstacles, it is crucial to develop standardized indicators and methodologies for assessing and reporting the environmental, social and economic performance of NbS.

Digital technologies supporting NbS projects: case study–a transition to sustainable ports

Digital and innovative technologies—such as the Internet of Things (IoT), Artificial Intelligence (AI), virtual and augmented reality, automation and blockchain—are becoming key prerequisites for optimizing operations, enhancing and guaranteeing port system resilience, promoting sustainable development, and ensuring high safety standards for both port users and port workers, also contributing to the overall sustainability of the whole maritime international supply-chain (Parola *et al.*, 2021). The evolution of emerging digital technologies has greatly improved all the processes and operations which concern data gathering, storage, analysis and reporting, thus enabling new services and added value across the logistics chain, reducing costs, improving efficiency, accelerating digital transactions and creating new business opportunities. In the coming years, maritime-port logistics will face substantial changes due to the widespread introduction and adoption of digital technologies and innovative standards. Collecting, storing, and using "big data" (large datasets analysed by computers to reveal patterns, trends and connections) will become increasingly critical for efficient port operations and competitiveness. Digitalization will reduce logistic operation times, yielding dual positive effects: lower operating and management costs as well as reduced emissions and consequent negative externalities. Improved logistics performance, guaranteed by smart technologies, is demonstrated to reduce environmental and local community impacts generated by port operations and processes.

Initiatives aimed at digitalization and automation significantly impact port productivity. Introducing these innovations enhances operational efficiency, markedly reducing time, costs, space and equipment needs. Remote-control systems help optimize operations and reduce manual interventions, enabling faster, safer and more reliable processes.

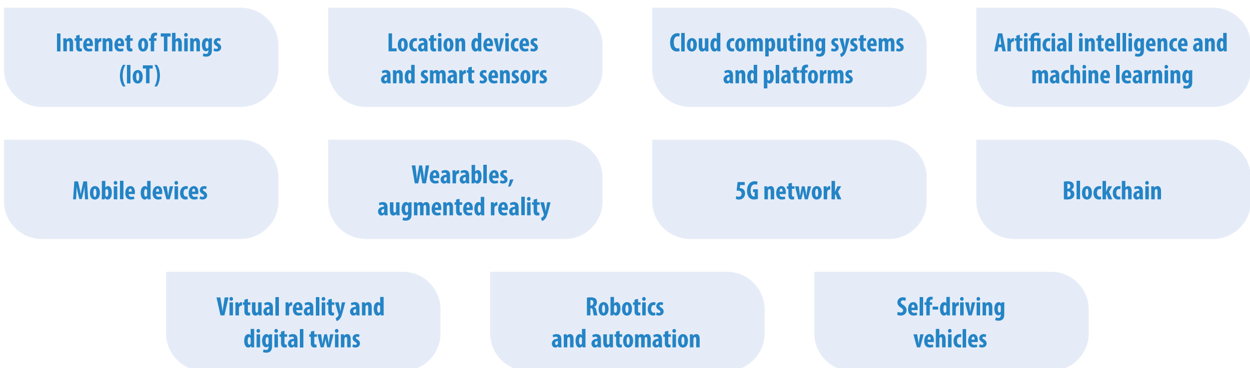
In parallel, adopting advanced monitoring technologies is becoming crucial for enhancing port safety and security. Ports increasingly equip themselves with advanced software and hardware infrastructures to protect port areas from potential threats, including cyberattacks.

Beyond operational and security aspects, the "smart" dimension of ports generates significant environmental benefits. Digital technologies play a key role in supporting environmental performance monitoring, promoting more conscious and sustainable resource management. Specifically, intelligent sensor-based systems enable real-time measurement of air emissions, noise pollution and water quality, providing an integrated view of environmental impacts from port activities.

Digital technologies have also been demonstrated to contribute significantly to improving energy management practices in ports. Integrating predictive algorithms allows more accurate energy demand forecasting, enabling energy management systems to reduce waste and optimize port-related energy consumption.

Given the above, it can be argued that the smart dimension constitutes a fundamental pillar for the implementation of a sustainable port model, where intelligent infrastructures and digital technologies serve as enablers of operational efficiency, environmental impact mitigation and improved energy performance. Within this framework, particular emphasis should be placed on the strategic potential of NbS, which, when synergistically integrated into the digital and managerial architectures of "Smart Ports", can significantly enhance environmental resilience and climate adaptation capacities. The integration of digital innovation and nature-based approaches not only strengthens the sustainability of port systems, but also supports their systemic dimension, enhancing the integration between physical infrastructure, ecological functionality and operational governance.

Figure 7.1: Emerging digital technologies enabling the development of Smart Port infrastructure



8. NbS in Environmental Performance Reviews

Key messages

- EPRs are a powerful tool for aligning national environmental, climate and development strategies, and offer a unique platform to mainstream NbS across sectors.
- EPRs can help identify opportunities and gaps in national policy frameworks, including where NbS can be integrated into infrastructure, biodiversity and climate planning.
- The EPR process fosters multi-stakeholder engagement, bringing together government, civil society and international experts to co-develop actionable recommendations.
- While some countries have begun referencing NbS in their EPRs, systematic integration remains limited, and there is significant potential to strengthen their inclusion.
- EPRs can serve as a starting point for scaling NbS, especially when recommendations are translated into national roadmaps, investment plans and cross-sectoral strategies.

Practical tips

- Use EPRs to identify entry points for NbS in national infrastructure, biodiversity and climate policies.
- Leverage EPRs as a platform to integrate NbS into national policy frameworks.
- Include NbS explicitly in EPR recommendations and make links to SDGs, NDCs and NAPs, as appropriate.
- Engage a wide range of stakeholders—including ministries, local authorities, NGOs and academia—during the EPR process to ensure diverse perspectives on NbS.
- Leverage EPR findings to develop bankable NbS projects and attract climate finance.
- Track and document NbS references in EPRs to build a regional evidence base and share lessons learned.

This chapter provides an overview of the Environmental Performance Reviews (EPRs), their value in supporting cooperation across sectors and stakeholder groups, and for aligning strategies towards different policy objectives. Through their expert review process, they provide a unique tool for aligning common datasets across policy goals, developing plans and strategies, including for the development of supportive enabling environments in the form of policies and capacity building. The EPR process presents a significant opportunity to support countries in scaling up and mainstreaming of NbS. This chapter concludes with an overview of examples of NbS within existing EPRs, lessons learned and good practices.

8.1 Overview of EPRs

An EPR is an independent, external assessment of the progress a country has made in reconciling its environmental and economic targets and meeting its international environmental commitments. The EPR Programme of the ECE originated from the EPR Programme of the Organisation for Economic Co-operation and Development (OECD), which was launched in 1991 to help OECD countries improve environmental management in their countries. The Programme was extended to the ECE region in 1996.

The ECE EPR Programme assists and supports ECE member countries:

- In assessing and improving their environmental management and performance—it evaluates a country's efforts in managing natural resources, reducing and reversing negative trends.
- It examines how the environment is incorporated into socioeconomic policies, highlights policy gaps, and promotes information exchange on policies and experiences among countries.
- It helps in the integration of the environmental policies into relevant sectors such as agriculture, energy, transport and health.
- It promotes greater accountability to the public.
- It strengthens cooperation with the international community and contributes to the achievement and monitoring of relevant SDGs (ECE, no date, h; ECE, no date, i).

The EPR process is voluntary, undertaken only at the request of the country. It consists of six steps: preparation, 8–12 day in-country review mission, expert review, peer review, publication and launch (ECE, 2022c). There have been several cycles of EPRs to date:

- *First-cycle EPRs:* carried out since 1995, they establish baseline conditions regarding trends, policy commitments, institutional arrangements and routine capabilities for conducting national evaluations.
- *Second-cycle EPRs:* carried out since 2000, they assess progress and help to stimulate greater accountability. Emphasis is placed on implementation and financing of the environment policy, integration of environmental concerns into economic sectors, and promotion of sustainable development.
- *Third-cycle EPRs:* carried out since 2012, include environmental governance and financing in a green economy context, countries' cooperation with the international community and environmental mainstreaming in priority sectors.
- *Fourth-cycle EPRs:* carried out since 2023, they encourage countries to undertake further reviews and elaborate road maps to implement recommendations. Key additions include the possibility to include a nexus-related chapter, such as on air-transport-health, or an integrated chapter on greening selected sectors.

8.2 Value of EPRs in investing in countries and fostering multisectoral cooperation

An important feature of the EPRs is their ability to foster multisectoral cooperation. They bring together various stakeholders across the entire process of the EPR to facilitate a holistic, cross-cutting approach. From the early stages of the process, a team of international experts is formed to undertake the in-country review mission, which will conclude with an analysis and the generation of recommendations that are specific to the country (ECE, no date, j). Experts span a broad range of backgrounds and are provided in-kind by countries and organizations and through ECE consultancies. The scope of each EPR is agreed with the Government of the reviewed country during the preparation step. During the in-country review mission, the international experts meet with a broad range of stakeholders, including representatives of Government, Parliament, judicial institutions, local authorities, NGOs, academia and business, as well as international organizations active in the country under review, who share expertise and experience and provide input on the themes covered by the EPR. Multistakeholder discussions are undertaken to identify any gaps in existing environmental, climate and development policies, including in areas such as water management, infrastructure and disaster risk reduction. A national coordinator supports the EPR, and a national contact person is appointed for each chapter. They ensure that international experts meet all relevant parties during the in-country mission.

EPRs also aim to generate a greater involvement of the public in debates and decisions on environmental issues.

The final stage of the EPR process is the launch of the EPR. This involves national environmental authorities, other relevant ministries and agencies, country offices of international organizations and NGOs. Launch events vary depending on the country, but may include press conferences, presentations at parliamentary committees, seminars for international organizations, workshops for government officials with participation of NGO representatives and the public, or a combination of any of the above.

Dissemination of environmental information is a key element of the EPR process. The reports are available in English. To make the information accessible, efforts are made to provide reviews in the national language of the reviewed countries. Printed copies are distributed free of charge to the national environmental authorities, and electronic versions of all reports can be downloaded for free on the ECE website.

8.3 Aligning development with sustainability and climate resilience goals

EPRs are a powerful tool for supporting countries to align development with sustainability and resilience goals. They help to identify relevant environmental challenges that exist within the country and assess the impact of human activities on the environment and human health. This includes an assessment of the vulnerability of different sectors to climate change, as well as the impacts that arise from development such as land use change, expansion and intensification of agriculture, unsustainable production and consumption, and GHG emissions and pollution, which have negative consequences for nature and people. The impacts of economic development across sectors are analysed in all EPRs that are undertaken, while some EPRs also include a specific chapter on health and the environment.

Through the identification and analysis of sector-specific risks and vulnerabilities, the EPRs help to understand the environmental and governance needs and provide relevant recommendations and actionable insights that are tailored to the relevant country. For example, EPRs often result in recommendations that countries integrate climate considerations, such as mitigation or adaptation, into national planning and develop action plans for each sector that account for future climate change impacts. In doing so, countries can strengthen their efforts and policies relating to sustainable development, climate mitigation and adaptation. EPRs do not only provide hard impact targets but also targets for the enabling process that help to deliver on them. EPRs can often be used as a basis for transforming recommendations into bankable projects, providing both short-term and long-term benefits through more effective national policy development and by addressing key gaps relating to climate change and sustainable development. Following the EPRs, countries have committed to implement these recommendations, demonstrating the usefulness of the EPR process. The implementation rate of EPR recommendations varies from country to country, on average exceeding 67 per cent.

The EPR process plays a critical role in ensuring consistency, convergence and alignment in policy, and to ensure that activities do not undermine broader sustainability and climate goals by degrading nature. EPRs are an example of regional review mechanisms contributing to monitoring, evaluation and reporting on SDGs. Since 2017, EPRs have included the review of relevant goals and targets of the 2030 Agenda and provided recommendations to the countries on the achievement of the SDGs. A more recent, but key focus of EPRs is the promotion of sustainable nature-based approaches such as NbS as part of the portfolio of recommendations. This has arisen following the recognition that natural ecosystems can support progress on addressing development challenges and providing wider benefits for the economy, environment and people, including health and well-being.

8.4 Examples of successful NbS projects highlights from recent EPRs

There is evidence from recent EPRs that countries are beginning to consider the value of nature more explicitly, including for providing benefits for environmental and health outcomes, and mitigating and adapting to climate change. Examples are discussed below.

The **Second EPR of Armenia (2024)** identifies that soils are crucial for mitigating climate change through carbon sequestration benefits but recognizes that trade-offs may occur between carbon sequestration and agricultural sector goals, such as crop yields. It notes that there is currently an absence of NbS approaches, which, if implemented, could improve crop productivity and simultaneously improve the health of ecosystems and soils. A specific chapter on agriculture and the environment (Chapter 15) highlights that current agricultural practices, across both crop and livestock, are impacting native habitats and biodiversity within the country. Unsustainable pasture management is a particular problem. It further notes that "nature-based solutions seeking to protect, sustainably manage and restore natural and modified ecosystems in ways that address societal challenges effectively and adaptively, to provide both human well-being and biodiversity benefits, are not developed and promoted."

There are only five formal references to NbS, including one in the recommendations section of the EPR: to "Set up a specific programme aiming to restore degraded lands by using phytoremediation and other suitable ecological methods and nature-based solutions, to remove and stabilize contaminants from the soils" (recommendation 15.3 (b)). However, the EPR includes a specific chapter (Chapter 12) on biodiversity and protected areas, which analyses trends and pressures, monitoring, policies and recommendations, and makes references to ecosystems and their benefits throughout the EPR. The EPR highlights that measures are needed, but currently the use of technologies to reduce pressure on water and land resources is not promoted, and farmers lack the capacity to preserve and restore soils and lands. A priority requiring further attention is monitoring biodiversity and ecosystems, upgrading soil conservation and management, and adopting sustainable agriculture practices. Top environmental priorities for the next 5–10 years include: establish a comprehensive state monitoring system for biodiversity and update the information and knowledge on the conservation of species, plant communities, habitats and ecosystems; upgrade soil conservation, protection and management in line with international standards and sustainable land management practices; and reduce pressure from agriculture on water ecosystems and increase efforts to prevent, stop and reverse land degradation caused by non-sustainable practices and methods of agriculture.

The **Third EPR of Azerbaijan (2024)** similarly notes that large-scale green networks, green infrastructure, and NbS are not yet developed or foreseen. It explains that there are no prescriptions for the greening of rooftops, facades, streets or courtyards, or incentives for the transformation of impervious surfaces into green surfaces or subsurface solutions for rainwater harvesting. However, the Cabinet of Ministers approved the Norms for provision of residential areas with greenery in 2018, which specified that, during the design of new residential areas, the percentage of greenery should be at least 40 per cent of the allocated area, and, during the re-design of residential areas, it should be 25 per cent. The EPR recommends that the Government consider NbS as a preferred adaptation option to improve the security of energy production and transmission (recommendation 8.3 (d)). Additionally, it advises promoting NbS and green infrastructures in urban areas (recommendation 8.4 (d)) and integrating NbS at the neighbourhood and building scales (e.g., green roofs and green walls) to mitigate and adapt to climate change (recommendation 8.5 (d)). The EPR also suggests incorporating landscape and ecological considerations and NbS in the development and maintenance of industrial parks, districts and special economic zones (recommendation 16.1 (e)).

The **Third EPR of Kyrgyzstan (2024)** notes that NbS which support climate mitigation through carbon storage or avoided GHG emissions have not been considered. It recommends that the Cabinet of Ministers prioritize NbS as preferred climate adaptation options (recommendation 7.4 (c)). The 3rd EPR highlights actions like expanding protected areas, urban rainwater harvesting, sustainable forestry and climate-proofing energy, transport and water systems. With 60 per cent of the population living in rural, mountainous regions, NbS are crucial for livelihoods and climate adaptation, although limited infrastructure poses a barrier to development.

The **Fourth EPR of Tajikistan (forthcoming in 2025)** notes that implementing NbS and sustainable urban drainage systems in Dushanbe is not yet part of the 2022 Green City Action Plan. It identifies potential for NbS to address flooding and heatwaves in urban areas and highlights Tajikistan's collaboration with China, Japan and the Republic of Korea to leverage their expertise and technologies in environmental programmes, policy development, sustainable production and consumption, and NbS development. The EPR of Tajikistan highlights that NbS in urban areas can improve air quality and reduce heat stress, benefiting public health. Sustainable water management can help to prevent waterborne diseases, for example, the protection of wetlands can support human health by safeguarding water quality through natural filtration.

The **Fourth EPR of Montenegro (2025)** includes reference to NbS in the "Green Agenda: Climate Change Adaptation in the Western Balkans" project (2024–2026). It promotes regional cooperation and knowledge sharing, with a focus on gender equality and NbS, as a solution to help Montenegro, along with other Balkans countries, adapt to climate impacts such as temperature rise and extreme weather. However, in Chapter 5 (Climate Change) it notes that NbS are not implemented to mitigate or adapt to climate impacts in urban areas. Further, no legal provisions exist to ensure that a certain percentage of permeable soil is maintained to mitigate the urban heat island effect and flooding.

The **Second EPR of Morocco (2022)** invests in ecosystem-based adaptation. Morocco is working on a roadmap proposed by experts in the Morocco EPR from 2022. It is aiming to increase the national research capacity on ecosystem-based adaptation to climate change. It is also preparing the implementation of the roadmap to create opportunities, particularly within the private sector, to develop NbS in the whole of Morocco. Priority plans include: planting and restoring degraded land through argan farming and local water and soil conservation practices; promoting agroecological transition for small farmers in vulnerable areas; promotion of NbS for protection against extreme climatic events among local authorities and state services; supporting nature-based community initiatives for biodiversity and climate protection; development and animation of a collaborative web platform dedicated to NbS and traditional practices and knowledge related to nature protection.

The **Fourth EPR of Uzbekistan (forthcoming)** takes an innovative approach having just four chapters, one of which is dedicated to NbS. The terms of reference were developed in consultation with IUCN, as well as the country under review. The chapter addresses the implementation of NbS (barriers, projects, funding, etc.); integrated approaches; research and innovation for NbS; the legal, policy and institutional framework; and assessment and recommendations. Tentative findings are that afforestation is central to Uzbekistan's NbS; wetland restoration supports biodiversity and migratory birds despite water scarcity challenges; NbS lack legal recognition, limiting integration into infrastructure, urban planning and climate adaptation strategies; and a national knowledge-sharing platform is needed to consolidate practices, improve awareness and scale up NbS across sectors.

8.5 Policy and regulatory hurdles (insights from EPRs)

EPRs across the ECE region reveal that while NbS are increasingly acknowledged for their potential to address climate, biodiversity, and health challenges, their integration into national policy and regulatory frameworks remains limited and uneven. A recurring theme in EPRs is the limited legal and institutional recognition of NbS: in fact, while many countries acknowledge the potential of NbS in principle, they are rarely embedded in national legislation or infrastructure planning frameworks.

For example, Armenia's Second EPR (2024) notes that NbS are not yet developed or promoted, despite their potential to restore degraded lands and improve soil health (ECE, 2024b). Similarly, Azerbaijan's Third EPR (2024) highlights the absence of large-scale green infrastructure and NbS in urban and territorial planning, and recommends integrating NbS in the development and maintenance of industrial parks and districts as well as special economic zones (ECE, 2023).

Fragmented governance structures exacerbate this policy gap. NbS span multiple sectors (environment, health, infrastructure, agriculture), yet institutional silos often prevent coordinated planning and implementation. Kyrgyzstan's Third EPR (2024) underscores that NbS have not been considered as solutions to increase carbon storage or avoid GHG emissions and recommends NbS as preferred adaptation options (ECE, 2024c).

Another challenge is the weak integration of NbS into national development and infrastructure investment plans. For instance, in Tajikistan, the Fourth EPR (forthcoming 2025) observes that NbS are not included in the Green City Action Plan for Dushanbe, despite their relevance for addressing urban flooding and heat stress (ECE, 2024d). This reflects a broader trend across the region, where NbS are often treated as supplementary rather than core components of infrastructure and climate resilience strategies.

Technical and regulatory standards for NbS are also underdeveloped. Without clear guidelines, performance metrics, or monitoring frameworks, planners and investors face uncertainty in evaluating the effectiveness and cost-efficiency of NbS relative to conventional infrastructure. Montenegro's Fourth EPR (2025) notes the absence of legal provisions to ensure permeable surfaces in urban areas, which could otherwise support NbS for flood and heat mitigation (ECE, 2025).

Capacity constraints further limit the uptake of NbS. Many EPRs point to a lack of technical expertise, institutional readiness and public awareness. Armenia's EPR emphasizes the need for capacity building in sustainable agriculture and soil conservation to reduce ecosystem pressures and enable NbS implementation.

Even where enabling policies exist, enforcement mechanisms and financial incentives are often lacking. Azerbaijan's Third EPR recommends promoting NbS and green infrastructure in urban areas, including green roofs and walls, but acknowledges that regulatory or fiscal instruments do not yet support such measures.

Moreover, while environmental impact assessments (EIAs) and strategic environmental assessments (SEAs) are widely used, they rarely consider NbS as viable alternatives to grey infrastructure. Integrating NbS into these assessment tools could help mainstream their use and ensure that infrastructure development aligns with sustainability and biodiversity goals.

The EPR programme itself recognizes these challenges and has evolved to address them. The fourth cycle of EPRs, launched in 2023, places greater emphasis on aligning national policies with the SDGs, the Paris Agreement and the Kunming-Montreal GBF (ECE, no date, h), encouraging countries to develop roadmaps for implementing EPR recommendations, including those related to NbS, and to strengthen institutional coordination and stakeholder engagement.

In sum, while EPRs have been instrumental in raising awareness and generating tailored recommendations, they also underscore that mainstreaming of NbS requires stronger legal mandates, institutional coordination, technical guidance and financial incentives to overcome policy and regulatory hurdles. Strengthening these enabling conditions is essential to unlock the full potential of NbS in delivering climate resilience, biodiversity conservation and public health benefits across the ECE region.

8.6 Lessons learned and good practices

EPRs are currently specific to countries in the ECE region that are not members of OECD (which has its own EPR programme for its members) and could be helpful in other countries if rolled out more broadly. The efficiency and effectiveness of the methodology have already attracted attention from countries outside of the ECE region, leading to requests for knowledge transfer from ECE to other United Nations regional commissions (ECE, no data, k). For example, Morocco, which is outside of the ECE region, was reviewed by ECE in cooperation with the Economic Commission for Africa, and Mongolia with the Economic and Social Commission for Asia and the Pacific.

Informal discussions with government authorities have highlighted the usefulness of EPRs in providing valuable inputs that are beneficial for their day-to-day work. As an independent external assessment, EPRs offer governments and other national stakeholders an appropriate framework through which they can identify and address key environmental issues within their country. National environmental authorities use EPRs strategically to raise awareness within the government of pressing environmental problems. EPRs are particularly effective in tailoring recommendations to the country under review and ensuring that they align with national priorities. They enable relevant stakeholders to assess the current state of the country and have it reviewed by independent experts to understand what improvements are required. Countries are subsequently able to use EPRs as they set commitments and track progress on other national targets, informing strategies such as NDCs and NAPs under the Paris Agreement. Engaging multiple stakeholders is considered especially important since it allows countries to get recommendations from experts including international organizations, which serve as a good base for starting new projects. The tailoring of recommendations to specific entities, such as the ministry of environment, economic development or climate change, and sectors, is considered very beneficial to guide the country on who should undertake what activity.

The EPR mechanisms and its associated expert and peer review processes are considered to go a long way towards improving environmental governance and performance nationally, including increasing awareness of the benefits of natural ecosystems. Several countries have EPRs which acknowledge that NbS have not yet been integrated into plans and activities. However, while some EPRs have included the term "nature-based solutions" formally, this is not yet standard practice across EPRs and NbS are not fully integrated across sectors. This illustrates a lack of awareness and understanding of NbS, a key barrier to uptake, which EPRs can help to address. Successful implementation of NbS initiatives relies on increased awareness and collaboration among government, international financial institutions (IFIs), the private sector, civil society and academia, and funding for NbS across the lifecycle of projects.

9. Funding opportunities, challenges and barriers

Key messages

- Despite their cost-effectiveness and multiple co-benefits, NbS remain underfunded, especially compared to conventional infrastructure.
- Public funding dominates NbS financing, but there is growing interest in mobilizing private capital through blended finance, green bonds and ecosystem service payments.
- Barriers to financing NbS include lack of awareness, limited technical capacity, fragmented governance and absence of standardized valuation methods.
- International climate and biodiversity finance mechanisms offer opportunities to support NbS, but access requires alignment with national strategies and robust project design.
- Innovative financing approaches—such as outcome-based payments, insurance-linked instruments and nature-positive investment frameworks—can help scale NbS.

Practical tips

- Align NbS projects with national climate and biodiversity strategies (e.g. NDCs, NBSAPs) to improve eligibility for international funding.
- Use natural capital accounting and ecosystem service valuation to build strong investment cases for NbS.
- Engage finance ministries and private sector actors early to build understanding and support for NbS.
- Bundle NbS with grey infrastructure projects to attract co-financing and demonstrate integrated solutions.
- Explore blended finance models that combine public, private and philanthropic resources.
- Develop enabling policies and regulatory frameworks that recognize NbS as eligible infrastructure investments.

NbS and sustainable infrastructure are gaining prominence as cost-effective, long-term, cost-efficient and scalable strategies to address climate change, biodiversity loss and public health challenges. Despite their clear advantages, the deployment of NbS and sustainable infrastructure in the ECE region is constrained by significant financing gaps: current investment levels remain disproportionately low, and many countries lack access to financing instruments tailored to their specific needs and risk profiles. Addressing these gaps requires a concerted effort to mobilize climate finance, integrate NbS into policy frameworks and build capacity at all levels for implementation.

This chapter aims to explore global and regional trends, and present existing and emerging climate finance mechanisms that can be mobilized to promote NbS and sustainable infrastructure in the ECE region. It also aims to identify financial and institutional barriers and provide concrete examples and case studies to inform national policymakers, development partners and private investors.

9.1 Climate finance landscape overview

Climate finance plays a critical role in advancing the transition toward low-emission, climate-resilient development. It supports both mitigation and adaptation strategies aligned with the objectives of the Paris Agreement, the 2030 Agenda for Sustainable Development and UNEA resolutions, including the endorsement of NbS as central to global climate and biodiversity action. In the context of sustainable infrastructure, climate finance is equally essential to catalyse the systemic shift toward green, inclusive and resilient urban and regional development.

Over the past decade, the climate finance landscape has evolved significantly, driven by growing political will, international commitments and the increasing urgency for impactful climate actions. Financial flows now encompass a wide range of actors, including multilateral development banks, bilateral donors, national governments, private investors and philanthropic organizations, each contributing through diverse instruments such as grants, concessional loans, equity investments, guarantees and blended finance mechanisms.

Despite this progress, climate finance remains heavily skewed toward mitigation, particularly in sectors with clear revenue models such as renewable energy and low-carbon transport. Adaptation, and especially NbS, continues to face significant underinvestment due to perceived risks, limited commercial returns and a lack of standardized metrics for impact assessment. This imbalance underscores the need for a more holistic and equitable approach to climate finance—one that recognizes the cross-cutting benefits of NbS for climate resilience, biodiversity and public health.

Emerging trends also point to the growing role of innovative financial instruments, such as sustainability-linked bonds, nature bonds and biodiversity credits, which aim to align financial returns with environmental and social outcomes. These tools, alongside traditional public finance, are essential to mobilize the trillions needed annually to meet global climate and biodiversity goals. Moreover, the integration of climate risk into financial decision-making—through climate disclosure frameworks and green taxonomies, for instance—is reshaping how capital is allocated, creating new opportunities for NbS-aligned investments.

In this evolving landscape, it is increasingly evident that climate finance must not only grow in volume, but also improve in quality, accessibility and alignment with long-term sustainability objectives—those articulated in the 2030 Agenda for Sustainable Development, those stated in the Paris Agreement, and in support of the Kunming-Montreal GBF. Strengthening institutional capacity, fostering cross-sector collaboration and embedding NbS into budgeting and planning frameworks will be key to unlocking the full potential of climate finance in delivering transformative, nature-positive outcomes.[2]

9.2 Defining NbS and sustainable infrastructure in the context of climate finance

Climate finance refers to financial flows aimed at supporting mitigation and adaptation actions to combat climate change. According to the United Nations Framework Convention on Climate Change (UNFCCC), it is "drawn from public, private and alternative sources—that seeks to support mitigation and adaptation actions that will address climate change" (UNFCCC, 2021). Climate finance is central to achieving the Paris Agreement, which aims to limit global warming to well below 2°C, and ideally 1.5°C, above pre-industrial levels. It also supports progress toward multiple Sustainable Development Goals (SDGs)—notably SDG 13 (Climate Action), and other interconnected SDGs: SDG 7 (Affordable & clean energy), SDG 14 (Life below water) and SDG 15 (Life on land).

Within this framework, NbS and sustainable infrastructure are increasingly recognized as a necessary component of climate finance strategies. Sustainable infrastructure can include built infrastructure, natural infrastructure or hybrid infrastructure that contains elements of both, emphasizing resilience, community responsiveness and the incorporation of NbS that not only support biodiversity but also deliver long-term cost savings and health co-benefits, thus aligning with the SDGs, the Paris Agreement and the Convention on Biological Diversity (CBD).

2 According to UNEP, "nature-positive" refers to actions that halt and reverse nature loss by enhancing biodiversity, restoring ecosystems, and ensuring that economic activities contribute to the health of the planet rather than depleting it. This concept, strongly endorsed during the CBD COP15 and reaffirmed at COP16 through the Kunming-Montreal GBF, aligns with global efforts to place biodiversity recovery at the heart of climate and development agendas. A nature-positive approach ensures that climate finance not only addresses emissions and resilience but also restores ecosystems and supports the long-term viability of life-supporting natural systems.

Importantly, climate finance is increasingly recognized as a key mechanism for scaling up NbS, which can address both mitigation and adaptation needs simultaneously. For example, large-scale afforestation in degraded drylands captures carbon (mitigation), while also reducing dust storms and improving soil and water retention (adaptation), as for the RESILAND programme in Uzbekistan supported by the World Bank. Similarly, the restoration of wetlands buffers communities against drought and flood risks (adaptation) and acts as a carbon sink (mitigation) as for the Central Asia Water and Land Nexus (CAWLN) programme in Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan, funded by the GEF and implemented by FAO.

Beyond their climate objectives, NbS contribute significantly to biodiversity conservation, which is now a core element of global financing priorities following the 2024 UN Biodiversity Conference (CBD COP16). The conference reinforced commitments to halt and reverse biodiversity loss by 2030, protect at least 30 per cent of the world's land and marine areas, and significantly scale up financial resources for nature protection and restoration. The GBF agreed at CBD COP16 calls for scaling biodiversity finance and integrating ecosystem-based approaches into climate strategies. NbS—such as restoring natural habitats, reintroducing native vegetation and protecting ecological corridors—not only build climate resilience but also safeguard and enhance integrity of natural habitats and species diversity. By investing in NbS, climate finance supports ecosystem health, community well-being and international biodiversity targets, reinforcing commitments under both the Paris Agreement and the Kunming-Montreal GBF.

9.3 Global trends in climate finance and NbS finance and sustainable infrastructure

Global climate finance flows have grown, even amid global crises such as the COVID-19 pandemic, inflationary pressures and geopolitical instability. In fact, annual climate finance flows reached US$1.46 trillion in 2022, more than doubling from US$674 billion in 2018. This upward trend reflects increasing commitments from both public and private sectors, particularly in mitigation-focused sectors such as renewable energy, low-carbon transport and energy-efficient buildings (CPI, 2024).

Despite this growth, the scale of investment remains far below what is needed to meet the goals of the Paris Agreement. To stay on a 1.5°C pathway, global climate finance must increase nearly fivefold to approximately US$7.4 trillion annually by 2030. In addition to this, the distribution of finance remains heavily skewed: 90 per cent of total flows in 2022 were directed toward mitigation, while adaptation received just 5 per cent, amounting to US$76 billion. This imbalance is particularly concerning given the increasing climate vulnerability of many regions and the cross-cutting benefits of adaptation investments, especially those involving NbS (CPI, 2024). The OECD 2024 assessment of climate finance flows confirms that while developed countries collectively mobilized US$115.9 billion in climate finance in 2022, surpassing the long-standing US$100 billion goal, only a fraction of this was directed toward adaptation and NbS. Adaptation finance reached US$32.4 billion, representing 28 per cent of total flows, while mitigation continued to dominate (OECD, 2024a).

The financial instruments outlook mirrors this disproportion: mitigation finance is dominated by market-rate debt (57 per cent) and equity (32 per cent), largely driven by private capital seeking returns in sectors with established revenue models; in contrast, adaptation finance relies overwhelmingly on public sources (92 per cent), typically in the form of grants, concessional loans and technical assistance (CPI, 2024). These instruments are essential for supporting adaptation in countries with limited fiscal space and high climate vulnerability, but they remain insufficient in scope and scale. Blended finance—which combines concessional public funding with commercial investment—is gaining traction as a means to de-risk adaptation and NbS projects. However, its deployment remains limited and requires further innovation and institutional support to scale effectively.

Regional disparity in climate finance is also stark: advanced economies account for over 80 per cent of total climate finance flows, while Least Developed Countries (LDCs) and Small Island Developing States (SIDS)—despite being among the most climate-vulnerable—receive less than 5 per cent. Encouragingly, climate finance to LDCs more than doubled from US$19 billion in 2018 to US$39 billion in 2022, but this still falls short of their needs (CPI, 2024).

Looking at NbS, current public and private spending on NbS globally is estimated at US$200 billion per year with over 80 per cent sourced from public finance. To meet international climate and biodiversity targets under the Paris Agreement and the Kunming-Montreal GBF, this figure must nearly triple to US$540 billion annually by 2030 (UNEP, 2024b). This financing gap underscores the urgent need to scale up and diversify funding sources for NbS.

9.4 Climate finance financial instruments can finance NbS and sustainable infrastructure

The global climate finance architecture is evolving to bridge this financing gap. Public finance remains the backbone of NbS funding, particularly in developing and climate-vulnerable countries. Instruments such as grants, concessional loans and green budget allocations are essential for early-stage and non-commercial projects. Key public sources include national climate budgets, multilateral development banks (MDBs) and global climate funds such as the Green Climate Fund (GCF), the Adaptation Fund (AF) and the Global Environment Facility (GEF). These institutions play a critical role in de-risking investments and supporting capacity building. Private finance, while still limited in the NbS space, is beginning to grow. Instruments such as green bonds, sustainability-linked loans and impact investment funds are increasingly used to mobilize private capital. In 2023, global green bond issuance reached a record above US$580 billion, with a growing share directed toward nature-positive infrastructure (CBI, 2024). However, the monetization of ecosystem services and the lack of standardized metrics for NbS impact remain key barriers to scaling private investment. Blended finance is emerging as a powerful tool to attract institutional investors and unlock larger pools of capital by improving the risk-return profile of NbS projects. Instruments such as resilience bonds and climate risk insurance are also gaining attention for their ability to fund proactive adaptation measures and ecosystem protection before disasters occur.

Despite the growing global awareness of NbS, the pace and scale of investment remain insufficient. Bridging the financing gap will require a coordinated effort to scale public finance, mobilize private capital, and deploy innovative financial instruments that align economic incentives with environmental outcomes.

9.5 Climate finance outlook in the ECE region

Between 2018 and 2022, climate finance flows in the ECE region increased steadily, with a growing, albeit modest, role for private capital. The financing landscape is characterized by a blend of public and private capital, with international development finance institutions playing a central role in providing concessional loans, grants and technical assistance to support early-stage project development and catalysing investment (CPI, 2024).

MDBs are increasingly acting as catalysts, crowding in private capital through blended finance, credit enhancements, and risk-sharing mechanisms. Blended finance, in particular, is a powerful tool in this context, combining concessional public funds with private capital to de-risk investments and make them more attractive to commercial financiers. This is especially relevant for projects like watershed restoration, climate-resilient agriculture and urban green infrastructure, where public benefits are high but financial returns may be uncertain or long-term.

For instance, in 2024, the **European Bank for Reconstruction and Development (EBRD)** achieved a record investment of €2.26 billion across six Central Asian economies—Kazakhstan, Kyrgyzstan, Mongolia, Tajikistan, Turkmenistan, Uzbekistan—nearly doubling its annual investment in the region compared to 2023. This funding supported 121 projects, with over 60 per cent directed toward sustainable infrastructure and 58 per cent aligned with green economy initiatives reinforcing the EBRD's role as the region's largest green lender. All operations were fully in line with the Paris Agreement, highlighting the Bank's commitment to sustainable and climate-resilient growth in Central Asia (EBRD, 2025). In March 2025 as part of the High-Impact Partnership on Climate Action, EBRD also launched the Central Asia Nature Partnership, a platform which encourages nature-positive business models, helping countries in the region better integrate ecosystem services and natural capital into their economies, thus serving as a regional response to the increasing environmental degradation and climate vulnerabilities that threaten livelihoods and biodiversity.

In 2024, the **Asian Development Bank (ADB)**, backed by the **Green Climate Fund**, launched the **Glaciers to Farms** (GCF, 2024) programme to address the impacts of glacial melt and climate change in Central Asia, the South Caucasus and Pakistan. The programme will begin with risk assessments in Azerbaijan, Kyrgyzstan, Tajikistan and Uzbekistan, focusing on preserving water resources and supporting sustainable agriculture and infrastructure. This initiative aims to mobilize up to US$3.5 billion to invest in NbS and climate-resilient infrastructure. This initiative exemplifies how GCF is helping to integrate NbS into broader infrastructure and climate resilience strategies by combining scientific risk assessments, ecosystem restoration and community-based adaptation to protect both livelihoods and biodiversity in high-risk areas.

In addition to the above programme, ADB also launched the **ADB Nature Finance Hub** (ADB, 2025) to accelerate investment in nature-positive solutions, also across Central Asia. The Hub supports governments and private sector actors in identifying, structuring and financing nature-based projects, including wetland restoration, sustainable land use and biodiversity conservation. By offering technical assistance, blended finance instruments and policy support, the Hub contributes to scaling up nature-aligned investments that deliver both climate and ecological benefits.

In **Uzbekistan**, the newly established **Italian Climate Fund**,[3] managed by Cassa Depositi e Prestiti, approved a €100 million **policy-based loan** to the Ministry of Finance, which aims to advance the country's green economy transition by strengthening climate-related public financial management, thus supporting the development of monitoring and evaluation systems for climate impacts, the integration of green criteria into public budgeting, and fiscal reforms such as the reduction of fossil fuel subsidies.

Green and sustainability-linked bonds are gaining traction, channelling private capital into projects with clear environmental outcomes. For example, in August 2020, Kazakhstan issued its first green bonds on the Astana International Exchange, marking a significant milestone in the country's transition toward a greener economy. This initiative was supported by the UNDP and funded by the GEF under the "De-risking Renewable Energy Investment" project, in partnership with the Ministry of Energy and the Damu Entrepreneurship Fund. The green bonds were developed using international standards, including the Green Bond Principles and the Climate Bonds Standard, making Kazakhstan the first among Commonwealth of Independent States countries to adopt such a framework (UNDP, 2020).

Additionally, innovative instruments like **debt-for-nature swaps** and **bio-credits** are being explored to monetize ecosystem services and create tradable assets linked to conservation outcomes as they hold significant potential for advancing green development in Central Asia and the Caucasus, where countries face mounting debt pressures alongside urgent climate and biodiversity challenges. Debt-for-nature swaps offer a strategic opportunity to restructure sovereign debt in exchange for commitments to invest in ecosystem restoration, climate adaptation and sustainable land use—particularly relevant for countries like Kyrgyzstan, Tajikistan and Uzbekistan. Meanwhile, bio-credits—tradable units tied to measurable biodiversity outcomes—could unlock new revenue streams for conservation by monetizing the region's rich natural assets, such as alpine meadows and steppe ecosystems. While both mechanisms are still in early stages, they are gaining traction as innovative tools to align fiscal sustainability with environmental resilience, especially with support from international donors, climate funds and development banks.

Private finance holds significant potential to accelerate the deployment of NbS and sustainable infrastructure in Central Asia and the Caucasus, yet its role remains underdeveloped due to a range of structural and market barriers. Instruments such as ESG-aligned investments, impact investing, private equity, commercial green lending and insurance-linked securities offer promising avenues to mobilize capital toward nature-positive outcomes. For instance, Kazakhstan's early adoption of green bonds (see case study 9.1) and ESG disclosure frameworks has laid the groundwork for attracting institutional investors to sectors like sustainable agriculture and water resilience. However, private investment is often constrained by the perceived high risk and low return of NbS projects, which typically involve long payback periods and uncertain revenue streams. The small scale and fragmentation of many NbS initiatives further limit their appeal to large investors, while the lack of standardized metrics and reporting frameworks complicates due diligence and impact verification. Commercial banks and private equity firms are beginning to explore sustainability-linked loans and ESG-tied performance incentives, but uptake remains limited without blended finance structures to de-risk investments. Overcoming these barriers will require coordinated efforts to aggregate projects, develop robust valuation tools and expand the use of blended finance to crowd in private capital and scale NbS across the region.

Other **blended finance initiatives** such as the **UNEP FI** and the **European Investment Bank's Natural Capital Financing Facility (NCFF)** offer valuable models for financing NbS and sustainable infrastructure that could be adapted to Central Asia and the Caucasus. The NCFF combines flexible financing, such as loans and equity, with technical assistance to support projects that deliver biodiversity and climate adaptation outcomes, including green urban infrastructure, ecosystem-based flood protection and sustainable agriculture. While primarily implemented in EU countries, this model is highly relevant for the region, where similar barriers—such as limited technical capacity and a lack of bankable projects—persist. Meanwhile, UNEP FI has been instrumental in promoting blended finance as a tool to align private capital with environmental goals. It emphasizes

3 The Italian Climate Fund (ICF, Fondo Italiano per il Clima) represents the main public instrument to pursue Italy's commitment, together with other OECD countries, to collectively mobilize at least €100 billion per year in climate finance towards emerging and developing countries. Established in 2022, the Italian Climate Fund aims to support climate change mitigation and adaptation in developing countries, as well as to protect biodiversity and combat desertification. With an initial endowment of €4.2 billion over 5 years (2023–2027), in addition to €40 million per year from 2027 for non-repayable contributions and management expenses, the ICF is structured as a revolving Fund which operates with a wide range of instruments, aimed at serving different types of counterparties: financing for initiatives promoted by companies, (corporate or project finance vehicle company, of any nationality), financing to the public sector, (governments, central banks, state public bodies of partner countries), financing and guarantees in favour of financial institutions, investments in funds, issue of guarantees. The Fund aims to finance projects to combat climate change in countries receiving public development assistance identified by the OECD Development Assistance Committee. On the geographical scope, priority is set on the macro-areas of Africa and the Middle. For more information, see Mase (no date).

building investable project pipelines, standardizing impact metrics and using concessional finance to de-risk investments. These approaches are particularly suited to the region's needs, where many NbS opportunities remain underfunded due to perceived risks and valuation challenges. Adapting these models could help unlock new sources of finance and accelerate the integration of NbS into national development strategies.

9.6 Financial and economic constraints, but also opportunities for NbS

While NbS and sustainable infrastructure offer significant environmental and health co-benefits, their implementation across the ECE region is often hindered by persistent financial and economic barriers. These include high upfront capital costs, long payback periods and the lack of standardized, investment-ready project pipelines. Moreover, the diffuse and long-term nature of NbS benefits makes them difficult to monetize within conventional financial frameworks. This often results in underinvestment, as many of the positive externalities are not captured in traditional cost-benefit analyses or reflected in financial returns.

However, these challenges also present clear opportunities for innovation in financing and policy. One promising avenue is the development of robust methodologies for valuing the full spectrum of NbS co-benefits, including health outcomes, ecosystem services and climate resilience. Tools such as natural capital accounting and ecosystem service valuation frameworks can help integrate these benefits into public investment decisions and financial risk assessments. For example, the UN System of Environmental-Economic Accounting (SEEA) offers standardized approaches to quantify and communicate the value of nature in economic terms.

To address the lack of bankable projects, governments and development partners can invest in project preparation facilities and technical assistance programmes that help local authorities and developers design, structure and scale NbS interventions. Establishing standardized templates, performance metrics and reporting frameworks can also reduce transaction costs and improve investor confidence.

Blended finance mechanisms can play a catalytic role in de-risking NbS investments and improving their financial viability. Instruments such as green bonds, sustainability-linked loan, and results-based financing can be tailored to support NbS, especially when backed by guarantees or credit enhancements from multilateral development banks. The GCF, GEF and EIB are already supporting such models in the region.

Moreover, emerging instruments like bio-credits and biodiversity offsets offer new pathways to monetize conservation outcomes and attract impact investors. These tools, when underpinned by transparent governance and rigorous monitoring systems, can help bridge the gap between ecological value and financial return.

Finally, integrating NbS into NDCs and NAPs can significantly enhance climate resilience and unlock new financing opportunities: by embedding NbS into these national strategies, countries can align their climate actions with global biodiversity and sustainability goals, ensuring a holistic approach to environmental and social challenges, benefitting the most vulnerable, in particular women and youth.

In summary, while financial and economic constraints remain a significant barrier to scaling up NbS and sustainable infrastructure, they also highlight the need and opportunity for systemic innovation in how nature is valued, financed and integrated into national development planning and budgeting. By aligning national strategies and financial systems with environmental and health objectives, the ECE region can unlock the full potential of NbS to deliver resilient, inclusive, and sustainable outcomes.

9.7 Technical requirements and ineligible costs under IFIs

International Financial Institutions (IFIs) are key enablers in financing sustainable infrastructure and NbS across the ECE region. However, accessing their funding requires compliance with a set of rigorous technical requirements along with awareness of the types of costs that are ineligible. Technical requirements and ineligible costs can vary from IFI to IFI, but they generally focus on ensuring projects are well-defined, implemented effectively, and that funds are used appropriately. Understanding them is essential for designing viable and bankable projects.

Technical requirements

Technical requirements refer to the formal set of criteria and standards that projects must meet to be considered eligible for funding. These requirements are designed to ensure that projects are not only feasible and effective, but also aligned with the institution's strategic goals, safeguards and fiduciary standards. They serve as a gatekeeping mechanism to guarantee that proposed projects are firstly, aligned with IFI's strategic priorities; secondly, scientifically and technically sound, with clear methodologies and evidence-based design as well as economically viable, demonstrating value for money and long-term sustainability; thirdly, socially and environmentally responsible, complying with safeguard policies and contributing to inclusive development; and, last but not least, operationally feasible, with robust implementation plans, risk mitigation strategies and monitoring frameworks.

For NbS projects, meeting these requirements can be particularly challenging due to the non-linear, adaptive and ecosystem-driven nature of such interventions. In fact, NbS often involve complex ecological processes, community engagement and long-term stewardship, which are harder to quantify and standardize. The technical criteria in Table 9.1 should be kept into consideration for NbS projects seeking IFI funding.

Table 9.1: Key technical criteria for IFI funding

	Criterion	Description
1	**Project design and feasibility**	NbS projects must be grounded in robust technical design. This includes detailed ecological restoration plans, hydrological modelling and biodiversity assessments that demonstrate scientific rigor. Feasibility studies are essential to confirm that the proposed interventions are practical and context-appropriate, while climate risk assessments help justify the relevance of NbS in addressing specific vulnerabilities.
2	**Economic and financial analysis**	A key challenge for NbS lies in articulating their economic value. Projects are expected to present cost-benefit analyses that account for both direct and indirect benefits, such as ecosystem services and public health improvements. However, calculating economic rates of return can be complex due to the long-term and diffuse nature of NbS benefits. Financial sustainability must also be demonstrated, even when revenue streams are not immediately apparent.
3	**Environmental and social safeguards**	Compliance with environmental and social safeguard frameworks is mandatory. This includes conducting environmental and social impact assessments, engaging stakeholders and developing mitigation plans. Special attention must be given to gender equity, Indigenous rights and the inclusion of vulnerable groups in project design and implementation.
4	**Monitoring and evaluation (M&E)**	Effective M&E systems are critical for tracking project outcomes. NbS projects must define clear indicators for biodiversity, climate resilience and community well-being. Establishing baseline data and measurable targets is often challenging due to the lack of standardized metrics for ecosystem services, but innovative approaches are encouraged to ensure accountability and adaptive management.
5	**Institutional capacity and implementation arrangements**	IFIs require assurance that implementing agencies have the institutional capacity to manage funds, procure services and oversee technical execution. Governance structures must support cross-sectoral coordination and adaptive management, particularly important for NbS, which often span multiple sectors and jurisdictions.

Ineligible costs

In the context of IFIs, ineligible costs refer to expenses that cannot be financed or reimbursed under the institution's funding rules and guidelines. These exclusions are designed to uphold the integrity of development financing by ensuring alignment with institutional mandates, promoting transparency and accountability, and safeguarding the efficient use of public and donor resources. These institutions tend to be more inclined to fund capital investments, technical assistance and project-specific activities. Typically, the following categories of costs are considered ineligible:

- Land acquisition and resettlement, unless explicitly included in the project scope and fully compliant with safeguard policies;
- Political or religious activities, which fall outside the scope of development financing;
- Retrospective financing, meaning costs incurred before project approval or without prior agreement from the IFI;
- Recurrent operational expenses, such as salaries of permanent staff or routine maintenance;
- Long-term maintenance and operations;
- Non-climate-aligned interventions, including fossil fuel infrastructure, unsustainable land use practices, or activities deemed environmentally harmful—particularly under climate and sustainability-focused funds.

In addition, extensive community engagement processes may sometimes be considered ineligible to be covered through government resources or complementary funding. Also, in some cases, IFIs avoid financing activities that may trigger complex safeguard issues, such as land tenure disputes.

Land acquisition costs are generally excluded from loan eligibility, especially when such costs are associated with legal complexities, displacement risks, or lack of transparency. Further examples of ineligible costs are shown in box 9.1 for European Investment Bank financing, but each IFI has its own eligibility criteria and safeguards that will impact financing decisions.

Box 9.1: Eligibility of costs for European Investment Bank financing

EIB financing is available only for certain projects that comply with the bank's environmental and social safeguards, sectoral lending policies and others. In addition, projects are excluded if they: would result in limiting people's individual rights and freedom, or violation of human rights; include activities prohibited by national legislation or international agreements ratified by the European Union; are ethically or morally controversial; or deal with ammunition, weapons, explosives, or equipment or infrastructure dedicated to military or police use.

Further, certain projects are considered unacceptable in climate and environmental terms:

- Activities not aligned with the principles and goals of the Paris Agreement, as defined in the EIB Group Climate Bank Roadmap. In terms of mitigation goals, this excludes a range of highly emission-intensive activities in sectors such as energy, transport, industry and the bioeconomy. In terms of adaptation goals, this excludes activities with a substantial residual risk to current and future climate change;
- Any activity involving significant degradation, conversion or destruction of critical habitats;
- Conversion of natural forests into plantations (plantations are not considered an NbS). This includes irrigated forests, logging, clear cutting or degradation of (and commercial concessions over) tropical natural forests or high conservation value forests in all regions, as well as the purchase of logging equipment for this purpose;
- Unsustainable fishing methods (such as drift net fishing in the marine environment using nets more than 2.5 km in length and blast fishing);
- Extraction of mineral deposits from the deep sea;
- Extraction or mining of conflict minerals and metals.

The source below also identifies additional categories of projects that are generally not accepted from multi-beneficiary intermediated loans and other intermediated debt products:

- Projects in the mining sector;
- Manufacturing of explosives and nitrogen compounds;
- Nuclear energy and manufacturing within the nuclear industry (such as processing of nuclear fuel, uranium enrichment, irradiated fuel reprocessing);
- Hydropower;
- Waste incineration and collection, treatment and disposal of hazardous waste;
- Thermal power stations;
- Industrial manufacturing activities covered by the EU Taxonomy Delegated Acts associated with significant CO_2 emissions;
- Air transport and related infrastructure (such as airports and airport installations) and services and manufacturing and acquisition of aircraft and related machinery;
- Desalination;
- For-profit projects in the education sector outside the European Union.

Source: European Investment Bank (2022) *EIB eligibility, excluded activities and excluded sectors list*, European Investment Bank: Luxembourg, available at EIB (2022).

Understanding what constitutes an ineligible cost is essential for project developers, especially when designing NbS projects which often include costs considered ineligible or difficult to justify under traditional IFI financing frameworks. Common examples include:

- Land acquisition for ecosystem restoration, unless directly linked to project outcomes and justified through safeguards;
- Long-term maintenance and stewardship, which are essential for NbS but often fall outside the scope of capital investment;
- Community engagement and participatory planning, which are critical for success but may be seen as "soft" costs;
- Integration of Indigenous knowledge and cultural practices, unless explicitly tied to measurable project outputs;
- Monitoring of biodiversity and ecosystem services, which may lack standardized indicators or valuation methods.

By anticipating potential exclusions and proactively framing NbS components within the language and logic of IFI frameworks, project developers can bridge the gap between ecological ambition and financial feasibility.

Toward more inclusive financing

Many project proponents, especially local governments, civil society organizations and small-scale implementers, face significant barriers in meeting the technical, fiduciary and environmental standards required by IFIs. These barriers can be especially daunting for NbS, which often demand interdisciplinary planning, long-term stewardship and robust evidence of co-benefits.

To overcome these hurdles, early engagement with IFIs and access to technical assistance facilities are essential to help align proposals with funding criteria and prevent common pitfalls during project preparation. In response, IFIs and their partners have developed a range of **capacity-building instruments** to enhance project readiness and institutional capability:

- **Project Preparation Facilities** provide technical and financial support during the initial stages of project development, including feasibility studies, environmental assessments and stakeholder consultations. An example is the **GCF Project Preparation Facility** (GCF no date) which provides grants to Accredited Entities for pre-investment activities such as baseline assessments, gender analyses and stakeholder engagement plans.
- **Readiness and technical assistance programmes** which aim at strengthening institutional frameworks, policy environments and technical skills. For instance, the **GCF Readiness Programme** (GCF, no date, b) supports countries in developing NAPs, climate finance strategies and NbS integration into national planning.
- **Knowledge platforms and toolkits** developed by IFIs and development partners to support project design and implementation, as for example the **EIB Climate Adaptation Investment Advisory platform (ADAPT)** (INVEST EU, no date), an advisory platform that aims at facilitating the deployment of technical and financial expertise to address specific investment and market needs; or the **UNEP's NbS Toolbox** (UNEP-WCMB, no date), a collection of resources and tools to support the implementation of NbS. These tools are designed to help countries, cities, and other stakeholders integrate NbS into their strategies and actions to address environmental and societal challenges.
- **Regional and thematic networks** that serve as collaborative platforms to help build peer-to-peer learning and regional coordination.

In addition, to truly unlock the potential of nature-based interventions, many institutions are beginning to adapt their frameworks to better accommodate the unique characteristics of NbS, for example by expanding eligibility criteria to include ecosystem-based adaptation and hybrid infrastructure; promoting results-based financing that rewards ecological and social outcomes; and supporting blended finance models that combine public and private capital to de-risk NbS investments.

By evolving their technical requirements and recognizing the full value of NbS interventions, IFIs can play a catalytic role in scaling up NbS, transforming them from niche interventions into mainstream pillars of sustainable development and climate resilience.

9.8 Governance and coordination mechanisms

Given the inherently cross-sectoral nature of NbS (spanning environmental, health, infrastructure, agricultural and financial domains) robust institutional frameworks and multi-level coordination mechanisms are essential to ensure coherence, accountability and long-term impact.

At the institutional level, NbS governance should be embedded into national and subnational planning processes. This includes integrating NbS into national development strategies, NDCs, NAPs and infrastructure investment frameworks. For example, countries such as Armenia and the Republic of Moldova have begun referencing NbS in their NDCs and NAPs, recognizing their role in both mitigation and adaptation. To support this integration, countries are encouraged to establish dedicated NbS focal points or inter-ministerial committees that can oversee implementation and ensure alignment with biodiversity, climate and public health objectives. Legal and regulatory frameworks should also be strengthened to provide formal recognition of NbS, enabling enforcement, financing and long-term monitoring.

Coordination across sectors and stakeholders is equally critical. National coordination platforms can serve as hubs for dialogue and decision-making, bringing together government agencies, civil society, academia and the private sector. Inter-ministerial working groups can help align sectoral policies—such as those related to water, energy and transport—with NbS objectives. Decentralized governance structures can empower local authorities to implement context-specific solutions, while vertical coordination between national and local governments is particularly important for urban NbS.

Given the transboundary nature of many ecosystems in the ECE region, regional cooperation is vital. Mechanisms such as the ECE Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention) and its Nexus Dialogues facilitate cross-border collaboration on water-related NbS and ecosystem-based adaptation. The EPRs offer a structured mechanism to assess governance gaps and recommend institutional reforms. For example, the EPRs of Armenia and Azerbaijan have recommended the adoption of NbS to improve energy security and urban resilience.

Inclusive and participatory governance is another cornerstone of effective NbS implementation. Community-based governance models that empower local populations to co-manage NbS projects enhance ownership, sustainability and equity. The participatory forest restoration project in Morocco's Beni Boufrah region exemplifies how inclusive governance, through multi-stakeholder platforms and gender-sensitive approaches, can lead to successful ecological restoration and community empowerment. Gender-responsive governance frameworks are also essential to ensure that interventions address the differentiated needs and capacities of women, men and marginalized groups.

Finally, governance systems must be adaptive and evidence-based. Integrated monitoring frameworks aligned with the SDGs, the Kunming-Montreal GBF and the Paris Agreement are essential for tracking progress. Feedback loops—such as periodic reviews, stakeholder consultations and knowledge-sharing platforms—should be institutionalized to support continuous learning and improvement. Tools such as the IUCN Global Standard for NbS and the EU Handbook for Evaluating the Impact of NbS provide practical guidance for embedding monitoring and evaluation into governance systems (IUCN, 2020; EU, 2021).

In sum, scaling NbS requires a governance architecture that is inclusive, cross-sectoral, regionally coordinated and grounded in evidence. Strengthening these mechanisms will be critical to unlocking the full potential of NbS in delivering climate resilience, biodiversity conservation, and public health benefits across the ECE region.

Case study 9.1: Funding smaller-scale NbS projects for wastewater treatment

Kosovo* faces significant challenges with wastewater treatment—only 11 per cent of wastewater is currently being treated. This poses serious risks to freshwater ecosystems and public health. In Podujeva, a €30 million loan was issued to the Regional Company Prishtina to address wastewater treatment needs and improve it to EU standards. In addition to supplying conventional wastewater treatment funding, the project will deliver a small decentralized NbS wastewater treatment plant for a nearby village, which will result in a significant reduction of pollution from untreated wastewater discharges directly into the Llapi River, which is part of the Danube basin. It will benefit 50,000 people and support nature by reducing contamination of freshwater bodies with sewage.

This project provides an example of how the problem of scale can be tackled—NbS projects are often small in terms of their capital costs, and it is difficult to mobilize finance from multilateral development banks (MDBs) for transactions below the threshold of €1 million. Below this level, projects need other finance sources. In this project, a large utility called Prishtina is borrowing a larger funding amount for a traditional wastewater treatment facility and, as an addition to the project, further funding is provided for the pilot-scale NbS. Mainstreaming this model of adding NbS components to larger projects can be undertaken to enable the implementation of projects that would not otherwise reach the cost requirements to be eligible for MDB funding.

Source: Barza (2025).

Note: * References to Kosovo shall be understood to be in the context of United Nations Security Council Resolution 1244 (1999).

Case study 9.2: Using NbS for infrastructure to meet legal requirements of Biodiversity Net Gain (BNG) in the United Kingdom

In England, BNG is mandatory under the Schedule 7A of the Town and Country Planning Act 190 (as inserted by Schedule 14 of the Environmental Act 2021).

Developers must deliver a BNG of 10 per cent. This helps to ensure that a development will result in more or better-quality natural habitat than it was before development.

Developers are encouraged to consult an ecologist to assess biodiversity value, specifically to:

- Measure the biodiversity value of existing habitat;
- Receive advice on suitable habitat creation or enhancement for the land.

There is an official biodiversity metric which developers must use to measure how many units of biodiversity:

- A habitat contains before development;
- Are needed to replace the units of habitat lost and to achieve 10 per cent BNG.

There are three ways listed through which developers can achieve BNG: on-site units; off-site units and statutory biodiversity credits.

1. They can create biodiversity on-site within the red line boundary of a development site.
2. If developers cannot achieve all their BNG on-site, they can deliver through a mixture of on-site and off-site. Developers can either make off-site biodiversity gains on their own land outside the development site, or buy off-site biodiversity units on the market.
3. If developers cannot achieve on-site or off-site BNG, they must buy statutory biodiversity credits from the Government. This is considered a last resort. The Government will then use the revenue to invest in habitat creation in England.

Developers may combine all three options but must follow the steps in order.

NbS offer a potential way for infrastructure developers to meet infrastructure service needs whilst meeting their legal requirements under BNG. Scaling BNG, or versions of it, across the ECE region could offer an opportunity to increase uptake of NbS within infrastructure investments. Equally, by requiring developers to invest in biodiversity, this can help to make the case for investment in nature and direct some of the funding earmarked for infrastructure to NbS.

Source: DEFRA (2023), Haggis *et al.* (forthcoming). More information on BNG can be found at DEFRA (2023), which contains links to step-by-step guides, biodiversity metrics and biodiversity measurement tools.

10. Key challenges and considerations for planning NbS and success across the lifecycle

Key messages

- NbS offer a transformative opportunity to address the ECE region's environmental, health and infrastructure challenges in an integrated and cost-effective way.
- Scaling up NbS requires systematic integration into infrastructure planning and financing mechanisms, supported by robust evidence and stakeholder engagement.
- The report calls for mainstreaming NbS through EPRs, national climate and biodiversity strategies, and sustainable infrastructure initiatives.
- Cross-sectoral collaboration, capacity building and regional cooperation are essential to unlock the full potential of NbS.
- The ECE region can lead by example, demonstrating how NbS can deliver resilient, inclusive and sustainable infrastructure systems.

Practical tips

- Use this report as a roadmap to identify entry points for NbS in national and regional strategies.
- Invest in monitoring and evaluation to build the evidence base and support adaptive management.
- Foster regional knowledge exchange to share best practices and harmonize NbS approaches.
- Engage diverse stakeholders—including communities, private sector and academia—in NbS design and implementation.

This chapter provides an overview of the key challenges of NbS, and subsequently examines relevant factors for success of NbS by considering the following aspects:

1. Embed consideration of NbS from the start of the infrastructure project lifecycle
2. Engage multiple stakeholders across the project lifecycle
3. Identify a range of potential NbS options
4. Carefully consider location choices
5. Conduct a full appraisal of benefits and costs
6. Undertake monitoring
7. Undertake maintenance and adaptive management
8. Develop and share lessons learned

10.1 Key challenges of NbS

This report has demonstrated that NbS have potential to provide multiple benefits in principle, including meeting infrastructure development needs, supporting climate mitigation, building resilience to climate impacts, and generating positive environmental and societal outcomes, including public health. However, there are many complexities and challenges associated with NbS that can pose barriers to uptake. These include (UNEP, 2023):

- **Limits to effectiveness of service provision:** while NbS can provide many services, evidence to date shows that there are limits to their performance. For example, NbS are generally better able to protect against lower intensity hazards (e.g., less than 1-in-100-year floods), and are less effective for higher intensity hazards (e.g., higher than 1-in-100-year floods) (Dadson *et al.*, 2019). Equally, wetlands have limits in terms of their tolerance to pollutants, which can be a factor in the treatment of certain wastewater streams.
- **Variations and uncertainties in functional performance:** the ability of NbS to provide services can vary, impacted by factors including the season, species, ecosystem type, location and management. For example, some NbS may be seasonal and better able to provide services at certain times of year.
- **Time delays to benefit provision:** some NbS can require more time to develop and provide services than built infrastructure, particularly in the case of the restoration of badly degraded ecosystems, which can pose a challenge when services are needed immediately.
- **Concerns around the resilience of NbS:** ecosystems that underpin NbS can be susceptible to disease, pests, climate impacts and human activities such as infrastructure development.
- **Availability of data on costs and benefits:** there remains a lack of data on the relevant costs (e.g., implementation, management, monitoring) and benefits of NbS in different contexts, including their effectiveness at service delivery.
- **Sustaining benefits through management and maintenance:** many NbS will require maintenance to sustain benefits, which can be a challenge for projects where human and financial resources are limited.
- **Capacity to implement NbS:** human, institutional and technical resources are necessary for implementing successful NbS. This includes sufficient availability of people to deploy the solution, technical skills and technical resources for implementing, managing and monitoring NbS, and institutional capacity to create a supportive enabling environment.
- **Trade-offs:** there are various trade-offs that can occur with NbS. For example, while some NbS, such as restoration of forests, may provide benefits in terms of reduced sedimentation of water supplies, they can have trade-offs in terms of water availability which can have negative implications for water dependent sectors.
- **Costs and who pays:** given that NbS can provide multiple benefits simultaneously across sectors and stakeholder groups, there may be challenges as to who should pay for the NbS, and how costs should be distributed.
- **Multiple stakeholders:** NbS projects may require a broader range of stakeholders than built infrastructure, many of whom might have different views, such as infrastructure practitioners, governments, NGOs, NbS experts, hydrologists, private landowners, and local and indigenous communities. Where multiple sectors and ministries are involved, many will have different interests (Balzan 2025).
- **Transboundary decision-making:** where built infrastructure and NbS extend across national borders, or resources are shared between upstream and downstream countries, decision-making will be required at a regional scale to maximize benefits and minimize negative outcomes. This will require engagement of a greater range of stakeholders to plan, implement, manage and monitor the NbS.

The rest of this chapter provides an overview of some of the key considerations for planning NbS projects that can help ECE countries to manage these challenges and undertake informed decision-making, while Chapter 12 provides key policy, financial and capacity building recommendations for supporting the uptake of NbS.

10.2 Key considerations and success factors for planning NbS

Box 10.1: Practical resource

- The **IUCN Global Standard for Nature-based Solutions** is a globally recognized framework for the verification, design, and scaling of NbS. It consists of eight criteria and 28 indicators, supported by guidance documents and a monitoring checklist to track outcomes across environmental, social and economic domains. It is accompanied by in-depth guidance which includes the scientific background for NbS and guidance on the criteria and indicators (IUCN, 2020b).

See also Annex 5 for more frameworks and tools.

Embed consideration of NbS from the start of the infrastructure project lifecycle: planning phase

Strategies that aim to capitalize on the benefits of NbS for meeting infrastructure and wider needs simultaneously tend to be most effective if grey and green infrastructure are planned in an integrated manner. Success factors include:

- **Embed NbS into infrastructure planning processes:** the potential success of NbS projects is improved the earlier NbS are incorporated into infrastructure planning. Attempting to add NbS retrospectively tends to be less effective than incorporating NbS from the start, particularly given that existing natural ecosystems and their ecosystems may be lost during the development of built infrastructure and insufficient space may remain once grey infrastructure is developed.
- **Identify and map out NbS in tandem with or before grey infrastructure options:** NbS should be considered at the earliest opportunity in project development, before or alongside grey infrastructure options.

Engage multiple stakeholders across the project lifecycle (planning, design, construction, operation, management, maintenance, monitoring)

Successful NbS projects require stakeholder engagement from the start and through the co-design, implementation, operation and maintenance stages. Success factors to consider in the process include:

- **Assess relevant stakeholders to include:** effective stakeholder analysis involves identifying and engaging relevant stakeholders early in the project. A stakeholder mapping process can help to identify the relevant stakeholders. These may include infrastructure practitioners, utility companies, local communities, NGOs, morphologists, hydrologists, environmental agencies, ecologists, governance experts, local governments, social impact experts, women and indigenous and marginalized communities. NbS experts will be essential to enable consideration of relevant solutions for the local context. The integration of indigenous and local knowledge alongside technical and scientific knowledge can improve outcomes and increase community ownership.
- **Partnering with academic institutions:** partnering with schools, universities and educational institutions can help to raise awareness about NbS and support the decision-making process.
- **Participatory approach:** this should be taken across the full project lifecycle to include the full range of stakeholders both equitably and democratically (IUCN, 2020). Co-create shared visions and objectives, define benefits and collaborate to design, implement and manage projects, and reduce risks across the project lifecycle. Support effective communication and trust-building between different stakeholder groups.
- **Develop social safeguards:** this can be helpful to ensure that negative trade-offs of NbS do not negatively impact societies and to ensure that local communities are not denied access (Seddon *et al.*, 2021). A full understanding of potential costs, benefits and trade-offs can help to inform the development of appropriate social safeguards.
- **Allocate funding to support open and inclusive decision-making:** the implementation process needs to support openness, transparency in governance processes, and legitimacy of knowledge from different stakeholders including citizens, practitioners and policy stakeholders. Allocating funding to this can support the development of NbS that factor in value across different stakeholder groups. The design of solutions must consider the needs of

all users from the initial planning and design phases. Projects that address community needs and/or provide clear livelihood benefits have increased community participation and long-term success.

- **Community outreach and awareness raising:** direct involvement of communities in the planning and design of NbS can help to support inclusive efforts and avoid unintended consequences. Local communities can also provide invaluable information on the local socioeconomic and ecological conditions under which the NbS will operate. Effective community outreach and involvement can cultivate community ownership and feed back into long-term sustainability of the NbS. This may include training and educational programmes and community-based approaches to data collection and project implementation. Raising awareness on the project benefits and the issues that it will address can help to improve community participation and perceptions. Projects should be mindful of the community's schedule and minimize demand on community members' time and energy.
- **Develop a meaningful governance structure:** inputs from stakeholders can be implemented through a meaningful governance structure, which should include systems that reflect their views, help facilitate negotiations and modify planning as required. Planners can facilitate spaces for discussing ideas and suggestions related to NbS with the relevant stakeholders.
- **Working groups:** these can be established to include the broad range of stakeholders (ECE, no date, z). This can lead to more effective implementation and reduce social tensions.
- **Develop a grievance mechanism:** this should be made accessible to communities in case they are adversely affected by the NbS project.

Example guiding questions:

- Who are the key stakeholders that I should engage? For example, which local communities, NGOs, private sector, academia stakeholders, ecosystem experts are needed?
- Which government authorities are needed to implement this solution?
- Is there foreseeable resistance by powerful veto players?
- Are there foreseeable allies for this solution? Does this solution address immediate interests or needs of relevant actors?
- Does implementation of this solution require (time-consuming, complex) multi-stakeholder negotiation, or is the number of relevant actors clearly limited?
- Who uses and depends upon existing ecosystems, and who would be impacted by the implementation of the NbS (positively or negatively, directly or indirectly)?

Examples of NbS projects that have brought in multiple stakeholders and local communities

The Josefov Meadows Bird Park (Czechia) aimed to rehabilitate the wetland and grass meadow ecosystem and enhance local biodiversity with the restoration of traditional irrigation systems and the creation of new ecosystems such as ponds that provide food for birds and living space for endangered species of invertebrates. The project also provides environmental education to visitors through environmental trails and an observatory. The project brought together many stakeholders including NGOs, farmers, the local government and additional donors. The Czech Ornithological Society, which runs the project, also collaborates with the farmers who manage the connected meadows to provide sustainable management solutions for the park (Nature4Climate, no date, h).

Governments and conservation groups have historically excluded indigenous peoples in land use decisions about the Emerald Edge in Oregon and Washington (United States of America) and British Columbia (Canada). A project works to advance Indigenous and community-led NbS, focusing on protection, restoration and improved land management. The Nature Conservancy launched the Emerald Edge Accelerator in 2022 to scale up the impact of these solutions through community-driven conservation, drawing from relationships developed with indigenous peoples, local communities and other stakeholders (Nature4Climate, no date, j).

Case study 10.1: Participatory forest restoration in semi-arid areas, in Morocco

The semi-arid regions of North Africa face frequent challenges of land degradation that result from human and climate change induced pressures. Previous efforts to undertake ecological restoration of degraded land have had minimal success as they were typically conducted in a non-participatory and top-down manner. This project focused on the Beni Boufrah area in the Al Hoceima province of North Morocco. Aiming to serve as an example of more participatory ecological restoration in semi-arid areas of North Africa, this initiative included scientists, managers and local stakeholders in every part of the project to restore an area of *Tetraclinis articulata* forest in Morocco.

A group of researchers launched a Participatory Ecological Restoration project in the Beni Boufrah Forests. This approach was based on knowledge sharing, trust and active stakeholder participation with scientists, managers and local stakeholders involved in and guiding every step of the process from planning to monitoring outcomes. The participatory process was applied to all steps of the restoration initiative including the identification of restoration priorities, assessment of land-use options, definition of the restoration procedure, participatory plantation, evaluation, surveillance and monitoring. Specifically, the restoration efforts were conducted on a one-hectare area of land where 90 participants (57 men and 33 women) planted 250 plants. Given the area is primarily *Tetraclinis articulata*, a stakeholder workshop concluded that the planting of *Tetraclinis* and other wood species would be most appropriate.

Community members reported a wide range of ecosystem services provided by the restored forest area, including services linked to the most critical local problems of erosion and flooding. Improved integrity of the restored plot and recovery of native vegetation were reported as indicators of success. Monitoring has shown an increase in cover and composition of spontaneous vegetation.

A post-intervention report emphasized that the signature of an agreement between stakeholder groups was reported to represent their will to overcome disagreements, trust each other and work together for the purpose of conserving and restoring local natural resources. The active involvement of women was sought throughout each step of the project, although many women faced restrictions due to their responsibility for housework and family care.

Governance: The project is governed by a multi-stakeholder platform with 67 members. The board has 19 scientists and managers, 20 NGO members and local authorities and 28 local resource users.

Funding: It is funded by the University of Abdelmalek Esaadi in Morocco and the University of Alicante in Spain.

Monitoring and evaluation: A plot system was set up and is monitored by the scientific team. Simultaneously, a group of 15 stakeholders worked on conducting evaluations to monitor the progress of the programme.

Sources: NbSI (no date, a); Derak *et al.* (2018).

Identify a range of potential NbS options: planning phase

The NbS typology outlined in Table 1.1 (Haggis *et al.*, forthcoming) can provide a starting point for identifying NbS options capable of meeting the service need. Success factors to consider include (IUCN, 2020; Cohen-Schacham *et al.*, 2016):

- **Identify the service need(s):** NbS should be tailored to the local needs or requirements, for example, to address issues of sedimentation in water courses supplying hydro power, to protect roads from landslides, to reduce urban heat islands, or to improve mental health and well-being. A needs assessment can help to establish the service need and inform the design of an NbS.
- **Take a landscape approach when identifying NbS options:** the area relevant for an NbS may extend far away from the area identified to need the service. Ecosystems can influence certain processes, such as flows of sediments, nutrients and water, far beyond their location. For example, to safeguard storage capacity of hydropower reservoirs, a catchment-scale approach may be necessary, given that ecosystems and management practices in upstream

catchments can influence water and sediment flows downstream. A landscape, systems-wide approach is also necessary to avoid unintended consequences which may occur as a result of the NbS.

- **Conduct a baseline assessment:** robust baseline assessments of biodiversity, ecosystem services and ecosystem health are required prior to the intervention to understand how NbS can best provide the required services and support informed decision-making (IUCN, 2020a, IUCN, 2020b). This may gather information on:
  - **Land use, ecosystem types, location, extent and condition:** mapping ecosystems in and around the relevant area and their condition can help to understand whether interventions may be best focused on protecting existing ecosystems, restoring degraded landscapes, better managing ecosystems, or creating new ecosystems.
  - **Current and historical vegetation patterns:** this can be investigated for the project area to determine the appropriate native vegetation type to be used in the NbS.
- **Biodiversity and ecosystem and species selection:** the project should aim to work with native, locally-adapted ecosystems and avoid the introduction of invasive and non-native species. For example, in Morocco, to adapt to drought, species adapted to local conditions are used from the region.
- **Preserve and increase diversity:** diversity is key to the health and success of NbS projects (Key *et al.*, 2022). Therefore, practitioners should consider ecosystem and species diversity in NbS projects and maintain it across the lifecycle. Where appropriate, multiple ecosystem types can be used to support diverse NbS.

Example guiding questions:

- What are the existing ecosystems in the area?
- What ecosystems were historically in the area that might have been lost due to land use change and could be restored?
- What is the condition of the ecosystems? Are they healthy?
- What is the management status of the ecosystems; are they under protected areas?

Carefully consider location choices: planning phase

NbS are typically context specific, therefore their potential effectiveness and ecological suitability must be assessed within the context of the relevant locations being considered (Seddon *et al.*, 2021). Factors to consider when thinking about locations include:

- **Land ownership and land rights:** where NbS occur on private land, arrangements may need to be made to secure permission for use. Land rights and access to resources of different groups should be respected. It is important to ensure that the development of the NbS does not displace or adversely affect local communities.
- **Available space:** NbS often require more space than conventional infrastructure. This needs to be considered to ensure sufficient space is available for the NbS to provide the relevant benefits.
- **Condition:** the health and condition of the landscape can help to guide decisions over where to place grey or green infrastructure. For example, grey infrastructure may be placed in previously degraded areas to help avoid further habitat loss. For grey infrastructure, practitioners should prioritize the use of lands that have already been converted, such as urban areas, industrialized spaces or existing infrastructure, and aim to increase the multifunctionality of these lands, incorporating NbS where possible.
- **Upstream versus downstream:** where planners are considering strategies concerning flows of water, nutrients and sediments to an asset or location, such as to reduce sedimentation of a water reservoir, they will need to assess processes occurring at upstream locations and locate NbS accordingly.
- **Proximity to service need:** some NbS may need to be cited close to the service need, for example, where NbS are implemented for shade provision and heat reduction. For other NbS, benefits may arise from locations further away, for example, at the catchment scale.

Example guiding questions:

- Who owns the land? Do I need to purchase land or rent land for this NbS?
- How much space is available for implementing NbS, and is it sufficient for meeting the service need?
- What is the current condition of the relevant area?
- What is the relevant upstream area from the identified service need?

Conduct a full appraisal of benefits and costs: planning phase

Information on costs and benefits will be integral to selecting NbS options. Factors to consider include (UNEP, 2023):

- **Capex:** capital costs of implementing a given NbS, for example, land purchase, permits, site preparation, labour, transport, equipment. It may also include costs for additional measures, such as fencing to protect new saplings from grazing animals.
- **Opex:** operation and maintaining costs, for example weeding, pruning, litter picking, irrigation
- **Time:** number of years before the NbS is able to meet the required level of effective service provision
- **Space:** space required for an intervention.
- **Effectiveness** at meeting the required service needs.
- **Potential for generating multiple additional benefits for societies, economies and the environment**. Valuing the broader social, cultural and environmental benefits of NbS including their multifunctionality can help to make the economic case for an NbS option.
- If the wider values that NbS can deliver are not recognized effectively, this could lead to them being overlooked and missed opportunities to achieve benefits.
- **Consider existing and future threats to the NbS:** current and predicted development, environmental and climatic threats need to be considered when selecting viable NbS. This can support the selection of species that are adapted to future climate conditions, to ensure that they are resilient and endure long-term (IUCN, 2020). Where necessary, a climate impact assessment can help to identify climate vulnerabilities and the extent to which ecosystem services are impacted (Kapos *et al.*, 2019).
- **Consider the best time to implement:** some NbS can only be implemented at certain times of year. For example, to survive planting, trees often need to be planted at the beginning of the rainy season.
- **Consider costs and benefits over long timescales:** assessing costs and benefits over longer timescales can account for the longer timescales that some NbS take to develop and provide services. Evaluating outcomes at too short a timescale can miss the potential scale of value that they offer.
- **Alignment with national priorities:** consider how to align NbS with national priorities and commitments, including international frameworks such as the Paris Agreement and SDGs. This can help to make the case for funding from organizations (see box 10.2).
- **Account for the broad range of benefits using multicriteria analysis (MCA):** compare and prioritize options using MCA. This can help to account for the wider benefits that NbS can generate and assess them against conventional and hybrid infrastructure options.

Example guiding questions:

- Are the costs prohibitively expensive? Does it have high-up front costs, or is it comparatively affordable?
- How effective is it at meeting the primary service need?
- What wider benefits does this NbS result in, and does this make the case for investment when compared alongside economic costs?
- Does this NbS produce quickly verifiable results, or does it take decades for it to be effective or visible? Are there temporary built options or hybrid options that can be implemented while the NbS develops?

- Are there particular times of year in which this NbS might not do well that should be avoided, or times that would give the best chance of success?
- Are there any risks to the NbS that may need to be addressed to allow it to establish?
- How much space is required to implement the NbS?

Undertake monitoring: cross-lifecycle

As outlined in Chapter 7, monitoring is key to understanding the effectiveness of NbS, identifying unintended consequences, and building an evidence base that can help to build a business case on NbS and inform future decisions. Monitoring and evaluation should be ongoing throughout the entirety of NbS projects, to assess outcomes of the project, including performance across the lifespan, and whether the project needs to be adapted through adaptive management approaches (IUCN, 2020b). Factors to consider include:

- **Develop a robust, standardized monitoring and evaluation plan:** doing so prior to project implementation can be an integral component of success. The monitoring methodology must account for the outcomes of NbS across different spatial and temporal scales.
- **Establish a monitoring committee:** this can include representatives from relevant stakeholder groups, e.g. academia, government, communities, NGOs.
- **Set biodiversity safeguards:** the development of biodiversity safeguards may help to ensure that ecosystems are not being over-exploited (Seddon *et al.*, 2020). This may include the application of limits to certain practices, such as fishing.
- **Identify new risks:** identify new risks to the NbS and whether new actions are required to ensure the NbS continues to persist and provide services.
- **Assess how the NbS is developing:** identify opportunities to improve performance and assess how NbS is responding under changing conditions. If the solution is not effective, identify follow-on actions.
- **Gather gender disaggregated information:** men and women have different service needs. To ensure that the NbS is meeting the needs of both women and men, gender disaggregated data should be collected and used where possible.
- **Assign finance to long-term monitoring:** project planners should include the provisioning of financial and technical support throughout project lifespans to monitor outcomes, build an evidence base and identify any adaptive management requirements.

Example guiding questions:

- Who should be involved in the monitoring process?
- What are the key parameters that need to be monitored?
- How often should monitoring be conducted?
- What technical resources might I need for monitoring?
- Do the relevant workers have sufficient technical skills for monitoring?
- How much budget should be set aside for monitoring?

Undertake maintenance and adaptive management: construction, operation and maintenance phases

Long-term maintenance is critical to the effectiveness of NbS and to ensure performance is maintained. Key success factors include:

- **Develop a maintenance strategy:** maintenance strategies should be made an integral part of the development process. Strategies may need to consider invasive species removal, litter clearing, irrigation, pruning, planting of new seedlings, sand nourishment, etc.
- **Develop techniques for adaptive management:** NbS are flexible and responsive to the environment and can change over time due to local conditions and long-term drivers. Therefore, the implementation and management

approach should be adaptive and iterative, based on ongoing consultation and negotiation with different stakeholders (Cohen-Schacham, 2019).

- **Assign finance to long-term maintenance:** project planners should include the provisioning of financial and technical support throughout project lifespans to increase the chance of success. Funding should be allocated to ensure adaptive management approaches so that the NbS can adapt to any changing environmental and climatic conditions over time.

Example guiding questions:

- What maintenance requirements are anticipated?
- How often does maintenance need to be conducted?
- How much funding should we allocate to maintenance?
- Who will be conducting the maintenance, and do they have sufficient skills and technical resources?

Examples of NbS projects

For example, the main objective of Pro Vértes is to run a nature conservation management organization that, in cooperation with state conservation bodies, NGOs and local governments, ensures the sustainable management of Vértes Nature Park, Transdanubian central mountains, Hungary. Pro Vértes takes an active role in organizing and conducting nature conservation activities and tourism projects in cooperation with the region's local governments. Other activities include research, monitoring, education, awareness-raising, training, capacity building and the preservation of local cultural heritage. This is particularly important in the area as the natural forests, marshes and loess meadows in and around Vértes are valuable habitats and need to be preserved and managed in harmony with nature conservation objectives (Nature4Climate, no date, g).

In another example, Cherokee Forest is one of the largest remaining areas of forest in the Blue Ridge Mountain range, Northeast Tennessee (United States of America), that is not managed by the government or sold off for deforestation. Since the project's inception in 2017, over 8,600 acres have been protected: the equivalent of avoiding more than 38,000 teqCO_2 per year. The project's employees work to prevent invasive plants from entering the land while also supporting biodiversity research in the area. The forest management programme has also helped improve the soil quality, thereby supporting healthy waterways in the greater watershed region (Nature4Climate, no date, k).

The Cheakamus Community Forest is one of around 50 community managed forests in Canada's British Columbia province. To reflect the cultural partnerships in the region, the 33,000 hectares of forest are protected through joint management with the Lil'wat Nation, Squamish Nation and the Resort Municipality of Whistler. Established in 2009, the project uses sustainable management practices to harvest around 40 hectares per year. Much of the rest of the region is protected and part of a carbon offset programme; over the past 10 years, the project has generated about 150,000 tons of carbon offsets. In turn, the project has reduced emissions by around 10,000 tons of CO_2e per year and generated revenue to support fire mitigation and forest monitoring programmes (Nature4Climate, no date, f).

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Develop and share lessons learned: cross-lifecycle

Documenting and sharing lessons learned will be key to building an evidence base on what does and does not work across the lifecycle of NbS projects and informing others who are implementing NbS of what works or does not work in different contexts. This can help to understand success factors and challenges across the ECE region. Factors to consider include:

- **Standardize the documenting of lessons learned within infrastructure processes:** the process of project design and implementation should make the capture, documentation and sharing of lessons learned part of standard practice, to support others who are involved in NbS.
- **Share information on useful data and methods:** contribute new data and methods on NbS which can support implementation and scale up (IUCN, 2020b).
- **Share outcomes:** reporting of outcomes should be transparent and shared publicly to support knowledge sharing, stakeholder engagement, investment and policymaking. Include effectiveness, costs and benefits of NbS, and performance under different conditions and across different spatial contexts. This should include documentation of relevant challenges and circumstances where NbS do not work. For example, in locations in which there are huge temperature fluctuations, constructed wetlands are reported to have higher failure rates.

Example guiding questions:

- What worked well in this project?
- What did not work and why?
- Were there particular factors to success?
- What might need to be done differently if we were to replicate this?

Examples of NbS projects

For example, the main goals of the Salt of Life project in Bulgaria were to establish functional infrastructure for water management of the coastal lagoon in Atanasovsko Lake and to provide long-term improvements to habitat conditions, enabling adaptation to the effects of climate change. The project also focused on improving the visitor experience at the site, enhancing public understanding of the values of coastal lagoons and sharing the project results with a wider European audience of site managers, ecologists and the general project. The implementation of the project established a model for the inclusion of businesses such as the salt production company in the management of protected areas and Natura 2000 sites through facilitating their participation in direct conservation actions and demonstrating the ecological, social and economic benefits of preserving the lake (Nature4Climate, no date, i).

Case study 10.2: UNEP water management and NbS resources, Africa

UNEP's global water initiatives focus on facilitating climate-resilient water management strategies that integrate flood and drought mitigation, advance integrated water resources management (IWRM), and support ecosystem protection and restoration. Through multiple ecosystem-based adaptation projects worldwide, UNEP (no date, b) lessons learned and various reports, such as "A Watershed Approach in Ecosystem-based Adaptation," which highlight effective approaches particularly in Latin America and the Caribbean.

The UNEP-DHI Centre on Water and Environment (UNEP-DHI, no date) serves as UNEP's specialized centre of expertise for freshwater management. Established in 1996, the centre leverages over five decades of water management experience from its host organization, DHI. It supports UNEP's freshwater strategies by providing technical expertise, decision support tools, and project implementation targeting water challenges at local to transboundary scales. The centre collaborates widely to promote sustainable water governance with a focus on achieving SDG 6 (water and sanitation), flood and drought management, and ecosystem conservation.

In Africa, UNEP-DHI is actively engaged in the project "Reversing Ecosystem and Water Degradation in the Volta River Basin," running from 2023 to 2028 and funded by the GEF. This project targets environmental threats like climate change, poverty, and pollution across six West African countries by enhancing transboundary governance, restoring ecosystems, and promoting sustainable livelihoods. UNEP provides critical support through water resource models, decision support tools, and drought early-warning systems, while strengthening local institutional capacity to ensure sustainable management of natural resources for nearly 19 million people in the basin.

In addition, UNEP (no date, c) has been publishing State of Finance for Nature reports every two years, aiming to quantify public and private finance flows to nature-based solutions, and the extent to which finance flows are aligned with global targets. Combined with country-specific analysis, these analytics and crucial findings are expected to inform policymaking, aligning fiscal policies and incentives to halt nature loss and work towards a nature-positive economy.

Source: Personal communication from Yoko Moroizumi (UNEP), 20 August 2025.

Box 10.2: Funding considerations

The United Nations Office for Project Services (UNOPS), in collaboration with the University of Oxford, developed the Sustainable Infrastructure Financing Tool (SIFT), now called "Fundable", to understand common key financing criteria of potential financiers for sustainable infrastructure projects. Underpinning SIFT is a database of 134 global infrastructure funds. They identified ten criteria typically used to assess concept stage projects:

1. Alignment with national strategy;
2. Alignment with SDGs: potential benefits across key targets of the 17 SDGs;
3. Alignment with the Paris Agreement (NDCs): demonstration of mitigation benefits;
4. Economic benefits;
5. Social benefits;
6. Benefits vulnerable communities;
7. Gender considerations: benefits in terms of gender equality through benefits to women;
8. Environmental considerations;
9. Climate resilient measures.

These criteria can be built into project proposals.

Source: Adshead *et al.* (2022).

11. Summary of key findings

Countries across the ECE region are facing a myriad of environmental and health challenges, including meeting development needs, mitigating and adapting to climate change, addressing a range of physical and mental health issues, and reversing environmental degradation and biodiversity loss. Many climate impacts are already occurring, including rising temperatures, floods, droughts, landslides and pollution of water and air. Compounded by unsustainable infrastructure systems, people within ECE countries are facing interlinked health issues, including respiratory illnesses, cardiovascular disease, heat-related mortality, stress, anxiety, shorter life expectancy and lower quality of life. While conventional built infrastructure systems provide many essential services such as water, energy, transport and waste removal, a disproportionate focus on built infrastructure is exacerbating the environmental and health issues occurring in the region. There is a pressing need for ECE countries to address these challenges and increase the sustainability and resilience of their infrastructure systems. NbS in the form of green or hybrid solutions offer promising alternatives and additions to built assets as they can provide many services relevant to infrastructure and support a more holistic range of benefits that are integral to positive environmental and health outcomes.

This report has provided an overview of the key environmental and health challenges that the ECE region is facing and assessed the potential benefits that NbS could provide to address them. There are five functions through which NbS can provide benefits to infrastructure and beyond. NbS can deliver infrastructure services directly and substitute for built assets; enhance the provision of infrastructure services and complement built assets; protect infrastructure services from climate impacts; benefit sector workforces, the human capital that underpins infrastructure services; and support multiple additional benefits for economies, societies and the environment, often termed "co-benefits".

While nature-based approaches have been implemented in the ECE region for hundreds of years, the term "nature-based solutions" has not yet been formally mainstreamed, and the integration of NbS into plans, projects and policies is still at an early stage. Some ECE countries have included references to ecosystems in their national commitments under the Paris Agreement on climate change; however, there is scope to strengthen ambition on NbS. This includes increasing the range of ecosystems which are referenced within NDCs and NAPs, setting quantifiable targets and recognizing explicitly their potential to synergize progress across both mitigation and adaptation components.

Through the careful planning, implementation and long-term stewardship of locally adapted NbS, countries can support integrated progress on climate change. While there are emissions associated with some NbS, for example through the use of mechanized machinery to prepare sites for restoration or during the transport of seedlings or workers, there is potential for NbS to reduce GHG emissions embedded across the lifecycle of built infrastructure by substituting for built assets, reducing maintenance requirements and the frequency at which built assets need to be repaired and replaced. By integrating NbS into infrastructure systems, countries can further reduce GHG emissions through avoided land-use change and sequestration of carbon emissions in natural carbon sinks. Evidence demonstrates that NbS can also be effective components of adaptation strategies, particularly for lower-severity climate hazards. They can help to protect infrastructure and ECE populations by reducing the frequency and severity of landslides, droughts, flooding, heat and wildfire, and support improved air and water quality. At the same time, NbS are integral to wider environmental outcomes, including protecting and increasing habitat extent, species diversity and ecosystem connectivity, and supporting the health of native ecosystems, all of which underpin biodiversity. These environmental benefits translate into tangible health benefits. For example, reduced physical health issues such as cardiovascular disease, respiratory illnesses, waterborne diseases and obesity, and better mental health outcomes through opportunities for social interaction, exercise and stress reduction.

To inform decisions on NbS and ensure the most appropriate solutions are selected which can maximize benefits and minimize potential negative trade-offs, it is essential to monitor the outcomes of projects long-term. Data on the costs and benefits of different green and hybrid solutions, including their effectiveness at providing services, is necessary to build an evidence base and enable comparison with conventional built solutions during the planning process. Pilot projects that harness NbS are helping to demonstrate the potential benefits that NbS can provide to countries within the region. Such pilot projects are key to raising awareness of the potential of NbS and building an evidence base of data on costs and benefits to inform future investment decisions.

EPRs provide a critical tool to support countries in aligning their datasets, plans and strategies to achieve integrated progress on climate, development and biodiversity. Although there are moves towards integrating NbS more systematically within EPRs, there is both a need and an opportunity to strengthen their inclusion. The expert review process can support the development of relevant plans and strategies to facilitate uptake of NbS, including through the development of a supportive enabling environment, including relevant policy actions. The integration of NbS into the recommendations of EPRs provides a useful starting point towards the mainstreaming of NbS in national planning processes.

Scaling NbS will require the mobilization of finance and development of supportive policy frameworks and regulation, institutional, technical and human capacity building and the development of an evidence base on the costs and benefits of NbS, including their effectiveness in different contexts. Countries across the region can support each other through the sharing of knowledge, lessons learned, and best practices as they implement NbS.

As ECE countries seek to address the interlinked environmental and health challenges that are ongoing in the region, there is a huge opportunity to scale NbS. By systematically considering NbS alongside built infrastructure in planning and investment decisions and prioritizing green and green-grey solutions where possible, there is potential to generate a much wider range of benefits than built infrastructure can alone. To maximize the potential for benefits and minimize potential negative trade-offs, NbS need to be embedded from the beginning of planning processes and across the infrastructure lifecycle. The integration of NbS into the recommendations of EPRs can provide a critical starting point for mainstreaming NbS within the ECE region.

12. Final policy, finance and capacity building recommendations

Scaling up NbS and sustainable infrastructure approaches requires supportive enabling conditions, including clear policy frameworks, financing mechanisms, capacity building and knowledge sharing. This closing chapter provides an overview of key recommendations for supporting the scale-up of NbS across the ECE region.

12.1 Policy recommendations for promoting NbS and sustainable infrastructure

Address NbS in all future EPRs, including by encouraging countries to set and report on NbS-related targets in their NDCs and NAPs. The EPRs provide a basis and opportunity for synergizing NbS approaches across different policy agendas, including sustainable development, climate mitigation, adaptation and biodiversity. Countries should be incentivized to embed NbS, identify synergies between sectors and goals, and set measurable targets where possible.

Integrate NbS into national infrastructure programmes, strategies and priorities. Embed NbS principles in law with specific finance targets (WB-PPIAF, 2023). Mainstream biodiversity considerations into the region's land-use, spatial and infrastructure planning, to maximize the use of NbS in infrastructure development, and restoration of NbS following decommissioning. Introduce an NbS standard in infrastructure planning. Stronger legislation and enforcement mechanisms to protect biodiversity and prevent land degradation, including sanctions for illegal activities. In particular, legal provisions on NbS can support the integration of NbS in sectors beyond biodiversity conservation.

Ensure institutional and governance frameworks facilitate stakeholder collaboration. Trade-offs that may arise through NbS can be minimized if all stakeholders are involved within the decision-making process (OECD, 2021).

Strengthen reporting mechanisms to capture synergies. Designing climate policies in a way that harnesses synergies and manages trade-offs between adaptation and mitigation can increase their effectiveness. Enhance reporting mechanisms to require countries to capture adaptation-mitigation linkages where they arise.

Enhance regulation to scale both public and private sector investment. Regulation can be enhanced to ensure that public budgets include investments in NbS. Strengthen regulations to support private sector investments and ensure private sector compliance, for example biodiversity offsets and carbon pricing.

Mandate monitoring and standardized data collection. Monitoring NbS is vital to inform decisions on NbS and hybrid approaches. Policies are needed to incentivize projects to gather long-term data on NbS outcomes, costs and benefits to build an evidence base, make a business case for scaling NbS, and inform multi-criteria assessments.

Reform infrastructure design standards: "old fashioned" design standards are enshrined in infrastructure planning and development processes. Flexibility or reform here would help to promote innovative approaches, including NbS.

Facilitate sharing of information. Establish a centralized online platform to document, exchange and scale up NbS practices and lessons learned across sectors.

Pilot projects. Encourage cross-sectoral collaboration and pilot projects demonstrating how NbS can support national goals in climate resilient infrastructure

Innovation. Promote the involvement of the private sector, national and international entities and research institutions in developing and implementing innovative NbS targeting infrastructure resilience to climate change.

12.2 Strategies for financing and investment

Financing is integral to NbS projects and is required across the full project lifecycle, from initial planning and design through to implementation, operation, management and maintenance.

Streamline public sector resources and increase private sector involvement in the financing of NbS: As outlined in Chapter 9, there are different financing instruments serving different purposes, yet financing is not sufficient to meet the need (e.g., due to public budgets) or their uptake is still limited (e.g., involvement of the private sector). There is a need to focus on how to streamline public resources towards more impactful operations and how to increase private sector involvement, for example through tax credits, green bonds and public-private partnerships.

Provide finance across the project lifecycle: Sufficient resources must be allocated for the early planning and management of projects (European Commission, 2024), all the way to monitoring outcomes long-term. Promoting sustainable, long-term investment into biodiversity-positive actions in the region on a consistent basis at national, regional and global scales in various sectors, while avoiding the financing of activities that contribute to biodiversity loss.

Subsidies: Eliminate subsidies that promote the excessive use or exploitation of nature, and where possible, redirect these towards NbS. Make more targeted use of subsidies and other incentives for NbS such as sustainable agriculture.

Invest in data collection and information processing: Knowledge is instrumental for decision-making and informing the design. The continuous improvement of monitoring and communicating outcomes is a top priority (ECE, 2022b).

Embed multifunctionality as a funding criteria. Ensure funding capitalizes on the synergistic benefits that NbS can provide, such as for climate adaptation, mitigation, health and biodiversity. Look for synergies across projects (European Commission, 2024).

Require biodiversity to be included in development projects. Setting biodiversity targets as a requirement for new development projects can help direct funding towards NbS. For example, the Biodiversity Net Gain legislation in the United Kingdom requires all new developments to achieve a 10 per cent biodiversity net gain. See case study 9.3.

Increase the timeframes over which funding can be provided: to ensure access to funding for NbS that take longer timeframes to develop and provide services, and those that need long-term maintenance.

12.3 Capacity building

Ensuring sufficient human, technical and institutional capacity is a necessary part of scaling NbS projects across the region. It can help to ensure that the relevant stakeholders have the necessary skills and knowledge to undertake NbS projects.

Awareness raising on the concept of NbS: capacity building may include advancing the understanding of ecosystem services, NbS benefits and different stakeholder approaches.

Build technical capacity for NbS. Technical skills are required across the whole project lifecycle, from selecting the most appropriate NbS suited to local needs and contexts, implementing the solution, and monitoring outcomes long-term (Balzan, 2025). This includes capacity building on sustainable management practices to reduce pressures on ecosystems, including better guidance to farmers on using soil conservation measures (European Commission, 2024). Technical capacity is also required to identify bankable projects. Technical capacity can be built through:

- **Training programmes** to ensure sufficient skills development. Provide technical training on NbS for planners and practitioners, particularly those more accustomed to grey infrastructure. This may include the provision of workshops on NbS techniques and maintenance of NbS.
- **International expertise** can support capacity building for conducting monitoring.
- **Workshops** that also include local communities can support knowledge exchange, for example on local habitat restoration practices.

Build institutional capacity on NbS. Institutional capacity is needed to ensure the enabling environmental factors are present, including relevant regulations on NbS, and ensuring that NbS are embedded within processes. Government training can help to strengthen institutional capacities for NbS.

Establish national NbS focal points in ECE countries to coordinate cross-sectoral implementation. National focal points for NbS can support the coordination of NbS projects across countries, sectors and stakeholder groups.

Ensure workforce capacity for NbS. Scaling NbS requires the availability of workforces. Governments need to develop and invest in capacities and education for sustainable development in responsible authorities, the private sector and civil society, to support the transition to sustainable development.

Undertake public education campaigns, workshops and training: this can help to empower local communities to participate in the planning and decision-making surrounding NbS. This may include awareness raising of how NbS can support resilience against climate hazards, especially among poorer and more vulnerable communities. Assess opportunities for local stewardship and conduct outreach events and field trips to promote NbS stewardship. Train local communities to participate in data collection and reporting.

Engage facilitators: engage facilitators who can connect different disciplines and on a system scale to leverage knowledge from individual experts and share it in an accessible manner. Facilitators can help to transmit the value of ecological, social and economic benefits to stakeholders.

Embed local knowledge into projects. Improve public and private sector stakeholders' understanding of the importance of biodiversity, whilst also increasing access to information encouraging the participation of local communities and other members of the public in decision-making related to biodiversity, to better integrate their knowledge, interests and rights.

12.4 Knowledge sharing

The sharing of lessons learned, good practices on NbS, and data on costs and benefits will be critical to scaling successful NbS projects and ensuring their persistence long-term.

Build an evidence base on NbS. The knowledge base on the costs and benefits of NbS including their across different contexts is limited. Their effectiveness depends on several factors, such as land management, ecosystem type and social and environmental conditions. Building an evidence base of costs and benefits will be fundamental to understanding their applicability to different contexts, making the case for investment, mobilizing finance for NbS, and mainstreaming their integration into development processes.

Systematically document and share good practices. Documentation and sharing of good practices more systematically and comprehensively can support scaling of NbS across different contexts and sectors within the ECE region.

Strengthen transboundary knowledge sharing: where ecosystems, natural resources and infrastructure are transboundary, this will require coordination and cooperation, including knowledge sharing, across borders, to implement and maintain the NbS long-term. Integrated water resources management should be pursued. Despite some good examples, cooperation and participatory processes for water protection, allocation and other practical achievements are not implemented as deeply as they could be in the pan-European region. Water resources management is more efficient at the basin level and good governance is required to bring success to technology and financing. Co-management should be pursued towards environmental protection and benefit-sharing within an efficient and resilient transboundary cooperation framework in the subregions, as envisaged by the ECE Water Convention (ECE, 2022b).

Annexes

Annex 1: ECE member States (ECE, no date, aa) and their EPRs

Country	Date of ECE membership	EPR cycle	Date of publication
Albania	14 December 1955	First	2002
		Second	2012
		Third	2018
Andorra	28 July 1993		
Armenia	30 July 1993	First	2000
		Second***	2024
Austria	14 December 1995		
Azerbaijan	30 July 1993	First	2003
		Second	2011
		Third	2024
Belarus	28 March 1947	First	1997
		Second	2005
		Third	2016
Belgium	28 March 1947		
Bosnia and Herzegovina	22 May 1992	First	2004
		Second	2011
		Third	2018
Bulgaria	14 December 1955	First	1995
		Second	2000
		Third	2017
Canada	9 August 1973		
Croatia	22 May 1992	First	1999
		Second	2014
Cyprus	20 September 1960		
Czech Republic	28 March 1947		
Denmark	28 March 1947		
Estonia	17 September 1991	First	1996
		Second	2001
Finland	14 December 1955		
France	28 March 1947		
Georgia	30 July 1993	First	2003
		Second	2010
		Third	2016

Country	Date of ECE membership	EPR cycle	Date of publication
Germany	18 September 1973		
Greece	28 March 1947		
Hungary	14 December 1955		
Iceland	28 March 1947		
Ireland	14 December 1955		
Israel	26 July 1991		
Italy	14 December 1955		
Kazakhstan	31 Jan 1944	First	2000
		Second	2008
		Third	2019
Kyrgyzstan	30 July 1993	First	2000
		Second	2009
		Third	2024
Latvia	17 September 1991	First	1998
Liechtenstein	18 September 1990		
Lithuania	17 September 1991	First	1998
Luxembourg	28 March 1947		
Malta	1 December 1964		
Monaco	27 May 1993		
Montenegro	28 June 2006	Second*	2007
		Third	2015
		Fourth	2025
Netherlands (Kingdom of the)	28 March 1947		
North Macedonia	8 April 1993	First	2002
		Second	2011
		Third	2019
Norway	28 March 1947		
Poland	28 March 1947	First	1995
Portugal	14 December 1955		
Republic of Moldova	2 March 1992	First	1998
		Second	2005
		Third	2014
		Fourth	requested
Romania	14 December 1955	First	2001
		Second	2012
		Third	2021
Russian Federation	28 March 1947	First	1999
San Marino	30 July 1993		
Serbia	1 November 2000	Second*	2007
		Third	2015
Slovakia	28 March 1947		

Country	Date of ECE membership	EPR cycle	Date of publication
Slovenia	22 May 1992	First	1997
Spain	14 December 1955		
Sweden	28 March 1947		
Switzerland	24 March 1972		
Tajikistan	12 December 1994	First	2004
		Second	2012
		Third	2017
		Fourth	ongoing
Türkiye	28 March 1947		
Turkmenistan	30 July 1993	First**	2012
Ukraine	28 March 1947	First	1999
		Second	2007
United Kingdom of Great Britain and Northern Ireland	28 March 1947		
United States of America	28 March 1947		
Uzbekistan	30 July 1993	First	2001
		Second	2010
		Third	2020
		Fourth	ongoing

Source: (ECE, no date, ab).
Notes: * Montenegro and Serbia were covered by the First-cycle EPR of Yugoslavia (2002); ** 1st EPR of Turkmenistan was conducted according to the methodology of the second cycle; *** 2nd EPR of Armenia was conducted according to the methodology of the third cycle.

Annex 2: Initiatives relevant to NbS relevant to the ECE region

ECE initiatives on forest and land restoration

ECE assists countries to integrate biodiversity across different sectors and policy areas, including in targets of the GBF through legislative, normative and capacity building efforts (ECE, no date, a). In the ECE region several targeted efforts and initiatives support forest restoration and management:

- **ECCA30 Initiative:** a partnership between ECE, FAO, IUCN, WRI and the World Bank, aims to restore 30 million hectares of degraded and deforested land by 2030 across Europe, the Caucasus and Central Asia. This aligns with the global Bonn Challenge, an effort to restore 350 million hectares of degraded land worldwide by 2030, and other related global and regional goals. As part of this effort, countries in Eastern and South-Eastern Europe, the Caucasus and Central Asia have already pledged to restore 7 million hectares by 2030.
- **ECE Forest and Bioeconomy Section and its Committee on Forests and the Forest Industry** (ECE, 2023b) builds capacities for implementation mechanisms, stock taking and needs assessments.to promote sustainable forest management, monitoring the state of forests and provision of data for evidence-based policies in support of sustainable forest management at the national level (ECE, no date, d). It includes policy support and capacity building activities supporting countries in the region in strengthening vulnerable ecosystems, restoring degraded landscapes, and increasing their resilience, biodiversity and protective capacity. Information on forests and sustainable forest management in countries of the ECE region is shared through a dedicated knowledge platform—INForest (ECE, no date, r). In addition to the basic information on forest cover, the platform includes a broad set of data on forest characteristics, biodiversity, carbon, damages as well as on forest-based products, their consumption and trade. Other outputs include a study on Boreal Forests (2025), a study on Forest landscape restoration in Moldova (2025), and a study on Reporting on forest damages and disturbance (2024). A practical guide to forest landscape restoration and a comprehensive study on the state and trends of forests in the ECE region are under development.
- **ECE's National Policy Guiding Principles for Forest Landscape Restoration** (ECE, 2023c) further support these efforts: developed by ECE as a tool to help countries design and implement effective forest landscape restoration policies, strategies and laws (ECE, no date, g).
- **Joint ECE / FAO Forestry Programme (ECE / FAO, no date):** to promote sustainable forest management, ECE implements, in partnership with the FAO, a joint programme of work which includes monitoring the state of forests and provision of statistical information for evidence-based policies in support of sustainable forest management at the national level. It includes policy support and capacity building activities supporting countries in the region in strengthening vulnerable ecosystems, restoring degraded landscapes, and increasing their resilience and protective capacity. Recent outputs include a Forest Sector Outlook Study for the ECE region, a study on Forest landscape restoration in the Caucasus and Central Asia (2018) and a study on the State of Forests of the Caucasus and Central Asia (2019).

Other relevant initiatives

- **The World Bank's RESILAND Programme and its extensions (the Central Asia Regional Resilient Landscape Restoration Programme):** this aims to increase the resilience of regional landscapes in Central Asia, including regional infrastructure, such as roads and dams, and transboundary ecosystems that need to be managed as one. It also aims to tackle fragility along borders by increasing livelihood opportunities and jobs and improve regional collaboration on landscapes. It has developed guidelines to address hazards such as mudflows, floods and landslides, including through use of NbS. It incorporates international and regional best practices tailored to Central Asian ecosystems, and focuses on cost-efficiency, scalability and local institutional readiness. The initiative has included consultations with governments, communities and climate adaptation experts.
- Biodiversity also forms an integral part of the **EU4Environment** programme (EU4Environment, 2021). This is a €20 million programme funded by the EU and implemented in part by the World Bank. EU4Environment aims to help Armenia, Azerbaijan, Georgia, the Republic of Moldova and Ukraine, also known as the Eastern Partnership (EaP) countries, to better preserve their natural resources, enhance environmental well-being and promote sustainable

growth. The implementing organizations include the OECD, UNIDO, UNECE, and UNEP (2019–2024) as well as the World Bank (2021–2026). The EU4Environment's knowledge has contributed to the development of environmental restoration investment projects including the Armenia Resilient Landscapes Project (RESILAND) and the Moldova Restoring Ecosystems for Marine Pollution Prevention Project (RE-MAP) (World Bank, 2025). EU4Environment operates at both regional and national levels. It primarily supports government authorities in the EaP countries, but also collaborates closely with civil society, academia, and the private sector. The World Bank has an allocation of €6 million and leads on supporting country efforts to strengthen regulatory frameworks to promote sustainable forestry and better manage protected areas. It includes a focus on four key areas:

- A shared network of protected areas;
- Community action on ecosystem services;
- Preventing illegal logging and promoting legal wood trade;
- Effective strategies for funding natural capital conservation.

- **EU4 Green Recovery East** (EU4GRE): this supports Eastern Partnership countries in transitioning to a greener, more resilient and competitive economy. It has €21.3 million in EU funding (2025–2028) and aligns with the European Green Deal and Global Gateway, to promote environmental policy innovation that creates jobs, improves health and ensures sustainable resource management. It aims to (EU Neighbours East, no date):
  - Promote circular economy and resource efficiency. Help businesses adopt circular models to create new jobs, reduce costs and reliance on imports;
  - Protect water resources and reduce pollution, improving water quality through better management and monitoring to safeguard the health of both people and ecosystems. This includes an aim for EU-compliant, nature-positive and climate-adapted river basin management planning to be deployed in candidate countries;
  - Align with EU Environmental Standards; support governments in aligning with EU environmental policies;
  - Strengthen Environmental Data and digitalization, improving environmental data integration and sharing at country and EU level for better policymaking;
  - Enhance transboundary cooperation on environmental issues. Encourage regional collaboration on shared water and air resources to address cross-border pollution.

ECE initiatives on urban nature and green infrastructure

Recognizing the importance of urban nature for biodiversity, health, and climate resilience, ECE has launched several programmes to scale ecosystem-based efforts in urban areas:

- **San Marino Regional Urban Forestry Action Plan (ECE, 2023d):** guides collective efforts at local, national and regional levels for a greener and more vibrant urban environment, with multiple biodiversity benefits. It identifies how local and national governments can collaborate to plan and sustainably manage urban trees and forests to provide health, biodiversity, climate and sustainable development benefits. It provides a framework for how businesses, communities, academics, NGOs and international organizations can contribute to these efforts (ECE, no date, l).
- **Tree Policy and Action Lab (Tree-PAL):** supports cities and countries to plan, manage and expand urban trees and nature as an NbS for local, national and global goals. Tree-PAL bolsters capacity and helps to support first movers and drive systemic change to implement. At the city level it supports planning, governance and long-term implementation and finance. Building on city-level insights, it supports policy and action for a systemic national approach to implement urban trees and nature as NbS (ECE, no date, l).
- **Trees in Cities Challenge** (ECE, no date, s): a collaboration between the Joint ECE/FAO Section on Forestry and Timber, since 2019 invites local governments to make a tree planting pledge to support greener, more sustainable, healthier, food secure and climate resilient cities (ECE, no date, l).
- **Trees in Dry Cities Coalition** (ECE, no date, t): established by ECE and partners to address cities in drylands where trees can benefit biodiversity while slowing or reversing desertification and erosion.

- **Informal Expert Network on Urban Nature:** established in 2021 to provide a forum for knowledge exchange, coaching, capacity building and peer-to-peer learning to strengthen the management of urban nature, particularly trees and forests (ECE, no date, l).

ECE initiatives on water and ecosystem-based adaptation

In recognition of the multifaceted water challenges that are ongoing within the region, there are several water-related initiatives of relevance:

- The **Water Convention,** formally the **Convention on the Protection and Use of Transboundary Watercourses and International Lakes**: this is an ECE-specific treaty that originated under the ECE framework. It was adopted in 1992 and entered into force in 1996. Since 2016, it has been open to all United Nations Member States, not just ECE countries. It addresses biodiversity issues, particularly in transboundary basins, and has organized capacity building on water-related ecosystems, ecosystem services, ecosystem-based adaptation, water-food-energy-ecosystems nexus, the source-to-sea approach and financing ecosystem conservation. Promoting conservation and restoration of transboundary freshwater and water-related ecosystems is part of the Convention's 2025–2027 work programme.
- The **Protocol on Water and Health** (ECE, no date, u; ECE, 2013): aims to protect human health through better water management, including the protection of water ecosystems through better water management, and by preventing, controlling and reducing water-related diseases (ECE, no date, d).
- **Words into Action** Implementation Guide for Addressing Water-Related Disasters and Transboundary Cooperation (ECE, 2018) was published in 2018 under the Water Convention in support of the implementation of the Sendai Framework for Disaster Reduction 2015–2030 and in the light of the SDGs and Paris Agreement.
- 2019 publication on **Financing Climate Change Adaptation in Transboundary Basins: Preparing bankable projects** (ECE, 2018), developed by the World Bank in cooperation with ECE and others. Capacity building activities on the same topic were organized on the global level as well as for selected basins in 2017–2018.
- Coordination of a series of pilot projects and a global platform for sharing knowledge and experience on climate change and disaster risk reduction in transboundary basins. Strategic Frameworks for Adaptation to climate change in the Dniester (including its implementation Plan (Republic of Moldova and Ukraine, 2017) and Neman (Belarus, Lithuania, Russian Federation, 2015) River Basins were developed as one of the first transboundary adaptation strategies of this kind and are now partly implemented by the riparian countries. Climate change analysis and adaptation measures were also developed for the Chu-Talas basin (Republic of Kazakhstan and Kyrgyz Republic) in consultation with the Chu-Talas Water Commission, its dedicated working groups and other stakeholders.
- Through the Trees in Dry Cities Coalition, ECE launched a water webinar series to explore urban forestry and green infrastructure in water-scarce, climate-stressed cities. The series gathers municipalities, experts, and practitioners to share solutions for drought-resilient tree planting, water-sensitive urban design, and nature-based cooling. These webinars serve also as an incubator for good practices and case studies, supporting cities and national governments in integrating nature-based solutions into climate and water planning, especially for arid and semi-arid urban contexts.

EU policies mandating NbS (for EU and EEA member States)

In addition to ECE frameworks, EU member countries follow binding policies that advance NbS:

- **EU Nature Restoration Law** (ECE, no date, a): aims for no net loss of green space in urban areas and tree cover by 2030 and aims to increase the total area from 2030. Many cities are analysing urban forest biodiversity, replacing invasive species, increasing tree planting, and creating plans to increase green space.
- **EU Green Infrastructure Strategy** (European Commission, 2013): aims to preserve, restore, and enhance green infrastructure to help stop the loss of biodiversity and improve the health and resilience of ecosystems and sustain the benefits that they can provide.
- **EU Biodiversity Strategy for 2030** (European Commission, no date, b) promotes investments in green and blue infrastructure, as well as the systematic integration of healthy ecosystems, green infrastructure and NbS into urban planning.

- **Nature Restoration Regulation (entered into force August 2024):** the first continent-wide comprehensive law of its kind, and a key element of the EU Biodiversity Strategy, which sets binding targets to restore degraded ecosystems, in particular those with most potential to capture and store carbon and mitigate natural disasters. The regulation combines an overarching restoration objective for the long-term recovery of nature in the EU's land and sea areas with binding restoration targets for specific habitats and species. It states that these measures should cover at least 20 per cent of the EU's land and sea areas by 2030, and all ecosystems in need of restoration by 2050 (European Commission, no date). EU countries are expected to submit National Restoration Plans to the Commission within two years of the Regulation coming into force (i.e. by bid 2026), showing how they will deliver on the targets. They will also be required to monitor and report on their progress.
- **EU Water Framework Directive:** sets out rules to halt deterioration in the status of EU water bodies and achieve good status for Europe's rivers, lakes and groundwater. Has an objective to achieve good status of all water bodies by 2027 (EEA, 2024).
- **Urban Wastewater Directive:** encourages river and wetland restoration through nature-compatible water management.
- **New EU Water Resilience Strategy (European Commission, 2025):** this aims to restore and protect the water cycle, to secure clean and affordable water for everyone and create a sustainable, resilient, smart and competitive water-economy in Europe. The strategy will support Member States in managing water more efficiently, through the implementation of current EU water legislation (the Water Framework Directive and Flood Management Directive) and through more than 30 actions. Actions include to significantly scale up investment in NbS in infrastructure or in conjunction with infrastructure, as from 2026. Notes that action on water management should prioritize NbS but also needs to rely on human-made structures or a combination of both. Specifies key targets, including that by 2033, all EU cities above 100,000 inhabitants will set up integrated urban wastewater management plans prioritizing NbS and green / blue infrastructure (as per the Urban Wastewater Treatment Directive).

Wider initiatives relevant to the ECE region

In addition to the initiatives described above, there are several mechanisms in the ECE region that contribute to safeguarding the ecosystems on which NbS depend. These include efforts to manage industrial risk, regulate trade in endangered species, limit air pollution, and promote sustainable resource use. These initiatives help to create pressure for countries to move towards more sustainable approaches, including through investments and policies on NbS. While many of the above initiatives aim to increase the protection, restoration, sustainable management and creation of ecosystems, there are additional initiatives which focus on reducing some of the pressures on ecosystems which undermine biodiversity and ecosystem health. These can play a role in helping to safeguard the ecosystems that NbS depend upon:

- **The Convention on Long-range Transboundary Air Pollution** (ECE, no date, m) (Air Convention): addresses biodiversity issues resulting from air pollution through science-policy dialogues, access to emission, measurement and modelling data (EMEP, no date), and information on effects of air pollution on ecosystems, health, crops and materials. Its scientific international cooperative programmes (ECE, no date, o) on forests, water, vegetation, and soil and biodiversity data monitoring have advanced understanding of the complex interaction between pollution and biodiversity and helped develop pollution management concepts (e.g., empirical critical loads) to sustain policies and actions to reduce air pollution and protect biodiversity. This aligns with GBF Target 7.
- **The Convention on the Transboundary Effects of Industrial Accidents** (ECE, no date, n) cooperates to implement preventive, readiness, response and restoration measures in order to safeguard biodiversity from the impacts of industrial accidents.
- The **United Nations Fisheries Language for Universal Exchange** (UN/FLUX) (ECE, no date, v) provides a harmonized message standard that allows fishery management organizations to automatically access electronic data from fishery vessels and automate the collection and dissemination of the fishery activity data needed for sustainable fishery management and for detecting and combating illegal, unreported and unregulated fishing.
- National pollutant release and transfer registers in compliance with the **Protocol on Pollutant Release and Transfer Registers** (ECE, no date, p) help assess routine and accidental pollution effects on ecosystems and implement mitigation measures.

- The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) regulates trade in over 36,000 species of wild animals and plants among its 183 Parties. Joint work between the CITES Secretariat, UNCTAD and ECE's UN/CEFACT supports the exchange of electronic "eCITES" permits (ECE, 2020b) to strengthen control measures on international trade of CITES-listed species. These help to reduce pressures on biodiversity caused by unsustainable trade.
- The **Aarhus Convention** (ECE, no date, q) supports governments and stakeholders in ensuring effective and inclusive public access to information, participation in decision-making, protection of environmental defenders, including through a dedicated Special Rapporteur (ECE, no date, w), and access to justice in matters related to biodiversity, including in relevant international forums and regarding Genetically Modified Organisms and Living Modified Organisms (GMOs/LMOs). ECE collaborates with the Convention on Biological Diversity (CBD) and its Cartagena Protocol on various capacity-building resources related to GMOs/LMOs matters. The Aarhus Convention's Task Force on Access to Justice has also addressed biodiversity protection.
- **Environmental impact assessment** (ECE, no date, x) under the Espoo Convention helps countries cooperate to identify and mitigate risks of damage to fauna and flora before it happens, while its Protocol on Strategic Environmental Assessment (SEA) ensures that significant effects on flora, fauna, biodiversity, and natural sites are included in sectoral planning for forests, raw materials, mineral resources, water, wind, geothermal, tidal, and solar energy, as well as transport and land use. These instruments can be applied to marine biodiversity and in synergy with international agreements on regional seas.

Advancing cross-cutting cooperation. To reduce pressures on ecosystems, ECE supports countries in Europe and North America, whose natural resource production and consumption has significant global impact, to accelerate their circular economy progress. Helping to respond to this key priority for its member States, ECE normative and policy tools (e.g., ECE, no date, y) for sustainable resource management, value chain traceability and beyond are already supporting concrete efforts.

Annex 3: ECE member State NAPs and reference to NbS

Country	Date NAP posted	Examples of NbS in NAP
Albania	**27 October 2021**	Payment of Ecosystem Services projects linking land use practices with the generation of ecosystem services and sediment retention, water purification and water flows. Project agreed for implementation on achieving climate resilient infrastructure through mainstreaming ecosystem-based adaptation approaches in the Southeast Europe region. Includes support to countries in the region to integrate EBA into planning and engineering of communal and critical infrastructure, as well as infrastructure management policies, plans and regulations. Focus on agroecology practices, such as selection of heat- and drought-tolerant plants, optimized timing of operations; conservation tillage; crop rotation; vegetative shelterbelts to protect from snow, flooding, wind. Coastal NbS—encourage reforestation and afforestation and restoration of natural coastal habitats; enlarge existing protected areas.
Armenia	**24 September 2021**	Set out a list of measures for 2021-2025. Notes that the 2015 NDC of Armenia views NbS as the foundation for climate adaptation in Armenia. Identifies seven sectors with particular adaptation needs, including (a) natural ecosystems (aquatic and terrestrial, including forest ecosystems, biodiversity and land cover), (b) human health, (c) water resources management, (d) agriculture including fisheries and forests, (e) energy, (f) human settlements and infrastructure, and (g) tourism. Aimed to develop a draft government decree on "approval of the climate risks management and climate change adaptation plan for the forest management sector" and to integrate climate change factors into the management plan of Lake Sevan ecosystem management process.
Azerbaijan	**12 November 2024**	Numerous activities relating to NbS specified, a selection of which include development and implementation of appropriate measures on creation and expansion of protected natural areas; implementing incentive solutions to expand community-based forest management; mainstreaming biodiversity into development plans for industries including mining, tourism, forestry, fisheries and agriculture, including measures on climate adaptation; encouraging sustainable integrated planning and management of landscapes in the context of climate adaptation; encouraging the use of sustainable farming methods such as agroecology, multifunctional landscape planning and cross-sectoral integrated management; promoting the application of climate adaptation oriented biodiversity-friendly management techniques in the production of crops and livestock, forestry, fisheries and aquaculture; increased protection and connectivity of freshwater ecosystems.
Bosnia and Herzegovina	**21 December 2022**	Various NbS-related measures proposed. Includes agricultural management practices—movement to more resilient varieties, conservation agriculture and agroforestry, ecosystem-based approaches, crop rotation. Water-management practices include adoption and analysis of environment-based solutions. Biodiversity and forestry measures include GIS mapping of forest areas, afforestation with native and fast-growing species; tree health survey; development of monitoring system to monitor impact of climate change on biodiversity; increasing protected areas; development of pilot studies and installation of green roofs to combat rising temperatures; study of forest fires

Country	Date NAP posted	Examples of NbS in NAP
Israel	**23 March 2025**	Includes actions to maintain the resilience of ecosystems, such as preserving biodiversity and restoring open spaces, improving their functioning, maintaining connectivity and terrestrial ecological corridors; transitioning to climate-adapted agriculture such as conservation tillage; integration and preservation of natural and ecological systems within the built environment; examination and implementation of technologies and / or NbS to address immediate extreme weather events in the transport sector; implementation of nature-based stormwater management solutions, such as green roofs, with a watershed-based perspective as part of built infrastructure adaptation; afforestation and shading to reduce heat stress in the urban environment; annual tree planting, reduction of tree felling permits; actively integrating natural and ecological systems into the built environment and preserving existing systems through pre-adapted processes of planning and implementation; protection of terrestrial and marine ecosystems through the designation of nature reserves and ecological corridors; promotion of solutions to address invasive species; restoration of open spaces and improvement of their function with a focus on underrepresented habitats, sensitive and unique ecosystems and wetlands; development, planning and restoration of urban nature sites and implementation of NbS in urban areas.
Republic of Moldova	**26 June 2024**	Includes agricultural NbS such as implementation of conservation agriculture, including no-till agriculture; development of drought- and heat-tolerant varieties; planting of forest strips with locally adapted species to reduce soil erosion. It notes the need for extension of forest protection belts and forest areas, and forest restoration, given that forests play a special role in climate change mitigation and adaptation, but that ecosystem regeneration, afforestation and protection of ecosystems against climate impacts will require additional funding support. It aims for a minimum afforestation rate of 15 per cent through a focus on planting native species or creating silvo-pastoral systems. Also refers to a focus on ecosystem-based adaptation measures, including restoration of forest, steppe and meadow ecosystems (wetlands); managing the national ecological network and implementing a mechanism for monitoring and controlling invasive species, as well as relevant capacity building. Water management actions include analysis of ecosystem services at the watershed level and an ecosystem-based approach to water management, revitalizing natural wetlands and restoring natural banks of small rivers. Restoration of degraded forests and grasslands will help to improve agricultural productivity by improving river basin functions and protection against hazardous weather.
Serbia	**12 July 2024**	Priority areas including maintaining and increasing "green" surfaces in urban areas, in accordance with the concept of green infrastructure, and improving their maintenance in accordance with changing climate conditions. They note that green surfaces represent the implementation of the NbS concept to improve living conditions in urban areas, adapt to climate change, and improve human health and safety. They recognize that it can achieve multiple benefits, including reducing the urban heat island effect, increasing surface water infiltration capacity, and improving air circulation. They recognize the need to monitor biodiversity indicators and have a plan to develop a methodology for monitoring biodiversity status and climate vulnerability. Plan to integrate climate adaptation into nature protection programme. Notes the need for agricultural NbS, such as conservation agriculture and use of drought-resilient species. Includes measures to support local self-government units in implementing NbS-based adaptation, including public tenders for fund allocation for co-financing green infrastructure projects.

Annex 4: ECE member State NDCs

Country	Title	Version	Status	Submission date
Albania	Albania First NDC (updated submission)	2	Active	12/10/2021
Andorra	Andorra 2022 NDC Update	3	Active	08/11/2022
	Andorra Third NDC		Active	31/05/2021
Armenia	Armenia First NDC (updated submission)	2	Active	05/05/2021
Austria	EU NDC 2023 update	3	Active	19/10/2023
Azerbaijan	Updated NDC of the Republic of Azerbaijan	2	Active	10/10/2023
Belarus	Belarus First NDC (updated submission)	2	Active	11/10/2021
Belgium	EU NDC 2023 update	3	Active	19/10/2023
Bosnia and Herzegovina	Bosnia and Herzegovina First NDC (updated submission)	2	Active	20/04/2021
Bulgaria	EU NDC 2023 update	3	Active	19/20/2023
Canada	Canada's 2035 NDC		Active	12/02/2025
	Canada's First NDC (updated submission)	3	Active	12/07/2021
Croatia	EU NDC 2023 update	3	Active	19/10/2023
Cyprus	EU NDC 2023 update	3	Active	19/10/2023
Czechia	EU NDC 2023 update	3	Active	19/10/2023
Denmark	EU NDC 2023 update	3	Active	19/10/2023
Estonia	EU NDC 2023 update	3	Active	19/10/2023
Finland	EU NDC 2023 update	3	Active	19/10/2023
France	EU NDC 2023 update	3	Active	19/10/2023
Georgia	Georgia First NDC (updated submission)	2	Active	05/05/2021
Germany	EU NDC 2023 update	3	Active	19/10/2023
Greece	EU NDC 2023 update	3	Active	19/10/2023
Hungary	EU NDC 2023 update	3	Active	19/10/2023
Iceland	Iceland First NDC (updated submission)	2	Active	18/02/2021
Ireland	EU NDC 2023 update	3	Active	19/10/2023
Israel	Israel First NDC (updated submission)	2	Active	29/07/2021
Italy	EU NDC 2023 update	3	Active	19/10/2023
Kazakhstan	Kazakhstan First NDC (updated submission)	2	Active	27/06/2023
Kyrgyzstan	Kyrgyzstan First NDC (updated submission)	2	Active	09/10/2021
Latvia	EU NDC 2023 update	3	Active	19/10/2023
Liechtenstein	First NDC	1	Active	20/09/2017
Lithuania	EU NDC 2023 update	3	Active	19/10/2023
Luxembourg	EU NDC 2023 update	3	Active	19/10/2023
Malta	EU NDC 2023 update	3	Active	19/10/2023
Monaco	Monaco First NDC (updated submission)	2	Active	28/12/2020
Montenegro	Montenegro Third NDC		Active	21/02/2025
	Montenegro First NDC (updated submission)	2	Active	15/06/2021

Country	Title	Version	Status	Submission date
Netherlands (the Kingdom of the)	EU NDC 2023 update	3	Active	19/10/2023
North Macedonia	The Republic of North Macedonia First NDC (updated submission)	2	Active	16/04/2021
Norway	Norway First NDC (second updated submission)	3	Active	03/11/2022
Poland	EU NDC 2023 update	3	Active	19/10/2023
Portugal	EU NDC 2023 update	3	Active	19/10/2023
Republic of Moldova	Republic of Moldova First NDC (updated submission)	2	Active	04/03/2020
	Republic of Moldova NDC 3.0	3	Active	06/05/2025
Romania	EU NDC 2023 update	3	Active	19/10/2023
Russian Federation	Russian Federation First NDC	1	Active	25/11/2020
San Marino	San Marino First NDC	1	Active	26/09/2018
Serbia	Updated NDC Serbia	2	Active	24/08/2022
Slovakia	EU NDC 2023 update	3	Active	19/10/2023
Slovenia	EU NDC 2023 update	3	Active	19/10/2023
Spain	EU NDC 2023 update	3	Active	19/10/2023
Sweden	EU NDC 2023 update	3	Active	19/10/2023
Switzerland	Switzerland second NDC 2031–2035		Active	29/01/2025
	Switzerland First NDC (2021–2030 update 2024 including ICTUs)	4	Active	14/11/2024
Tajikistan	Tajikistan First NDC (updated submission)	2	Active	12/10/2021
Türkiye	Türkiye updated 1st NDC		Active	13/04/2023
Turkmenistan	NDC of Turkmenistan under the Paris Agreement	2	Active	30/01/2023
Ukraine	Ukraine First NDC (updated Submission)	2	Active	31/07/2021
United Kingdom of Great Britain and Northern Ireland	2035 NDC ICTU		Active	30/01/2025
	United Kingdom of Great Britain and Northern Ireland updated 2030 NDC	3	Active	22/09/2022
United States of America	United States of America First NDC (after rejoining the Paris Agreement)	2	Active	22/04/2021
	United States of America 2035 NDC		Active	19/12/2024
Uzbekistan	Uzbekistan First NDC (updated submission)	2	Active	30/10/2021

Source: UNFCCC (no date).
Note: ICTU – Information to Facilitate Clarity, Transparency and Understanding.

Annex 5: Key tools and frameworks

This annex provides tools and frameworks to support the implementation of NbS during: (5.1) planning & design; (5.2) maintenance; (5.3) monitoring.

Box A5.1: Planning and design stages

- The **IUCN Global Standard for Nature-based Solutions** is a globally recognized framework for the verification, design, and scaling of NbS. It consists of eight criteria and 28 indicators, supported by **guidance documents** and a **monitoring checklist** to track outcomes across environmental, social and economic domains. It is accompanied by in-depth guidance which includes the scientific background for NbS and guidance on the criteria and indicators (IUCN, 2020b).
- The **EU4Water Eastern Partnership NbS Catalogue** offers 34 fact sheets with guidance on designing and implementing NbS at the river basin scale, accompanied by a ranking methodology, cost estimates and policy recommendations.
- The **Catalogue of Natural Water Resources Management (NWRM, no date)** covers a range of actions and land use types. The catalogue represents a comprehensive range of measures that can support water management within catchments including agricultural measures (e.g., no till or low till agriculture), urban measures, such as urban forest parks and trees, basins and ponds.
- **Nature-based Solutions Evidence Platform** (NbSI, no date, c): this aims to consolidate and facilitate access to the large, dispersed evidence-based on the effectiveness of NbS for addressing climate impacts on people and economic sectors, to support global efforts to design and implement robust targets for nature in climate change and development policy. It provides an interactive map linking NbS to climate adaptation outcomes based on a systematic review of peer-reviewed literature. It enables users to:
  - Explore evidence on how effective different NbS are for addressing climate impacts;
  - Compare social, economic and environmental effects of different NbS;
  - Filter by region, country, habitat, intervention type, or outcome type;
  - Generate maps, graphs and download data;
  - Directly link from science to national climate policy.

Nature-based Solutions Guidance Tool: provides a library of guidance to help support implementation of high-quality NbS (NbSI, no date, h).

Think Nature Handbook: this has been developed as a guide for NbS, from project development to finance and policy making, including raising public awareness about NbS, and includes practical considerations (Somarakis, Stagakis & Chrysoulakis, 2019).

Decision-making tools: **Multi-Criteria Analysis (MCA)** and **Cost-Benefit Analysis (CBA)** for evaluating trade-offs across adaptation, mitigation and socio-economic goals. MCA is generally recommended for accounting for the full spectrum of benefits that NbS can provide, and to help identify possible trade-offs that may occur (OECD, 2021).

Ecosystem Services Valuation Database (ESVD, no date): This has the long-term goal of providing robust and easily accessible information on the economic benefits of ecosystems and biodiversity, and the costs of their loss, to support decision-making regarding the protection, restoration and management of nature. It aims to gather information on economic welfare values related to ecosystem services measured in monetary units. It provides data across all biomes, ecosystem services and geographic records, and can be contributed to as countries undertake and monitor projects.

InVEST: a suite of free, open-source software models that can be used to map and value the goods and services that nature can provide.

ARIES: An AI-powered and digital software for rapid ecosystem service assessment and valuation.

The Nature Conservancy: has various tools and datasets that can support decision-making, although some of these are limited in scope. For example, their "Mapping Ocean Wealth" tool provides data on the United States of America but is limited to other ECE countries. Their "planting healthy air" tool can show where trees can provide beneficial returns on investment (TNC, no date).

Aligning NbS projects with Sustainability Priorities:

National Adaptation Plan (NAP) Guidelines and the **UNEP Guidelines for Integrating Ecosystem-based Adaptation into NAPs** (UNEP, 2021c) provide step-by-step tools for incorporating NbS into national climate adaptation strategies, including a monitoring and evaluation component.

The UNDP's **NbS for NDCs Toolkit** and associated **Framework** has identified more than 100 tools and resources on NbS that can support decision-makers in enhancing their NDCs, including spatial datasets, guidance documents and other toolkits (UNDP, 2019), provide practical tools for integrating nature into national climate planning. IUCN's **guidance on NbS in NDCs** (Seddon, 2019), identifies key information that should be included in NDCs to help track ambition on nature more systematically.

Urban Nature Index: provides ready-made metrics (e.g., canopy cover, habitat quality, access to green space) aligned with the SDGs and Kunming-Montreal targets.

Box A5.2: Maintenance

Guidelines for the **Development of a Criteria and Indicator Set for Sustainable Forest Management** (UN & FAO, 2020). This provides various indicators including:

- Extent of forest resources: forest area; production; change; characteristics; growing stock; carbon stock; carbon change;
- Biological diversity: species; regeneration; naturalness; species distribution; invasive species; conservation; fragmentation; threatened species; protected areas; biodiversity conservation;
- Forest health and vitality: deposition; damaged forests; degradation; restoration; resilience;
- Productive functions of forest resources; increment; removals; biomass wood and non-wood forests; services;
- Protective functions of forest resources: soil and water protection; water protection;
- Socio-economic functions: productivity; gross domestic product; trade; revenue; investments; employment; wages; dependency; work safety; consumption; wood energy; recreation; traditional knowledge and cultural values; local communities; certification.

The **IUCN Global Standard for Nature-based Solutions** is a globally recognized framework for the verification, design, and scaling of NbS. It consists of eight criteria and 28 indicators, supported by **guidance documents** and a **monitoring checklist** to track outcomes across environmental, social and economic domains. It is accompanied by in-depth guidance which includes the scientific background for NbS and guidance on the criteria and indicators (IUCN, 2020b).

Box A5.3: Monitoring

The ECE Environmental Monitoring and Assessment Programme assists countries in their monitoring and assessment efforts through **Revised Guidelines for Environmental Indicators** (ECE, 2023e) and the first of their kind **Guidelines for national biodiversity monitoring systems** (ECE, 2023f).

ECE monitors biodiversity through **biodiversity-related forest indicators** (Forest data, no date) in the pan-European region. A **Joint pan-European Data Collection platform** has been developed to provide comprehensive information on forests and the environmental, economic, and social dimensions of sustainable forest management in the region (FAO, 2020). To help upgrade forest biodiversity monitoring systems, ECE developed **Guidelines for the Development of a Criteria and Indicator Set for Sustainable Forest Management** (FAO, 2019) and contributes to the "**European Forest Biodiversity Indicators at a Glance**" (FAO, 2023b).

The **EU Handbook for Evaluating the Impact of NbS** (European Commission, 2021) provides a practical impact assessment framework covering twelve societal challenge areas (e.g., climate resilience, health, biodiversity, economic opportunities). It includes methods and indicators to support robust impact evaluations and evidence-based policy. It aims to support practitioners in developing robust impact evaluation frameworks for NbS and support the development of an evidence base regarding impacts.

The **IUCN Global Standard for Nature-based Solutions** is a globally recognized framework for the verification, design, and scaling of NbS. It consists of eight criteria and 28 indicators, supported by **guidance documents** and a **monitoring checklist** to track outcomes across environmental, social and economic domains. It is accompanied by in-depth guidance which includes the scientific background for NbS and guidance on the criteria and indicators (IUCN, 2020b).

The UNEP Climate Finance Unit developed the **Positive Impact Indicators Directory** (https://landuseimpacthub.com/en/kpi-list) together with the impact-focused financial community. This has been designed to help harmonize monitoring and reporting across a range of environmental and social impact areas: biodiversity, sustainable production, climate action and sustainable livelihoods.

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Promoting Nature-based Solutions and Sustainable Infrastructure in the ECE Region:
Environmental and Health Co-benefits

As countries across the ECE region face intensifying climate, environmental and health challenges, the need for sustainable, resilient and inclusive infrastructure has never been more urgent. This publication offers a timely and practical guide to nature-based solutions (NbS) to protect, restore and manage ecosystems, addressing societal challenges while delivering benefits for people and biodiversity.

The report provides actionable insights for policymakers, planners and practitioners. It highlights how NbS can substitute for, complement and protect conventional infrastructure systems, while generating co-benefits such as improved air and water quality, climate resilience, biodiversity conservation and public health.

From green roofs and wetlands to agroforestry and urban parks, the report showcases real-world examples and case studies from across the region. It includes practical tips, planning guidance and links to tools and resources to support implementation. Whether addressing flood risk, heat stress, water scarcity or infrastructure vulnerability, NbS offer scalable, cost-effective solutions that can be tailored to local contexts.

This report also supports the integration of NbS into national climate and biodiversity strategies.

Designed to inspire and inform, this guide empowers stakeholders to embed NbS into infrastructure planning from the outset, unlocking the full potential of NbS to build a healthier, more resilient and sustainable future.

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