MULTISOURCE

Descriptions of co-created business models for innovative NbS^{WT} and their integration in urban water systems

Deliverable 3.3

This project has received funding from the European Union's Horizon H2020 innovation action programme under grant agreement 101003527.

Deliverable Number and Name	D3.3 - Descriptions of co-created business models for innovative NbS^{WT} and their integration in urban water systems
Work Package	WP3 – Business models for NbS^{WT}
Dissemination Level	Public
Author(s)	Maria Wirth, Iris De Cesare, Francesco Menconi
Primary Contact and Email	Maria Wirth, maría.wirth@alchemia-nova.net
Date Due	M36
Date Submitted	M35
File Name	MULTISOURCE D3.3-description of business models_final
Status	Submitted
Reviewed by (if applicable)	Jaime Nivala
Suggested citation	Wirth, M., De Cesare, I., Menconi, F. (2024) Descriptions of co-created business models for innovative NbS^{WT} and their integration in urban water systems. MULTISOURCE Deliverable 3.3, H2020 grant no. 101003527

This document has been prepared in the framework of the European project MULTISOURCE. This project has received funding from the European Union’s Horizon 2020 innovation action programme under grant agreement no. 101003527.

TABLE OF CONTENTS

Urban raingarden in Denmark. Photo: Maria Wirth

EXECUTIVE SUMMARY

Cities globally are facing increased challenges from urbanization coupled with adverse impacts of climate change, such as unprecedented extreme heat, drought periods, and floods. Adaptation measures are being deployed, but not fast enough. Record temperatures and flood damages continue to strike cities with increased frequency and intensity, leading to high costs to manage infrastructure damages, pollution, and human health, and lowering living quality in cities. Nature-based solutions (NbS) for urban climate change adaptation offer promising pathways to enhance water supply, manage stormwater, treat road runoff, support biodiversity, and increase living quality in urbanised areas. While the great potential of NbS is widely recognized, actors interested to deploy NbS are challenged by the complexity of the network of institutional agencies and private actors affected by the NbS project development, or involved in land ownership and management, and potentially in funding and realisation. Particularly for the implementation of NbS for the provision of effective water services, such as stormwater retention and treatment raingardens, or treatment wetland systems for water treatment and reuse, there is a lack the knowledge and tools to navigate institutional frameworks and facilitate planning, funding, and long-term management in multi-actor settings. Therefore, these solutions are implemented as single pilots, instead of large-scale concerted NbS projects necessary to effectively adapt to the effects of climate change.

The MULTISOURCE project, funded by the European Commission within the Horizon 2020 programme, delivers critical knowledge about the capabilities of NbS for water treatment, storage, and reuse (NbS^{WT}), as well as their implementation requirements and enablers. With seven pilots treating a wide range of urban waters, this project delivers new knowledge about enhanced natural treatment solutions and their ability to make cities more resilient to climate change, to remove waterborne contaminants and provide effective risk reduction for chemical and biological hazards. The seven pilots each address unique urban challenges and water treatment requirements using NbS^{WT}. They are located in Lyon (France), Merone (Italy), Oslo (Norway), Girona (Spain), Ypres (Belgium), Leipzig (Germany), and Bozeman (USA). The technologies include aerated treatment wetlands, raingardens, green roofs, and green walls. The MULTISOURCE project develops innovative tools, methods, and business models to support citywide planning and long-term operation and maintenance of NbS^{WT} in urban areas worldwide.

Within the scope of Work Package 3 on *Business Models*, this report presents the outcomes of a series of multi-sector and transdisciplinary stakeholder consultations and workshops aimed at gathering insights for building actionable business cases for the MULTISOURCE NbS^{WT} by which NbS can be effectively integrated into urban water management systems. This includes aspects of their strategic fit, wider economic value, and long-term sustainable delivery of their services. The process of collective knowledge generation aimed to gather the insights of public and private entities involved in urban water management in the MULTISOURCE partner cities and pilots, and provide suitable solutions for them.

Two metropolitan cities, the Metropolitan City of Milan (Italy) and Greater Lyon (France) and two municipalities, Oslo (Norway) and Girona (Spain) are part of the MULTISOURCE consortium and collaborated in facilitating the involvement of local and regional actors, providing contextual knowledge and co-creating knowledge outcomes.

Key highlights

- **Stakeholder involvement and collaborative business modeling:** Through multi-sectoral and transdisciplinary workshops and consultations, the project has engaged a broad spectrum of stakeholders—from municipal, metropolitan, and regional government agencies to water utilities, technical partners, and researchers. This collaborative approach has facilitated the generation of practical insights and solutions for the design of business models that ensure the economic viability and long-term sustainability of NbS^{WT} implementations.
- **Strategic integration into urban planning:** The business models developed under the MULTISOURCE project are tailored to integrate into the existing urban fabric, supporting municipal goals for sustainable development and climate resilience. This strategic and institutional integration is crucial for the widespread adoption and scaling up of NbS^{WT}.
- **Transferability of results:** The public institutional partners and seven MULTISOURCE technologies provided the opportunity to investigate business models for a diverse set of implementation objectives responding to diverse contextual challenges and requirements and diverse planning scales (from metropolitan scale to building scale). This way, the implementation arrangements discussed in this report may provide solutions for a wider range of contexts.

In conclusion, the synthesis of workshop outcomes and stakeholder consultations offers actionable insights and innovative approaches to replicate NbS^{WT} to promoting more livable, resilient, and sustainable cities. It serves as a valuable resource for urban planners and authorities, water industry, technology providers, and community actors, providing a knowledge foundation for integrating NbS^{WT} into urban water management and public procurement systems.

LIST OF ABBREVIATIONS

COD	Chemical Oxygen Demand
CSO	Combined Sewer Overflow
EU	European Union
NbS	Nature-based solutions
NbS^{WT}	Nature-based solutions for water treatment
O&M	Operation & maintenance
PE	Population equivalent
WP	Work package

1. INTRODUCTION

In recent years, the concept of nature-based solutions (NbS) has gained significant traction as an innovative and sustainable approach to addressing the complex challenges of urban water management. With increasing urbanization and climate change exerting added pressure on water resources, cities around the world are seeking effective strategies to enhance water resilience, improve biodiversity, and ensure sustainable urban development.

This report follows the European Commission's definition of NbS as "solutions inspired and supported by nature, designed to address societal challenges which are cost-effective, simultaneously provide environmental, social and economic benefits, and help build resilience" (European Commission, n.d.).

NbS often affect different actors and policy sectors (Toxopeus and Polzin, 2021). Multiple purposes and the land requirement of NbS require unconventional partnerships and unconventional planning, procurement, and management practices (Mayor et al., 2021). The multiple co-benefits bear the potential for more livable cities, climate resilience, environmental health, regeneration, and biodiversity. This raises the need and opportunity to engage across sectors to scale up the implementation of NbS beyond single pilot projects as well as to realize synergetic approaches to build NbS that provide multiple societal values. Business models help to answer questions related to how these systems can be organized and managed, financed, realized, and sustained in a way that they provide their intended services over the long term.

Within the scope of the MULTISOURCE project and WP3 on business models, the focus is placed on NbS applied to treat stormwater, wastewater, and greywater - NbS for water treatment (NbS^{WT}), and the exploration and co-creation of collaborative business models that integrate NbS^{WT} into the urban water management framework.

This report presents the outcomes of a series of multi-sector and transdisciplinary stakeholder consultations and workshops aimed at gathering insights for building business models for the MULTISOURCE NbS^{WT}, including aspects of their strategic fit, wider economic value, and long-term sustainable delivery of their services. The process of collective knowledge generation consists of several steps involving actors within and beyond the MULTISOURCE consortium. This process aimed to gather the insights of public and private entities involved in urban water management in the MULTISOURCE partner cities and pilots, and provide suitable solutions for them. The project partner cities and pilots include the Metropolitan Cities of Milan (Italy) and Lyon (France), Merone (Italy), Oslo (Norway), Girona (Spain), Ypres (Belgium), Leipzig (Germany), and Bozeman (USA).

Consultations with the technical partners leading the seven MULTISOURCE pilots were conducted to gain an understanding of the multiple values that the specific enhanced natural treatment systems could provide. Multi-stakeholder workshops involving the multidisciplinary and multi-sector partners of the MULTISOURCE consortium as well as local stakeholders within established strategic groups in Milan, Oslo, and Girona aimed to foster a collaborative environment where stakeholders from government, industry, academia, and non-governmental organizations came together to design viable business models that leverage the multiple benefits of NbS^{WT}. By promoting multi-disciplinary and cross-sectoral cooperation, the project sought to develop innovative, scalable, viable and sustainable business models that can be replicated across different urban contexts.

The interactive workshops were tailored to address specific aspects of NbS^{WT}. These workshops served as a platform for stakeholders to identify challenges, explore potential solutions, and articulate shared goals and objectives. The process was guided by a dual focus on environmental sustainability and economic viability, ensuring that the proposed solutions align with broader urban development goals while also providing opportunities for collaborative long-term funding and operation & maintenance (O&M).

The local multi-stakeholder workshops cover different contexts, types of NbS^{WT} and scales of planning, and therefore different partnership arrangements. The primary objectives of the workshops were to integrate diverse perspectives of enabling actors to define a common understanding of the:

- Existing urban challenges that could be addressed through NbS^{WT} and system dynamics as a foundation for collaboration,
- NbS^{WT} and their services and characteristics to address multiple challenges,
- Enabling environment,
- Actors with vested interests and enabling partners, and
- Roles of these actors/partners in a collaborative business case.

This report synthesizes the key insights and outcomes from the stakeholder workshops and consultations before and after these workshops and maps out the collaborative processes used to define the proposed business models. It highlights the innovative approaches discussed and the recommendations developed during the workshops for the five dimensions (or "five cases") of a full business case for public investments: Strategic, Economic, Commercial, Financial, and Management dimensions (Altamirano et al., 2021).

As cities continue to grow and evolve, the integration of NbS^{WT} into urban water management represents a critical opportunity to enhance ecological and water resilience. The findings and recommendations from these workshops provide a foundation for moving forward with innovative business models that not only address environmental challenges but also offer sustainable economic benefits. This report aims to contribute to the broader discourse on sustainable urban development, providing valuable insights for policymakers, industry leaders, and community stakeholders engaged in or considering similar initiatives.

2. THE MULTISOURCE PILOTS

This section provides information about the types of NbS^{WT} piloted in the MULTISOURCE project, their technology, the main urban challenges they are designed to address, their main innovative attributes, as well as insights into their contextual settings and costs.

Vertical Flow Aerated Wetland for treatment of combined sewer overflow in Merone (Italy)

Figure 1. Treatment wetland at the municipal wastewater treatment plant in Merone, Italy. Source: Rizzo, 2022.

- **Technology:** Vertical Flow Aerated Wetland and Free Water Surface Wetland
- **Challenges addressed:** Heavy rain events and water pollution from combined sewer overflows (CSOs)
- **Innovation:** Online sensors for COD and optimized regulation of aeration

The treatment wetland pilot in Merone, Italy, treats CSO upstream of the municipal wastewater treatment plant (IRIDRA, n.d.). The treatment wetland, constructed in 2020, aims to increase resilience to extreme events and reduce pressure on sewers, while mitigating pollution of receiving water bodies from CSO resulting from heavy rain events (MULTISOURCE, 2021). The system is designed for 13,000 PE and occupies a surface area of 5,500 m² (MULTISOURCE, 2021).

The aerated vertical subsurface flow treatment wetland system is modified for CSO treatment, extending over 4,000 m² and divided into two 2,000 m² basins, each further divided into two 1,000 m² sectors. Additionally, there is a 1,500 m² Free Water Surface Wetland system, designed to facilitate landscape integration and the creation of humid biotopes with high biodiversity.

The total construction cost for the system amounted to € 1.5 million EUR, which includes the execution of work, labor costs, and implementation of security measures. The annual maintenance costs are estimated at € 22,500, which covers the electricity supply, green area and vegetation management. The annual costs of extraordinary maintenance and the disposal of grit and sand amounts to approximately € 36,800 (Rizzo, personal communication, 2022).

Raingarden for stormwater treatment in Oslo (Norway)

Figure 2. Raingarden for road runoff treatment in Oslo, Norway. Source: K Karlstrøm, 2022.

- **Technology:** Raingarden for urban runoff treatment, storage and potential reuse for irrigation
- **Challenges addressed:** Improved water quality in the Oslo Fjord for local sea-trout habitat and potential reuse for irrigation
- **Innovation:** Exploring possibilities for alternative water sources for irrigating urban green areas, demonstrating the use of innovative sorption materials for water treatment

Oslo is challenged by an increase in precipitation, heavy rainfalls and cloudbursts, as well as heavily polluted urban runoff from the road network. The pilot in Oslo addresses this challenge through the establishment of a raingarden, which is part of a larger roadside stormwater system designed to store and treat stormwater runoff from urban roads. The pilot raingarden is 30m long and 1.7m wide. (Karlstrøm, personal communication, 2022)

The entire project comprises five raingardens ranging from 10m to 30m in length, as well as an underground stormwater basin. Retention and treatment volumes have not been measured, nor have annual maintenance costs been calculated. However, the raingardens are designed to require minimal maintenance, with the primary tasks being to ensure that inlets beneath the pavement remain open and to conduct mowing approximately every three years. The construction costs for the whole project amounted to € 103,598. The construction costs for a single raingarden are estimated at around € 38,409. Since becoming a MULTISOURCE pilot, an additional € 655 has been spent on test equipment, measuring cabinets, and several extra small basins (Karlstrøm, personal communication, 2022).

Intensive green roof for rainwater retention and storage for reuse in Leipzig (Germany)

Figure 3. Green roof for rainwater retention and storage for reuse in Leipzig, Germany. Image: André Künzelmann (UFZ). Source: multisource.eu

- **Technology:** Green roof and storage (five variations)
- **Challenges addressed:** Heavy rain events and excessive pressure on urban sewer systems
- **Innovation:** Improvement of evaporation efficiency and biodiversity through plant selection and management practices

The green roof pilot in Leipzig, Germany, features five different green roof designs with an area of 25 m² each, constructed in 2019. The green roofs primarily serve to prevent flooding by retaining rainwater in a drainage layer situated beneath the vegetation. Depending on their design, these green roofs can provide valuable habitats and contribute positively to biodiversity (MULTISOURCE, 2021).

The investment costs per m² for conventional intensive green roofs range at € 43-53 for 75L of water storage, € 45-55 for 80L, and € 56-66 EUR for 140L. Maintenance costs for intensive or retention roofs range from € 1.50-3 per m² per year (Optigrün, 2021).

Façade integrated green wall for greywater treatment and reuse in Girona (Spain)

- **Technology:** GRETA® and WetWall®: Façade integrated green living wall for greywater treatment
- **Challenges addressed:** Water shortages, urban heat islands, risk assessment of treatment for water reuse
- **Innovation:** Use of digital tools, promote citizen engagement, ecosystem services assessment

Figure 4. Green wall for greywater treatment and reuse.
Source: alchemia-nova research & innovation gem. GmbH, 2019.

This pilot represents a hybrid treatment wetland technology for greywater treatment, utilizing both vertical and horizontal flow treatment processes to treat domestic greywater. This green wall technology can be installed at different types of buildings, from residential apartment buildings to public schools or commercial buildings, or on any empty vertical spaces.

The green wall has a total surface area of 30 m² and reaches 4m high. Each of four sectors (panels) has a treatment flow of around 50L per day, resulting in a total treatment capacity of 300L per day for the whole green wall. The investment budget for the green wall is € 45,691 (€ 17,953 per sector) covering expenses for wastewater pretreatment, construction, equipment, planters, pipes, sanitation, controls, security and health, wastewater treatment, and irrigation water for the green wall itself. Adding 13% for general expenses and 6% for industrial profit, the total budget amounts to € 54,372 (ICRA, 2022).

Phytoparking™ System in T' Hof Bellewaerde, Ypres (Belgium)

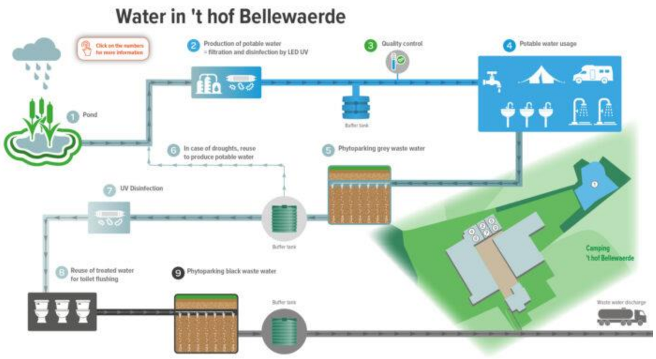


Figure 5. Phytoparking® technology at campsite in Ypres, Belgium. Source: multisource.eu

- **Technology:** Phytoparking™
- **Challenges addressed:** Wastewater treatment, storage and reuse where no net land is available
- **Innovation:** Compact (< 1m²/PE), can be retrofitted in parking lots and provide additional use for this space

The Phytoparking™ system has been implemented in five locations so far, one installation represented as a comprehensive monitoring and assessment pilot within the MULTISOURCE project. The MULTISOURCE pilot is implemented at a campsite - T' Hof Bellewaerde - in Ypres, Belgium. As this is a protected historical heritage site, excavation is prevented to a degree that prohibits conventional wastewater treatment and drinking water systems. The campsite is not connected to the central sewer system or water supply. The Phytoparking™ system is placed underneath the campsite's bicycle shed. It comprises two separate basins for the treatment of blackwater and greywater, respectively. Approximately 30% of the treated wastewater is recycled for toilet flushing. The campsite's drinking water is supplied by purified rainwater for most of the year. In the drier summer months, a fraction of the greywater undergoes additional filtration and disinfection processes to be reused as drinking water, to supplement the limited rainwater (Watercircle 't Hof Bellewaerde, n.d.). The Phytoparking™ system spans 75 m² and is designed to service 130 camping guests. The construction costs amounted to € 65,000 and the maintenance costs are estimated at € 350 per year (Martens, personal communication, 2022).

Rhizosph'air aerated treatment wetland for raw domestic wastewater, Lyon (France)

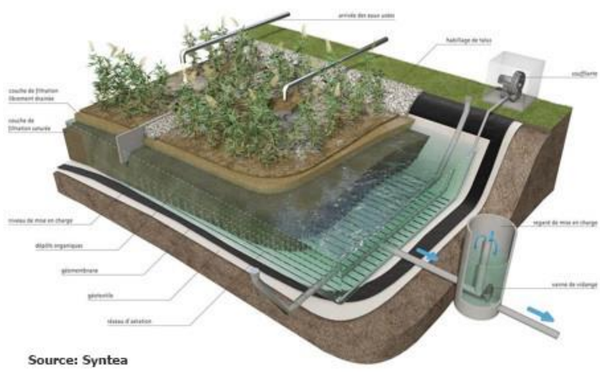


Figure 6. Rhizosph'air aerated treatment wetland. Source: multisource.eu

- **Technology:** Rhizosph'air aerated French vertical flow treatment wetland
- **Challenges addressed:** Simultaneous treatment of solids and wastewater, extreme rain events
- **Innovation:** Compact (< 1m²/PE), new design guidance, innovative ICT monitoring

The research pilot is located in peri-urban Lyon and consists of 9 pilots of 20m^2 each, with wastewater treatment as their main purpose. They are fed with wastewater abstracted from a combined sewer. This specific configuration of a vertical flow wetland allows the treatment of raw wastewater, including solids, after a simple filter screen. The system requires removal of the deposit layer only after 10 to 15 years. The automation of daily feeding based on monitored parameters enables the decentralized implementation of this enhanced system. It requires an on-site check once per week. As the system can handle 3-5 times the dry flow, the disruptive impacts of heavy rainfall are minimized. The technology's performance towards compliance with the EU Regulation for Water Reuse in Agricultural Irrigation (EU 2020/741) is currently being monitored and validated.

Its installation costs amount to € 200 per m^2. Routine maintenance involves weekly checks and harvesting of the reeds once per year. Organic deposits must be removed every 10-15 years (once reaching 20cm). During the first year, invasive plants must be removed. The system is expected to perform sufficiently without major maintenance for at least 30 years.

Treatment wetland for high-strength wastewater in Bridger and Bozeman (Montana, USA)

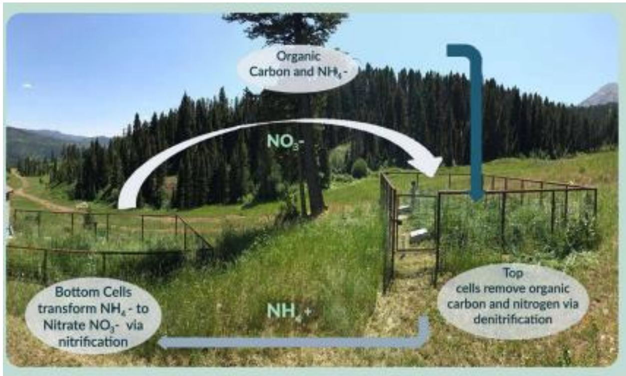


Figure 7. Treatment wetland in Bozeman, Montana. Source: Stein, 2022.

- **Technology:** Vertical flow treatment wetland with recirculation and partial saturation
- **Challenges addressed:** Operation in cold climate at a ski resort, highly concentrated (high strength) wastewater
- **Innovation:** Seasonal operation, recirculation for increased nutrient removal from high-strength wastewater

MULTISOURCE monitors two treatment wetland pilots in the United States, one at Bridger Bowl Ski Resort near Bozeman, Montana, and another at the Bozeman municipal wastewater treatment plant. In Bridger, a two-stage vertical flow treatment wetland was constructed in 2013 to provide secondary treatment of wastewater from the resort. The wetland features a top cell, where recirculating sand filters were replaced with native plants for nitrogen removal, and a bottom cell for nitrification (Bridger Bowl, n.d.). The wetland treats 7.5 m^3 of wastewater per day and covers an area of 95 m^2. It operates only during the ski season in winter. The installation costs, excluding labor costs for design and construction (provided in kind by Montana State University), amounted to € 45,600. The yearly maintenance cost is estimated at € 913 (Stein, personal communication, 2022).

The Bozeman treatment wetland is also a two-stage vertical flow wetland, with construction completed in November 2022. The system treats 7.5 m^3 of raw municipal wastewater per day and occupies an area of 57 m^2. The installation costs, excluding labor for construction provided by Montana State University, amounted to € 100,500 (Stein, personal communication, 2022).

3. Methodology

Multi-actor co-creation process to inform collaborative business models for NbS^{WT}

The methodology employed for co-creation and collecting information for collaborative business models for NbS^{WT} in urban water management was designed to integrate various data sources from a broad range of stakeholders in the NbS^{WT} and urban water management value chains, based on seven cases. These cases are centered around the seven MULTISOURCE pilots described above (see section 2). Key participatory elements of the knowledge creation process include consultations, interactive stakeholder workshops and collaborative analysis processes.

In a first step, consultation meetings with the pilot leaders were held in 2022, to characterize their purposes and potential co-benefits, technical design characteristics and innovation, as well as practical and design implications to realize co-benefits, as well as target markets and business case scenarios.

Two interactive workshops with the multi-sectoral MULTISOURCE consortium were conducted in October 2022 and March 2024. The first workshop served to validate an overview of potential customers, project sponsors, and implementation partners, their motivations to invest in NbS^{WT}, as well as their roles in the NbS^{WT} value chain. In the second workshop, the project partners drew five qualitative group models of the urban challenges and the strategic fit of selected NbS^{WT} in the contexts of Milan, Oslo, Girona, Lyon, and Leipzig, respectively, dissecting the system dynamics, and framing the NbS^{WT} services, integrating diverse sectoral perspectives. The pilot partners and local authority partners were actively involved in the relevant group corresponding to their local pilot context, while the other MULTISOURCE partners contributed across various thematic areas.

In a transdisciplinary process, researchers and technology providers from the MULTISOURCE consortium collaborated with MULTISOURCE counterparts from the Metropolitan Cities of Milan and Lyon as well as the Municipalities of Oslo and Girona to engage local enabling partners in initial processes to co-create business cases corresponding to their context-specific strategic priorities and framework conditions. These workshops were designed in collaboration with city or metropolitan authorities and technical partners. Each workshop included preparation and follow-up phases to enhance the effectiveness of the engagements and ensure further development of the results beyond the workshops. The scope and activities were developed collaboratively to ensure relevance and to address the specific needs of each city or region.

Impressions from the co-creation workshops in March and April, 2024. Photos: MULTISOURCE consortium.

Reporting and Analytical Framework

For water infrastructure or green infrastructure programs or projects to secure funding, it is essential to demonstrate how the proposed investment makes optimal use of limited public and/or private resources. Furthermore, it is crucial to provide proof that the investments and their procurement will maximize value for money. Essentially, a compelling investment case must be articulated.

The co-creation and present framework to report and analyze the results and implications for the business cases for NbS^{WT} follows the Framework for Water Security (FFWS) set out in the Handbook for the

Implementation of Nature-based Solutions for Water Security (Altamirano et al., 2021), which in turn utilizes the widely endorsed “five case model”. This model, recommended by HM Treasury, the Welsh Government, and the UK Office of Government Commerce, has been extensively applied within central government departments and public sector organizations over the past decade and is recognized globally as a best practice for managing public investments (Altamirano et al., 2021). The model outlines that the investment case for public funds includes five principal dimensions (figure 8):

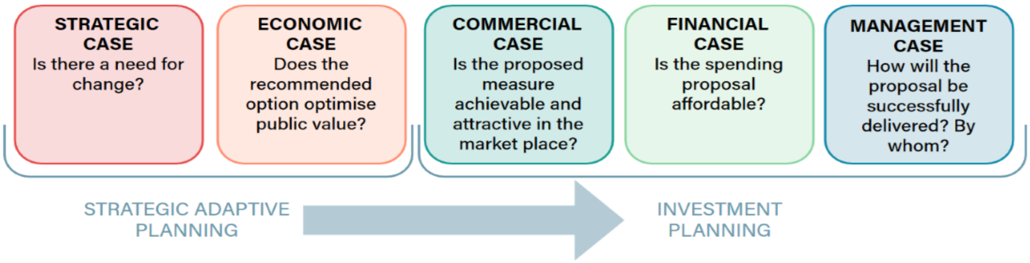


Figure 8 Five dimensions of a full business case (Altamirano et al. 2021. NAIAD project D7.3)

- **Strategic**: Analysis of how NBS fit into the specific environmental and administrative contexts of each city, challenges and services, solution scope and measures.
- **Economic**: Evaluation of the value for money in terms of economic, social, and environmental benefits, pains and gains, costs, and benefits (direct and societal).
- **Commercial**: Consideration of the capability and interest of the private sector to assume intended services or tasks, cost structures, technical design guidelines, technical implementation risks.
- **Financial**: Assessment of the financial feasibility of the NBS projects, revenue streams, funding available and/or secured, financing strategy.
- **Management**: Evaluation of the operational feasibility and management structures proposed for the NbS: Governance and procurement strategy, project delivery and finance model (*Who will fund, how to finance? Who is best positioned as commissioner of the work? Who should carry out the work? Who should operate the NbS asset? Who will monitor the level of service provision*)

A crucial component in developing these five cases is designing an appropriate implementation arrangement for each NbS^{WT} project or group of projects. By establishing such arrangements, the strategic and economic justifications for what is known in public sector investment as the “preferred option” can be elaborated upon to support the commercial, financial, and management cases.

The following considerations are based on the initial stakeholder consultations and collaborative modelling workshops. They are not comprehensive and require further co-creation and validation processes to develop full business cases.

4. Descriptions of business model components

4.1 Metropolitan City of Milan – NbS for enhanced stormwater management

Sources of information

This section describes the insights for public-private business cases for NbS contributing to enhanced stormwater management within the Sponge City Milan Strategy.

Sources of information integrated here include:

- Outputs of the multi-actor co-creation workshop with members of the stakeholder group of the NbS^{WT} Metropolitan Board, 10 participants including: (i) representatives of ATO - the watershed territorial authority, (ii) ERSAF - the agency of Lombardy Region responsible for the planning and knowledge promotion of the regional agricultural and forestry sectors, (iii) Gruppo CAP - the utility for the management of the Integrated Water Service for the Milan Metropolitan Area, (iv) the Metropolitan City of Milan (Environment and Land Protection Area), and (v) IRIDRA.
- Information provided in the consultation and co-creation processes by the Metropolitan City of Milan (CMM, consortium partner of MULTISOURCE and leader of the Stakeholder Group for the Sponge City Milan) and IRIDRA Srl (consortium partner of MULTISOURCE, pilot leader of the Merone treatment wetland for CSO, and member of the Stakeholder Group for the Sponge City Milan).
- Interactive workshop with members of the MULTISOURCE consortium - a multisectoral group including representatives from CMM and IRIDRA as well as other MULTISOURCE partners.
- Validation of the conclusions for business models by CMM (Sustainable Development and Decision Support Systems Service) and IRIDRA Srl.

Strategic dimensions

Figure 2 below shows the group system dynamics model co-created at the multi-actor workshop by representatives of the NbS^{WT} Metropolitan Board. The objective of this interactive session was to create a strategic case for NbS^{WT} interventions in the Metropolitan City of Milan. This section describes the climate and infrastructure challenge, the enabling environment, and the solution.

The Challenge

The top two local climate risks in Milan are urban flooding and increase of urban heat, with temperature rise of 3-7°C by 2090 and up to 10-20% increase of heat waves (Boschi, 2023). These are associated with increased health risks, a 12–24% increase in the 24h maximum precipitation, i.e. short-duration high-intensity events, up to 8–15% increase in the 5-day maximum cumulative precipitation resulting in increased water levels and flooding risk, and middle to a strong increase in the likelihood of severe droughts (Boschi, 2023). Main human factors exacerbating flood and heat risks raised by the workshop participants include urbanization, which involves urban sprawl, sealing of surfaces, and the reduction of natural land. A strategic driver contributing to naturalization (renaturation) of urban spaces is urban renewal (or urban regeneration).

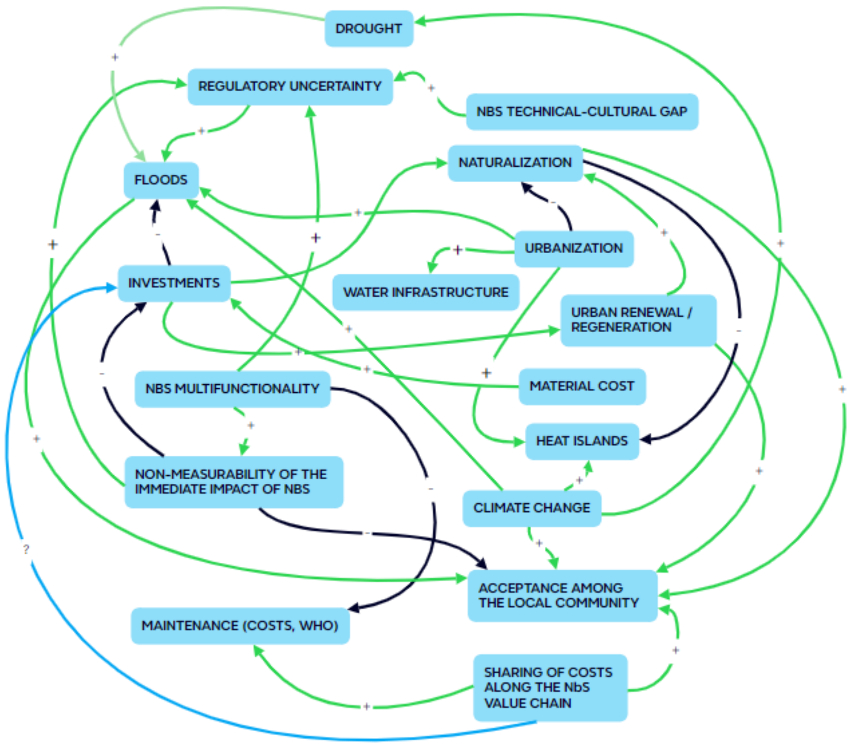


Figure 9. Group model showing the system of challenges, opportunities, and framework conditions in the context of Milan, co-developed by local and regional stakeholders

The actors present at the workshop recognized the potential of NbS^{WT}, such as bioretention systems (raingardens), to sustainably reduce flood risks and while also solving other mentioned urban challenges, and identified several considerations of the enabling environment that influence the adoption of these NbS in Milan:

- Insufficient assessment of sector-specific services: The impacts of NbS^{WT} are not sufficiently quantified for the different actors' interests and accounting systems (costs vs. benefits of specific water service of a green space, heat mitigation service), in particular service-specific costs of adequate maintenance. This results in limited institutional acceptance, limited investment, and normative (regulatory) uncertainty regarding the investability of NbS^{WT} in line with normative principles of value for money. Reference cases for collaborative projects would increase the confidence to build further investment partnerships for NbS^{WT}.
- Similarly, there is a lack of structured procurement processes of NbS^{WT}. Alternative funding options allow to circumvent regulatory uncertainty related to the use of water infrastructure budget (water tariffs) for NbS^{WT} but may remain singular projects at limited scale rather than mainstreaming NbS^{WT} into water services.
- There is the need to implement measures on the territory of other actors. As the problem is often not local, the narrative of territorial use conflicts could be communicated via a common vision of a territory within a system, possibly at regional decision-making scale as the watershed level goes even beyond the metropolitan scale.
- The lack of space in the urban area favors acceptance of using existing urban infrastructure, such as parks, to provide simultaneous water services, such as stormwater detention.

The Solution

The following elements of the solution were raised and agreed upon in the multi-actor workshop, comprising technological, managerial, and knowledge related aspects:

- The widespread sealing of surfaces in the past must be remedied for future protection from climate hazards.
- Nature-based sponge city measures are backed by policy priorities of reducing floods, polluted runoff and CSOs, and urban heat islands at the metropolitan level.
- Sponge City principles could be applied in ongoing and highly accepted efforts of urban renewal. Renaturation and de-sealing surfaces are widely accepted among the local community and implementing bioretention systems/raingardens within this frame could benefit of shared acceptance of functional greening design (as opposed to ornamental greening) and cost-efficiency.
- Hydraulic risk management fits into the administrative tasks at the level of the metropolitan territory (actor: CMM) and/or the river contracts (ERSAF). A large-scale vision at these levels could represent the vehicle for communicating the need and progress in implementing raingardens across the metropolitan territory, and bringing on board municipalities who must provide the land area, as well as private landowners.
- Reference cases and their quantification of hydraulic services, urban heat reduction, other ecosystem services must be gathered as a basis to derive design principles for replication and to build confidence. Quantifying the different ecosystem services enables project proponents to specify the amount of funding different partners can contribute to a collaborative project for multifunctional NbS. For example, if the margin of additional costs to implement hydraulic and treatment capabilities in a public park or on a parking lot are quantified, the wastewater manager can fund this amount, while the public or private entity responsible for the park or parking lot can fund the costs incurred without designing water services into this land.

Details on the management arrangements discussed by the participants are set out further below.

Economic dimensions

Table 1 below outlines the advantages and disadvantages of the NbS^{WT} discussed at the local multi-actor workshop. These include raingardens (bioretention systems) and associated actions of de-sealing and renaturation of sealed surfaces.

Table 1. Advantages and disadvantages of NbS^{WT} compared to alternative solutions in Milan

Alternatives	Advantages of the NbS^{WT} discussed	Disadvantages of the NbS^{WT} discussed
Costs of no action	• Hydraulic services towards flood risk mitigation, cost savings from avoided flood damages • Reduction of urban heat island effect and associated social and public health impacts • Water pollution control downstream of the urban catchment (from urban runoff and CSOs)	• Costs of implementation, land opportunity costs • Aesthetic character of raingardens is different from culturally common green spaces, lower cultural acceptance of raingardens replacing a purely aesthetic design
Expansion of sewer capacity underground	• Comparatively minimal excavation and disruption of urban (historical) infrastructure → savings of excavation and transportation costs and carbon emissions	• Larger spatial footprint, land opportunity costs, limited scale • Transaction costs due to regulatory uncertainty, asset value accounting

	• Savings of concrete material and carbon footprint • Cost savings from avoiding stormwater to be treated in centralized wastewater treatment plants.	uncertainty and/or reliance on other urban actors, lack of established procurement and permitting processes • Limited level of service compared to the large volumes possible with underground chambers and tunnels • Different (new) maintenance tasks than purely grey infrastructure system
Infiltration shafts	• Biodiversity benefits • Regenerative and urban cooling benefits of intensive urban greening, with associated social and public health benefits • Higher performance in stormwater pollution control (first flush treatment)	• Maintenance of greening • Higher land opportunity costs

NbS^{WT} could be added to enhance current grey hydraulic solutions in place. Decentralized raingardens could be installed at runoff hotspots and treatment wetlands could be placed to treat CSOs.

The Sponge City Milan project does not foresee energy-intensive systems, therefore rainwater collection systems with pumping for irrigation have not been included.

Commercial dimensions

There are suppliers available to meet the defined needs and envisioned levels of service. Technical experts and suppliers are already involved in shaping the Sponge City Milan project and are able and willing to undertake the required activities if delegated by the potential procuring authorities.

One key technical implementation risk and mitigation strategies came up in discussion at the stakeholder workshop:

Table 2. Technical implementation risk and mitigation strategies

Risk	Mitigation strategy
Inadequate maintenance or destruction due to lack of knowledge	• Needs signage "this is a hydraulic infrastructure, it is not a flowerbed" to ensure that it is recognizable and maintained adequately by municipal gardeners • Needs well-conducted handover at the transition to the long-term O&M phase with communication to all relevant actors (*what was done, why was it done, responsibilities, adequate maintenance*) and a follow-up assessment to verify that the handover has been effective

Financial and Management dimensions

The stakeholders discussed business models for two widespread urban spatial typologies that could be retrofitted with NbS for enhanced stormwater management:

- Street and parking lots
- Public parks

The following tables 3 and 4 showcase the services of NbS^{WT} that the workshop participants identified as relevant, the actors with an interest and/or responsibility to promote the provision of this services, as well as the roles of the listed actors in collaborative NbS^{WT} projects. Table 5 below summarizes a possible implementation arrangement as defined by the Stakeholder Group at the co-creation workshop.

Table 3. Example of a street and parking lot: Raingardens in San Giuliano Milanese

Services (values)	Actors with interest or responsibility for this service	Roles in a collaborative NbS^{WT} project
Efficient use of urban space	Municipality	Concession of area (public property), maintenance
	Local enterprises and citizens	Acceptance, property
Unsealing surfaces	Water utility (integrated water service manager responsible for sewerage, CSO, treatment)	Engineering, maintenance, project co-sponsor for water service
	ATO (watershed territorial authority)	Investment (project sponsor)
	Metropolitan City of Milan	Policies, administration, authorization, public space
	ERSAF (agency of Lombardy Region responsible for the planning and knowledge promotion of the regional agriculture and forestry sectors)	Management of river contracts, monitoring
Flood prevention (hydraulic risk mitigation)	ERSAF – administrative perspective of river contracts CMM – administrative perspective of territory	Investment, monitoring
Groundwater infiltration/ aquifer recharge, disconnection from sewer network	Water utility	Engineering, project co-sponsor for water service, maintenance
	ATO	Investment
	Municipality	Concession of area (public property), maintenance
Stormwater detention/ functioning of the sewer system	Water utility	Engineering, maintenance, project co-sponsor for water service
	ATO	Investment
	ERSAF	Management of river contracts, monitoring
Heat reduction through shading	Metropolitan City of Milan	Policies, administration, authorization, public space
	Municipality	Concession of area (public property), maintenance
	ERSAF	Management of river contracts, monitoring
	Local enterprises and citizens	
Urban renewal, urban regeneration	Metropolitan City of Milan	Policies, administration, authorization, public space
	Municipality	Concession of area (public property), maintenance
Enhancement of infrastructure services	Water utility	Engineering, maintenance, project co-sponsor for water service
	ATO	Investment
Realization of policy objectives (e.g., adaptation to climate change)	ERSAF	Management of river contracts, monitoring
	Lombardy Region	Policies
	Financiers	Financing

Value of assets (sewerage network)	Water utility	Engineering, maintenance, project co-sponsor for conveyance, connection, treatment elements
	ATO	Investment
	Municipality	Concession of area (public property), maintenance
	Property owner	Land
Pollution control/ water quality	Local enterprises and citizens	Acceptance, property
	ERSAF	Management of river contracts, monitoring
	Lombardy Region	Policies
Economic value and green jobs	Executing agents/ contractors (design and technical consultancy; suppliers, construction, maintenance)	Construction and maintenance services (agents)
	ERSAF	Education and training, monitoring
	Financiers	Financing

The abovementioned services also apply to the second urban typology specifically addressed in the workshop: public parks. The stakeholder group identified additional services that can or must be provided by stormwater collection from surfaces of roads and parking lots surrounding parks in which the NbS^{WT} are integrated. To each of these services, the participants allocated actors with a vested interest and/or institutional responsibility for these services, as well as their roles in a collaborative NbS^{WT} project (table 4 below).

Table 4. Example of a public park: Raingardens in Sedriano

Services (values)	Actors with interest or responsibility for this service	Roles in a collaborative NbS^{WT} project
Collective enjoyment, urban regeneration for water-proofing (climate resilience)	Citizens	Acceptance
	Park management agency	Maintenance
	Municipality	Concession of area (public property), maintenance
	ERSAF (park management)	Investment, monitoring
Safety of use	Citizens	Acceptance
	Municipality	Concession of area (public property), maintenance
Implementation of environmental and social policies	Citizens	Acceptance
	Park management agency	Maintenance
	Metropolitan City of Milan	Policies, administration, authorization, public space
	Municipality	Concession of area (public property), maintenance
	Institutional financiers	Financing
	ERSAF (park management)	Investment, monitoring
	Lombardy Region	Policies, investments
Sewer disconnection of parks, collection of stormwater from surrounding area and infiltration in park	ATO	Policies, investments
	Park authority	Concession of area, monitoring
	Water utility	Engineering, project co-sponsor for water service, maintenance
Flood prevention	Citizens	Acceptance
	Water utility	Engineering, project co-sponsor for water service, maintenance
Ecological connection	Citizens	Acceptance
	Park management agency	Maintenance
	Metropolitan City of Milan	Policies, administration, authorization, public space
	Municipality	Concession of area (public property), maintenance
	ERSAF (park management)	Investment, monitoring
	Lombardy Region	Policies, investments

The following table summarizes a possible implementation arrangement by project stage (large-scale planning, technical design and construction, and maintenance) applicable to both urban typologies detailed above. It lists relevant actors and outlines their respective roles.

Table 5: Possible implementation arrangement for NbS within a metropolitan scale Sponge City Milan

Project stage	Providers of funding and resources, and commissioners	Agents
Large-scale planning (territorial planning and identification of sites)	**Funding:** ● Lombardy Region ● CMM (urban redevelopment funds) ● ERSAF ● ATO (from tariffs) **Land:** ● **Municipality:** Grants concession of area for raingardens as integrated stormwater service plants for a certain period to the stormwater manager (water utility)	● Strategic body (Lombardy Region, ATO, CMM)
Technical design and construction	**Public property development:** Funding and financing providers: ● ERSAF ● ATO (tariffs) ● Municipality (e.g., for redevelopment of a car park) ● External financier **Private property development:** ● Private property owner (real estate developer) ● Public subsidy ● Philanthropist **Commissioners:** ● Metropolitan city manager, or ● Municipality, or ● Water utility (with funds from ATO) **In-kind provision of engineering services:** ● Water utility	● Contractor (by tender)
Maintenance	● Municipality (from budget for managing park and green spaces, from fees users pay for the parking lot), or ● Regional park authority, or ● Private property management funds ● Maintenance training: nurseries (suppliers of raingarden plants)	● Municipality or regional park authority ● Water utility (water service manager) ● Private actor if implemented on private property ● Maintenance training: nurseries

Incentives for private sponsorship

Future incentives for private actors (not in place yet) may involve tariff reductions for reducing discharge of rainwater to the sewer system. Sewer connection permits that condition certain discharge limits for properties provide a regulatory mechanism by which to facilitate private investment in on-site rainwater retention and infiltration.

Accounting of investment into the municipal land asset

The municipality or the metropolitan city can provide area for raingardens by concession for a defined period of time. This asset must be guaranteed, so that the water service manager (water utility) can invest in the implementation of raingardens on this area. The asset (raingardens as water service plants constructed on municipal land) is listed in the water utility's asset book. The water utility could invest in the development of the raingardens (with water tariff funds provided by ATO, the watershed management authority) and carries out the maintenance. Once the concession ends, the total amount or a portion of the investment may be amortized or depreciated within the tariff system. If it has been completely depreciated by the tariff system, the raingarden is transferred to the municipality (or the respective property management entity). If it has not completely depreciated, the municipality must pay the difference.

In this context, it is necessary to separate the works and related investments for regular maintenance of the space (e.g., paving, trees) from the works and investment needed to provide the hydraulic service (e.g., basin, raingarden vegetation). The latter works could be either taken over by the water utility or taken over by the municipality within its maintenance of public spaces and then sold to the water utility as an asset of the water utility against a clearly defined tariff impact.

4.2 City of Oslo - NbS for urban runoff treatment for water pollution control

Sources of information

This section describes insights for a public-private business model for NbS^{WT} for better stormwater management in the city of Oslo, Norway, in particular raingardens for urban runoff treatment. The business model dimensions are based on the following sources of information:

- Information provided in the consultation and co-creation process by the Agency for Urban Environment of the City of Oslo (consortium partner of MULTISOURCE) and NIVA (consortium partner of MULTISOURCE, pilot leader of the raingarden for road runoff treatment in Oslo).
- Results of a multi-actor co-creation workshop with members of the cross-sector stakeholder group on polluted groundwater facilitated by the City of Oslo: charts of group models depicting the system dynamics that constitute the challenge and documentation of the group discussions by the MULTISOURCE project counterparts of the City of Oslo and NIVA.

The participants of the location co-creation workshop divided into three breakout groups, where each group created a group model chart of the local challenges in Oslo as well as influencing (amplifying and dampening) factors and their relationships (see group model charts in Annex 1). The following stakeholder representatives participated in the groups:

Table 6. Participant affiliations and roles or topics of work by breakout group

Group	Represented organization	Participant roles or topic of work in the organization
Group 1	Agency for Urban Environment	• Rivers and aquatic biology • Road maintenance • Road planning
	Water and Sewerage Agency	• Pollution monitoring
	Agency for Planning and Building Services	• Stormwater planning
Group 2	Agency for Urban Environment	• Road planning • Environmental advisor
	Water and Sewerage Agency	• Water and sewerage planning in the city
	Agency for Planning and Building Services	• Stormwater planning
	NIVA	• Water and society research
Group 3	Agency for Urban Environment	• Rivers and water bodies • Road planning
	Water and Sewerage Agency	• Water and sewerage/pollution • Stormwater management
	NIVA	• Water quality research

The three group models generated by groups 1, 2, and 3, respectively, can be reviewed in Annex 1. The implications for the strategic, economic, commercial, financial, and management dimensions are described below.

Strategic dimensions

The Challenge

Each of the three groups centered their discussion primarily around water pollution of the Oslo Fjord as the main problem. The groups' narratives covered the network of environmental pressures, urban development (expansion and densification), and the enabling environment as well as collective efforts needed to mitigate pollution of the Oslo Fjord.

Water pollution and urban flooding

The Fjord already faces adverse impacts on aquatic life including fish populations, ecosystems, and the city's inhabitants who frequently engage with these water bodies for recreational purposes. Pollution of urban watercourses leading to the Oslo Fjord and urban flooding are further major challenges.

The primary sources of water pollution in Oslo are attributed to combined sewer overflow (CSO) and polluted surface runoff which directly enters the Fjord. As pollution from CSO has been better controlled, polluted surface runoff was the main focus of further discussions. Drivers of increased pollution include road traffic, use of chemicals, materials used in the urban environment, and misconnections in the piping network. The historical transformation of urban watercourses into underground piped networks has exacerbated these issues. This issue is compounded by the high volumes of stormwater due to urban densification and expansion, which overwhelms existing infrastructure and leads to urban flooding.

Soil contamination and infrastructure challenges

Contaminants from polluted soil often reach the groundwater. The local soil types, such as clay and quick clay, disfavor natural infiltration of rainwater and the construction of bioretention systems. The urban landscape is further stressed by the lack of space, which complicates the implementation of necessary infrastructure improvements and environmental solutions.

Regulatory and planning challenges

The existing zoning plans in Oslo are outdated and lack sufficient guidelines for effective stormwater management. There is a noted disconnect between the goals of urban development and environmental sustainability. Developers often prioritize financial gains over sustainable practices, underlining the need for stringent and enforceable regulations that guide urban development. It is necessary to steer real estate development with building legislation and technical guidelines for enforcement, which can dictate construction practices through building permit applications. Moreover, providing space in the streetscape is necessary to alleviate the existing pollution and flood related challenges. The width and depth of streets create challenges as space is occupied by infrastructure.

Knowledge gaps and resource limitations

A pervasive lack of awareness about environmental issues among residents and authorities, coupled with limited municipal resources, hinders effective environmental management. This shortfall affects routine maintenance such as the clearing of sand traps and the expansion of stormwater management systems, which are vital for mitigating pollution.

Climate change and urban pressures

Climate change exacerbates these challenges, increasing the frequency of heavy rain events that lead to greater surface erosion and particulate matter runoff into water bodies. These effects not only strain the CSO systems but also impact the overall resilience of the urban environment against environmental stressors. Drought and biodiversity loss were also mentioned as challenges related to the challenge of urban runoff and the use of NbS, but not discussed more in detail.

Integrating Nature-based Solutions for water treatment

The conflicting goals at the municipal level highlight the complexity of prioritizing and implementing NbS^{WT}. Urban densification, for example, increases pressure on available space, making it difficult to balance developmental goals with environmental sustainability. However, objectives such as enhancing traffic security, reducing vehicular congestion, and promoting active urban living present opportunities to integrate NbS^{WT} that support water management and contribute to achieving broader urban sustainability goals. This requires cross-sectoral cooperation and cooperation between the different city government bodies.

Conclusion

The environmental challenges faced by Oslo require a holistic and integrated approach to urban planning and environmental management. Implementing robust stormwater management plans and urban green spaces are crucial in alleviating the environmental strain. Success in these areas demands cross-sectoral cooperation and concerted efforts among politicians, city planners, developers, and the community. Ultimately, the collective goal is to restore and preserve the ecological balance of the Oslo Fjord and ensure the sustainable development of the city's urban and natural environments.

The Solution

Solutions for the treatment of polluted water are needed, nature-based if possible. A strategic emphasis on NbS was highlighted to effectively tackle the environmental challenges of water pollution and urban runoff in Oslo. NbS were pointed out as a possibility to intercept water pollution before it reaches rivers and the Fjord.

These solutions not only mitigate the direct impacts of urbanization on the natural water systems but also enhance urban livability and sustainability. NbS can provide the opportunity to simultaneously address other urban challenges, such as by reducing traffic and increasing recreational space.

NbS such as green roofs, permeable pavements, and raingardens can significantly help to absorb rainwater, thereby reducing stormwater runoff and alleviating pressure on the city's sewage systems. The integration of these systems into city planning is essential to decrease the creation of impervious surfaces that contribute significantly to runoff and CSO. Captured rainwater could simultaneously be used for tree irrigation, alleviating water stress during drought periods.

Moreover, the restoration and reopening of enclosed streams were proposed as environmental strategies. Planning for space to accommodate these streams is crucial, as it not only facilitates the natural treatment of polluted waters but also enhances the ecological and aesthetic value of urban spaces.

The implementation of NbS^{WT} should be approached with a multifunctional perspective. Thoughtfully designed green spaces not only serve as effective stormwater management tools but also provide substantial benefits such as reduced urban heat islands, improved air quality, and increased biodiversity. Additionally, these spaces offer opportunities for recreational activities and can contribute to traffic reduction by promoting non-motorized forms of transportation.

Wastewater treatment plants must be considered as a complementary measure to NbS^{WT}, ensuring a comprehensive approach to water purification.

The adoption of NbS^{WT} within Oslo's action plan for stormwater management reflects a strong commitment to sustainable urban development. This approach requires careful integration into existing and future urban planning policies to ensure that environmental objectives align with developmental goals.

Economic dimensions

Table 7 below outlines the advantages and disadvantages of the raingardens for surface runoff treatment discussed at the local multi-actor workshop and previous consultations with the Agency for Urban Environment of the City of Oslo (representatives of road planning). This illustrates the conditions in which treatment raingardens provide greater economic benefits than alternative scenarios and solutions.

Table 7. Advantages and disadvantages of treatment raingardens compared to alternative solutions in Oslo

Alternatives	Advantages of treatment raingardens	Disadvantages of treatment raingardens
Costs of no action	• Water pollution control, treatment of polluted runoff from urban surfaces such as roads and reduction of pollutants entering receiving water bodies • Reduction of stormwater entering the sewer system, reduction of CSO • Hydraulic services towards flood risk mitigation, cost savings from avoided flood damages • Road safety improvement, barrier between car lanes and bicycle or pedestrian footpaths • Irrigation of urban trees, reduction of water stress during drought periods	• Costs of implementation, including land opportunity costs*
Expansion of sewer capacity underground	• High cost savings due to reduced excavation. Sewer pipes must be laid deep in the ground, below frost levels. • Savings of concrete material and carbon footprint • Cost savings from avoiding stormwater to be treated in centralized wastewater treatment plants.	• Transaction costs related to reliance on other urban actors and lack of established procurement and permitting processes • Limited level of service compared to the large volumes possible with underground chambers and tunnels • Different (new) maintenance tasks than purely grey infrastructure system • Larger spatial footprint and land opportunity costs*
Infiltration shafts	• Benefits of vegetation (aesthetics, recreation, biodiversity if designed accordingly) • Higher performance in stormwater pollution control (first flush treatment)	• Maintenance of greening • Larger spatial footprint and land opportunity costs*
Conventional urban green space without specific hydraulic or treatment services by design	• Water pollution control, treatment of polluted runoff from urban surfaces such as roads and reduction of pollutants entering receiving water bodies • Flood resilience of green spaces and more effective hydraulic services towards flood risk mitigation • Irrigation of urban trees, reduction of water stress during drought periods (if designed accordingly)	• Higher design and maintenance costs

*Spatial trade-offs can be minimized as raingardens can be designed as narrow strips and are suitable for urban contexts with spatial constraints.

The treatment raingardens could be added to enhance current grey hydraulic solutions in place. Decentralized raingardens could be installed at hotspots of runoff volumes and/or pollution impacts.

Commercial dimensions

There is a supplier who can provide the technology according to the defined needs.

The following insights on the enabling environment were provided by local actors at the co-creation workshop:

In the municipality, the challenge of division and siloed operations is prominent, affecting both the agency level and the Oslo city council departments, notably those responsible for urban development and water, environment, and community centers. This fragmentation is compounded by the absence of comprehensive national guidelines, necessitating the development of robust frameworks at both the national and municipal levels to effectively address these issues.

One significant area of concern is the lack of clear pollution limits, particularly affecting water quality. Without definitive parameters specifying necessary reductions, it remains challenging to incorporate such requirements into zoning plans. This issue is under review, with efforts underway to establish clear guidelines.

The implementation of solutions to manage stormwater runoff is further complicated by urban densification, which restricts available space. Conflicting developmental goals exacerbate this issue, highlighting the need for more flexible norms in urban planning, such as the design of streets. This flexibility would facilitate the integration of Nature-Based Solutions (NBS) into urban areas, promoting multifunctional spaces that could enhance environmental resilience.

The varying goals and interests of politicians and city government bodies play a crucial role in the prioritization of administrative efforts. Enhanced cooperation among these bodies is essential to mitigate the risk of conflicting objectives, which currently hinders solution implementation.

Several barriers impede progress, including the expansion of impervious surfaces that contribute to urban growth and an overwhelmed sewage system. Additionally, a general lack of awareness means that efforts to reduce pollution may not receive the necessary support and engagement from the community.

However, there are also significant opportunities. For instance, nature-based solutions can mitigate runoff issues, and collaborative planning among politicians, authorities, developers, and residents can foster sustainable urban management. Education plays a pivotal role in raising awareness and garnering public support.

To enable these solutions, the development and implementation of comprehensive stormwater management plans are crucial. Utilizing NBS can enhance water quality, and establishing regulatory frameworks that prioritize sustainable development can guide municipal efforts towards more effective environmental management.

Financial and Management dimensions

As a basis to further define the collaborative implementation arrangement, relevant actors with interests (pains, gains, jobs to be done/mandates) in the services of treatment raingardens were defined. In the local co-creation workshop, after visualizing the challenge and solution in the group models, the participants identified the respective local actors with an institutional interest or responsibility to provide these services (see charts in Annex 1). Table 8 provides an overview of the key services, actors with jobs, pains, and gains related to these services, and their roles in the green wall project.

Table 8. Overview of main services of treatment raingardens in Oslo and related actors

Services (values)	Actors with interest or responsibility for this service
Treatment of stormwater, reduction of CSO	Water and Sewerage Agency
Reduction of CSO, correct sewer misconnections, adequacy of private connections	
Drought mitigation	Agency for Urban Environment
Biodiversity increase	
Liveable city	
Road safety	
Transport services	Norwegian Public Road Administration
Treatment solutions for treating polluted water	Infrastructure owners (road directorate, railway, etc.)
Water quality in the Oslo water sub-region (local catchment)	Oslo city council
Livestock and wildlife	Oslo city council
Pollution control of the Oslo Fjord	State Administrator
Compliance with regulations and building permit requirements	Real estate developers, private property owners
Environmental health of their community	Residents

Concentrated on the collective definition of the strategic case, characterizing the challenge and the solution, and defining relevant services and actors. On this basis, further dimensions of the business case will be defined.

4.3 City of Girona - Green wall for greywater treatment at a public school

Sources of information

This section describes the business case for a green wall for greywater treatment and reuse planned to be installed at a public school in Girona, Spain.

Sources of information integrated here include:

- Outputs of a multi-actor co-creation workshop with the actors involved in the green wall project in Girona. The 12 participants included representatives of: Girona City Council (Ajuntament Girona, MULTISOURCE partner) – departments for Urban Development, Climate Action, and Education (responsible person for the seven municipal kindergartens, including the kindergarten from where the greywater will be sourced), Director and Facility Manager of the Escola Ágora and El Tren (the public school and the kindergarten where the green wall will be installed), and ICRA (the Catalan Research Institute, MULTISOURCE pilot leader and local specialized technology provider).
- Information about the technology and the MULTISOURCE pilot in Girona by the pilot leader ICRA as well as green wall technology supplier alchemia-nova GmbH.
- Validation of the conclusions for business models by ICRA and the City of Girona.

Strategic dimensions

Figure 2 below shows the group system dynamics model co-created at the multi-actor workshop by the local actors involved in the green wall project in Girona. The objective of this interactive session was to create the strategic case for green walls for greywater treatment and reuse, and greywater-irrigated urban greening more generally, in the city. This section describes the main factors constituting the urban challenge and the solution.

The Challenge

The participants at the local co-creation workshop highlighted water scarcity as the main urban challenge. They recognized the potential of NbS^{WT}, such as the green wall to sustainably to reduce water consumption and provide water-efficient urban greening, which in turn supports the reduction of local extreme heat. The participants mapped several environmental and human factors of overall urban challenges in Girona (in black) as well as the role of urban green and main institutional drivers of urban greening (in green). Figure 6 below showcases the group model created in the local co-creation workshop.

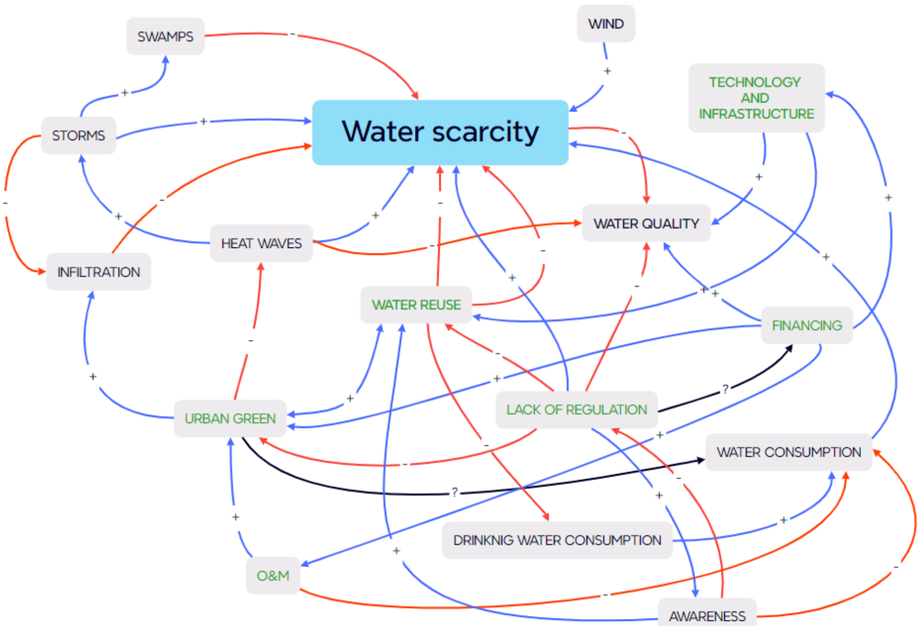


Figure 10. Group model showing the system of challenges and framework conditions in the context of urban greening for climate adaptation in Girona, co-developed by local and regional actors

The Solution

Urban greening and water reuse were identified as the solution to simultaneously combat two main environmental and societal challenges the city of Girona is facing, namely water scarcity and heat waves.

Lack of regulation was raised by the workshop participants as a main barrier of widely adopting NbS^{WT} for water reuse and thus in turn hindering the amelioration of Girona's main challenge of water scarcity. Awareness was identified as a factor that can promote conducive regulation (in the graph shown as reducing lack of regulation). Awareness can also reduce water consumption and promote water reuse. The green wall will be installed at a public school, and it is planned to be used as a demonstration for educational and awareness raising activities. This way, the green wall can significantly contribute to improved awareness for the climate adaptation services of urban greening and the feasibility and safety of decentralized water reuse, and thus target a lever of several factors that can alleviate water scarcity.

To ensure the success and sustainability of the green wall, the participants highlighted the importance of identifying the actor responsible for carrying out the maintenance and ensuring that a specified protocol and routine is followed.

Economic dimensions

The green wall for greywater treatment and reuse simultaneously provides a secondary water source and local ambient cooling effects. Attached vertically to the façade of a building, it does not require horizontal ground space. This makes it highly suitable for dense urban areas.

The main beneficiary groups defined by the local partners of the planned green wall installation include students at the public school, the city council, ICRA, neighbors of the site, the local educational community. Table 11 below allocates local actors to the services to be provided by the green wall.

Table 9 summarizes the advantages and disadvantages of the green wall for greywater reuse compared to alternative solutions for water reuse and heat mitigation:

Table 9. Advantages and disadvantages of the green wall for greywater treatment compared to alternative water reuse and heat mitigation solutions

Compared to	Costs of no action	Mechanical and chemical greywater treatment for reuse	Conventional green walls irrigated with drinking water	Other NbS^{WT} for greywater treatment and reuse
Advantages of the green wall for greywater treatment	• Local ambient cooling from evapotranspiration and associated social and public health impacts • Water reuse: Irrigation of urban green infrastructure with secondary water source (greywater), primary water resources are not compromised, effluent can be used for irrigation of other green spaces and other non-potable uses • Regenerative psychological effect of intensive vegetation	• Regenerative and cooling effects of intensive urban greening • Biodiversity gains (with the appropriate design)	• Competing water use with other municipal water demands, exacerbate water scarcity	• Near-zero net land required, no land opportunity costs • Can be installed in dense urban areas and provides ambient cooling benefits to the surrounding space
Disadvantages of the green wall for greywater treatment	• Stress and limited use of public space during heat waves • Public health: Costs related to adverse effects of extreme heat • Loss of secondary water resources	• More expensive, requires suitable façade	• More expensive, requires more specialized suppliers	• More expensive (if low-cost land is available for other solutions) • Less robust, more maintenance • Energy consuming

Commercial dimensions

There are suppliers available to meet the defined needs and envisioned levels of service. ICRA (*WetWall®*) and alchemia-nova GmbH (*GRETA®*) have developed suitable green wall systems that can be installed at the school and further locations. ICRA is based in Girona and is able and willing to undertake required installation and maintenance activities as planned by the procuring authority.

The following operational, financial, technical, and environmental risks and mitigation measures were identified by the participants of the local co-creation workshop, see table 10 below. The allocation of financial and operational responsibilities was beyond the scope of the workshop and are to be defined.

Table 10. Risks and mitigation measures identified by local partners of the green wall project at a public school in Girona

Type of risk	Risk	Mitigation/adaptation measure
Operational	Lack of wastewater (greywater) production and therefore lack of water supply	Storage and recirculation of the treated effluent, may supplement with rainwater
	Vandalism	
	Inadequate maintenance (particularly while the school is closed for summer holidays in August)	Plan for daily maintenance (routine check) even during school holidays
	Lack of acceptance	
	Lack of communication/coordination	Provide maintenance protocol and guide
	Demotivation	Continuation and pressure from the students and schools
Financial	Overestimating or underestimating construction costs	
	Inflation	
	Strong dependence on political backing. A change in local government may lead to a lack of support, which may lead to budget cuts.	Continued effort to acquire third-party funding (national, EU, philanthropy) to co-fund larger maintenance costs beyond routine checks and works
Technical	Filter/plant failures	
	Lack of stock of materials	
	Water quality lower than expected	Reduce the water discharge/flow to achieve better quality
	Infiltration/loss	
Environmental	Allergies	
	Pathogens	
	Storms/wind	
	Pests	Diversify types of plants to increase system resilience to pests

Financial and Management dimensions

As a basis to further refine the long-term allocation of responsibilities, the main services according to the collaborative mapping of the system (see system model chart above) are listed along the respective local actors with an institutional interest or responsibility to provide these services. Table 11 provides an overview of the key services, actors with jobs, pains, and gains related to these services, and their roles in the green wall project.

Table 11. Overview of main services, related actors and their roles in the collaborative green wall project in Girona

Services (values)	Actors with interest or responsibility for this service	Roles in the collaborative green wall project
Increased water availability through greywater reuse	• Girona City Council: Climate Action department	• Project sponsor, commissioner/ tender for construction
Ambient cooling	• Girona City Council: Climate Action and Urbanism departments	• Project sponsor, commissioner/ tender for construction
Citizen awareness and education (water reuse, NbS, urban farming)	• Girona City Council: Education department	• Provides installation site (in kind contribution) • Supports education programme
	• Escola Àgora (public school hosting the green wall)	• Hosts installation • Conducts routine checks and maintenance (in kind contribution)
	• University of Girona • ICRA	• Facilitation of multi-actor engagement and partnership • Organization of knowledge transfer open days
Development of sustainable technical solutions (piloting, monitoring, and assessment)	• ICRA	• Supplier, patent holder • Conducts monitoring

Table 12 provides an overview of the roles of the actors involved in the long-term green wall project by stage of the project: planning and installation, and O&M.

Table 12. Implementation arrangement for the installation and long-term O&M of the green wall project in Girona

Project stage	Main activities	Funding providers and commissioners	Agents
Planning and installation	• Planning, technical design and production of the green wall • Tender for the works • Technical site preparation for installation (greywater separation, holding structure) • Construction management and steering • Installation of the green wall	• Girona City Council (construction, installation) • European Commission (personnel costs and monitoring costs paid by the Horizon 2020 MULTISOURCE project)	• ICRA (supplier, supervision) • Producer of green wall (supplier/contractor) • Construction company (contractor)
O&M	• Maintenance (routine, troubleshooting of technical failures) • Urban farming • Monitoring of water quality • Educational programme	• Girona City Council (depends on continued political support) • Escola Àgora (in kind) • ICRA (in kind) • Urban gardeners/ local citizens (in kind)	• School management (daily routine checks, urban farming) • ICRA (bi-weekly checks, water quality monitoring, specialized maintenance) • Urban gardeners (urban farming)

4.4 Greater Lyon - Treatment wetlands for wastewater treatment in small communities

Sources of information

This section describes the insights for a public-private business case for treatment wetlands for wastewater treatment in small communities.

Sources of information integrated here include:

- Expertise and experience of the pilot leader (INRAE) for the Rhizosph'air treatment wetland for raw domestic wastewater
- Interactive workshop with members of the MULTISOURCE consortium - a multisectoral group including representatives from INRAE and the Greater Lyon regional public authority

Strategic dimensions

Figure 4 below shows the group model developed in the workshop conducted with MULTISOURCE partners. A representative of the metropolitan city of Lyon (Grande Lyon) participated in the collaborative modelling of the strategic case for this type of NbS^{WT}.

Poor water quality was highlighted as a key problem, with the need to improve water treatment of water discharged to the river. Due to urban sprawl, wastewater volumes are increasing, requesting new wastewater plants to be constructed. Treatment wetlands provide additional treatment capacity and thereby directly help to improve water quality. Treatment wetlands are a low-energy-consuming solution and thus reduce the operational energy required for wastewater treatment. They can also contribute to biodiversity. As an investment into public water infrastructure, it may contribute to an increase in water tariff, which may balance out by providing wastewater treatment at comparatively low costs compared to conventional mechanical grey systems. By providing environmental quality (water quality and biodiversity), this solution may increase public satisfaction.

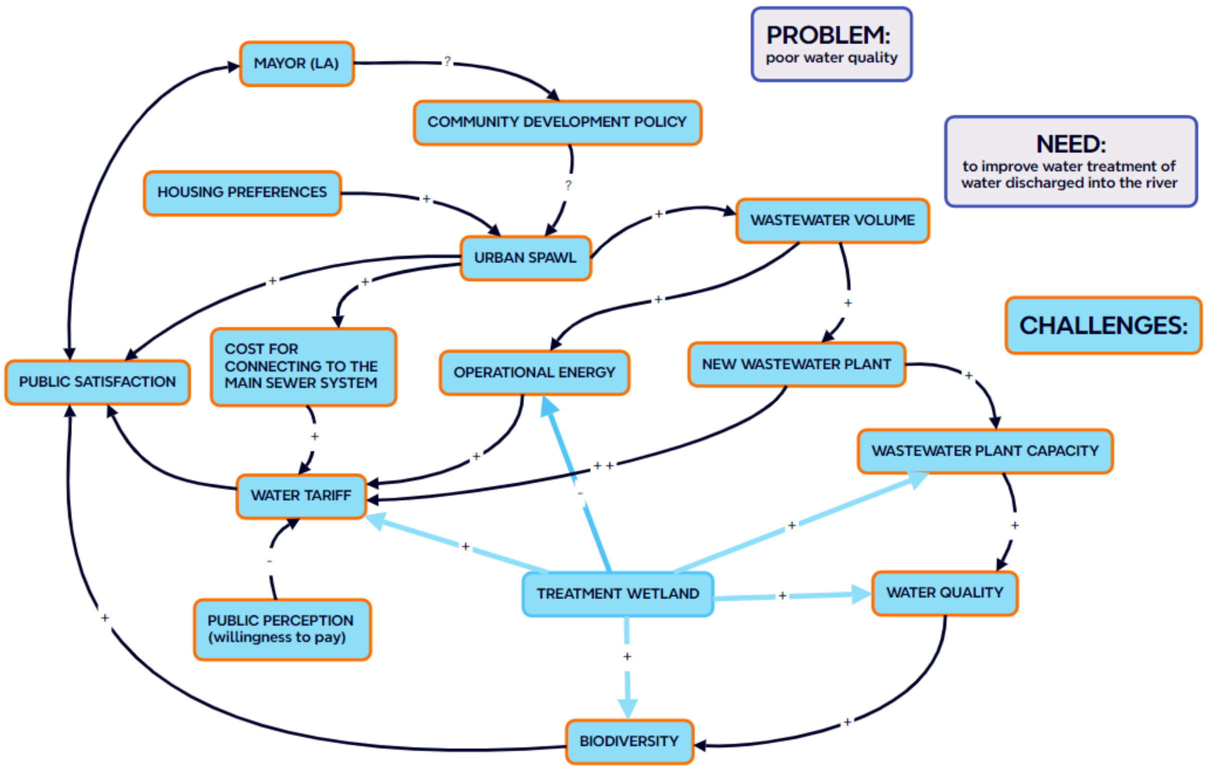


Figure 11. Group model showing the system of challenges, opportunities, and framework conditions in the context of Greater Lyon

Key services:

- The Rhizosph'air system piloted in MULTISOURCE is ideally suited for peri-urban areas or small communities with sufficient available space (requires just below 1m^2 per person) and represents a soft impact, low-cost, and low-maintenance technical solution. It can be applied to communities with combined sewers.
- Biodiverse habitat functions can be designed into the system, with additional costs and no additional treatment benefits.
- Treated wastewater could be reused for agricultural irrigation.

Economic dimensions

The costs of no action result in increased pollution. Treatment wetlands can be installed to increase the service capacity of existing municipal wastewater treatment plants in growing communities. They can also be installed, where wastewater is currently discharged without treatment.

Advantages of the Rhizosph'air system over alternative municipal wastewater treatment solutions are listed in table 13 below:

Table 13. Advantages and disadvantages of the Rhizosph'air system compared to alternative solutions

Alternatives	Advantages of Rhizosph'air	Disadvantages of Rhizosph'air
Conventional treatment wetlands	● Higher spatial efficiency, smaller spatial footprint ● Treats solids as well, no primary settling tank needed ● Can handle 3-5x the dry water flow - can withstand heavy rain events ● Automation enables decentralization	● Energy consumption, access to electricity
Grey (biological, mechanical, chemical) wastewater treatment technologies	● Low-cost ● Low-maintenance, very robust (at least 30 years before major maintenance is needed) ● Ecosystem services, biodiversity benefits	● Larger spatial footprint, land opportunity costs, limited scale

Commercial dimensions

There is a supplier who can provide the technology according to the defined needs.

Financial dimensions

Possible revenue streams and project funding are described in table 14 below.

Table 14. Services, revenue streams, and funding sources

Services	Revenue streams	Project funding
● Wastewater treatment	● Water tariffs ● Taxes, transfers	● Water/wastewater utility ● Municipality
● Biodiversity/renaturation	● Taxes, transfers	● Biodiversity/renaturation programme (environmental policy, municipal authority responsible for urban environment)
● Reclaimed water for agricultural irrigation	● Farming products	● Water utility ● Agribusiness if agricultural irrigation

Management dimensions

Possible governance and procurement strategies:

- Public procurement contracts
- Public-private partnership
- Collective public or public-private investment scheme

Table 15 provides an overview of the roles of the actors involved in a long-term treatment wetland project by project stage, i.e. planning and installation and O&M. Three types of roles are differentiated: (i) Funding providers and commissioners of the work, (ii) Actors conducting the work (agents), and (iii) Actors in charge of monitoring the level of service provision.

Table 15. Possible implementation arrangement for treatment wetlands for wastewater treatment

Project stage	Funding providers and commissioners	Agents	Monitoring
Planning and installation	● Local public authority and/or regional water authority	● Treatment wetland engineering company ● Water/wastewater utility	● Permitting agency (local authority in charge of sewer or stormwater management) ● Water/wastewater utility
O&M	● Water/wastewater utility ● and/or local public authority and/or regional water authority	● Startup-phase (removal or invasive plants): green space manager/TW engineering company ● Routine checks: water/wastewater utility ● Major/specialised/troubleshooting: Treatment wetland engineering company	● Water/wastewater utility

4.5 Phytoparking^{TM} technology for wastewater treatment and reuse

Sources of information

- Expertise and experience of the pilot leader (RIETLAND) about the Phytoparking^{TM} system
- Input to, and validation of the conclusions for business models by the pilot leader

Strategic and economic dimensions

Main services: Decentralized wastewater treatment, storage and reuse

Main innovation: Compact (<1m^2/PE) and zero-land requirement, can be retrofitted in parking lots - provides additional use for parking lots

As a small-scale system for wastewater treatment and water reuse, the Phytoparking^{TM} technology is suitable for decentralized management scenarios, for treatment of different types of wastewater, for further reuse or infiltration. Phytoparking^{TM} has been applied to treat greywater, blackwater, and mixed domestic wastewater. The MULTISOURCE project pilot is set in a campsite that is **not connected to the sewer system or piped water supply**. The system could be applied to any public or private multifunctional area, such as parking lots or squares adjacent to infrastructures producing and consuming water.

A structure with grass tiles and permeable paving on top of the Phytoparking^{TM} treatment plant allow the simultaneous use of the green space, in contrast to other treatment wetlands, while also treating **different types of urban wastewater**. This allows multifunctional use of space and makes the system **particularly suitable in**

- **dense built areas, where land use opportunity costs are high,**
- **where no net vacant area is available,**
- **where excavation is prevented on greenfield area**, e.g., in protected historical heritage sites in the case of the MULTISOURCE pilot in T' Hof Bellewaerde, where excavation was only permitted in existing buildings. The depth of a Phytoparking^{TM} is 130cm.

In this pilot, the water utility has placed a treatment train that upgrades rainwater to drinking water. After the drinking water is used for showering, washing, or cooking, the greywater is treated in Phytoparking^{TM} *grey*. The treated water is reused for toilet flushing and treated afterwards in Phytoparking^{TM} *black*. Rainwater is treated with a microfilter, nanofiltration, and UV disinfection to drinking water quality. During high demand and low precipitation in summertime, the effluent of Phytoparking^{TM} *grey* is sent to the drinking water treatment cycle. Phytoparking^{TM} effluent can also be used in agricultural irrigation. An info board at the campsite describes the system and its functions. The integrated hybrid treatment system can be applied in **water scarce contexts** benefitting from partial wastewater reuse.

A key advantage of reusing treated wastewater over rainwater is that this requires less storage as wastewater is continuously produced. The rainwater can in this case be infiltrated in the soil to replenish the groundwater table and should not be used for flushing toilets.

Advantages of the Phytoparking^{TM} system over alternative wastewater and reuse solutions are listed in table 16 below:

Table 16. Advantages and disadvantages of the Phytoparking^{TM} system compared to alternative solutions

Alternatives	Advantages of Phytoparking^{TM}	Disadvantages of Phytoparking^{TM}
On-site treatment wetlands	• Multifunctional use of surface • Zero net land required • Reuse of treated wastewater • Low energy consumption	• Limited biodiversity gains • Decentralized systems have to meet lower standards than centralized systems
On-site mechanical/ chemical treatment technologies	• Less excavation, less construction works, less permits	• May be more expensive and labor intensive (water samples checked 2x per week)
Connection to central sewer/ wastewater management systems	• Significant cost savings by avoiding connection to centralized sewer system • On-site waste water treatment for reuse • Water reuse can be marketed as green practices (example of MULTISOURCE campsite pilot)	• Decentralized management and control (monitoring costs)

Commercial dimensions

The Flemish private commercial company RIETLAND has provided the Phytoparking^{TM} technology and similar systems to custom cases. Six Phytoparking^{TM} systems have been installed and are operational so far, including retrofit cases and new building constructions, privately funded cases and grant funded cases. RIETLAND implements projects combining Phytoparking^{TM} with infiltration in partnership with the French private commercial company ECOBIRD.

Financial dimensions

Table 17 below outlines possible revenue streams and project funding for an implementation on private/semi-private property and for a public/utility project on public property.

Table 17. Possible revenue streams and project funding

	Revenue streams	Project funding
Private/ semi-private property	• Camp site guests (innovative green technology supports marketing) • Real estate sale or rent • Facility management fees • Cost savings for drinking water by reusing treated wastewater on site. Some private organizations are obliged to treat their water, or else they pay fines. This case enables the calculation of a very predictable return on investment. • Parking lot fees • Subsidies	• Real estate development project for planning and installation • Property owners and tenants • Grant or subsidy
Public/utility project on public property	• Water tariffs, taxes, transfers	• Larger stormwater management or infrastructure improvement project

Management dimensions

Possible governance and procurement strategies:

- Privately driven water stewardship investments
- Public-private partnership, for example, where the real estate developer takes on the role of financing and managing the installation and maintenance, and the local public authority contributes by subsidizing or sharing some of the costs associated with the project.
- Public procurement or public-private partnership for public space and service

Architects and engineering firms have included the Phytoparking™ system in their projects. Table 18 provides an overview of suitable potential funding providers, project commissioners, agents, and actors in charge of monitoring the level of service provision.

Table 18. Possible implementation arrangement for the Phytoparking™ system

Project stage	Funding providers and commissioners	Agents	Monitoring
Planning and installation	• Real estate owner/developer • Urban wastewater manager (water utility or local public authority), as part of an urban development project	• Supplier (RIETLAND)	
O&M	• Property owner or manager • Urban wastewater utility	• Routine O&M: Facility manager • Specialized O&M: RIETLAND by service contract	• Property owner • Specialized monitoring by supplier

4.6 Green roofs for rainwater retention or storage for use

Sources of information

- Expertise and experience of the pilot leader (UFZ) for the green roof for rainwater treatment
- Stakeholder interviews
- Interactive workshop with members of the MULTISOURCE consortium - a multisectoral group including the pilot leader
- Validation of the conclusions for business models by the pilot leader

The following information serves as a strategic hypothesis, which can provide an understanding of the strategic fit of this type of technical solution when analyzing a specific contextual set of challenges and solutions in a given city or region.

Strategic dimensions

Figure 5 below shows the group model developed in the group exercise during the workshop with the MULTISOURCE consortium. The group focused on tracing back the drivers and barriers shaping the demand for green roofs for rainwater retention and treatment, with the context of Leipzig (pilot location) in mind, but the factors named are largely transferable to other European cities facing similar climate and urban development challenges.

Factors driving and affecting the implementation of green roofs: The group defined four main considerations that determine the business model for treatment green roofs:

- The problem,
- Policy areas (macro level trends),
- Strategies defining the enabling environment, and
- Economic aspects.

In particular, the definition of the problem as well as the macro-level trends and policy priorities (summarised as “policies”) shape the strategic dimension of the business model for treatment green roofs. The problem is centered on insufficient stormwater management and flood risk, which is leading to pollution and damage to transportation infrastructure, basements, ground-level commercial spaces, etc. Current urbanisation practices are contributing to flood risks and thereby pollution, possibly from CSOs or urban surface runoff. Macro-level trends adversely impacting flooding include renovation subsidies and regulations, climate change effects, urbanisation with sealing of surfaces, and traffic as a contributor to adversely affecting surface runoff water quality.

Renovation subsidies and regulations could alternatively provide avenues of steering renovation practices towards the implementation of bioretention systems, such as green roofs. MULTISOURCE partner UFZ is working with the City of Leipzig on the city’s Green Roof Strategy and public engagement and knowledge sharing activities (e.g. guided tours, Green Roof Academy).

Two main services of green roofs for urban water management were highlighted: **Rainwater retention** and **rainwater capture for reuse**:

- Rainwater retention delays and reduces the volume of rainwater discharged to the sewer system during a heavy rain event and thus reduces the pressure on the sewer system capacity, reducing flooding and potential consequential pollution.
- Rising temperatures and the urban heat island effect are driving urban greening as well as cooling solutions using water directly. This increases freshwater demand amid increasingly erratic precipitation patterns. Intensive treatment green roofs can store rainwater for various urban uses.
- These two services stand in direct trade-off to each other, as the green roof must be drained to be able to provide a buffer during heavy rain events.

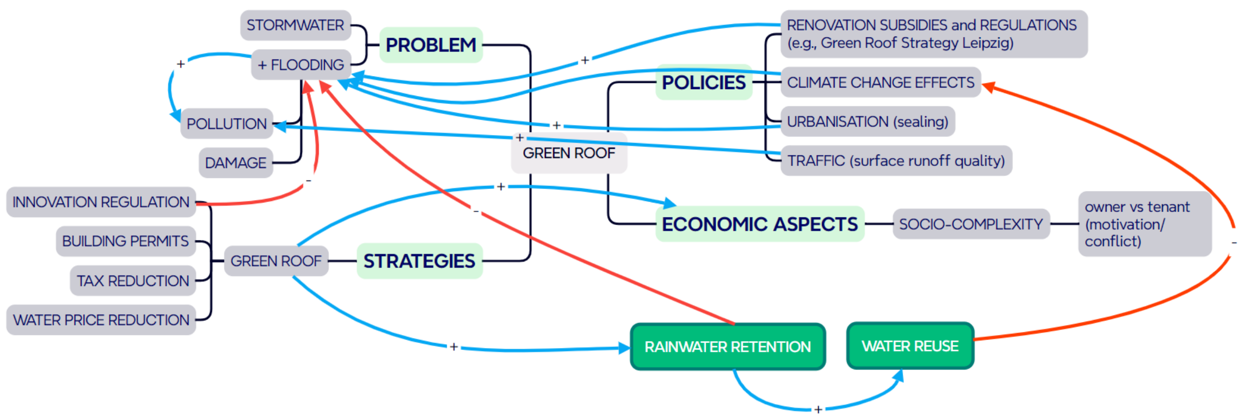


Figure 12. Group model showing the system of challenges, opportunities, and framework conditions in the context of green roofs in Leipzig

Based on the knowledge and experience of the pilot partner UFZ in monitoring and developing the green roof technology, as well as engagement with stakeholders, **several key design considerations were identified:**

The green roof for retention and/or treatment can take several forms, e.g., as a carport (retention green roof with a cistern below), a retention system with a simple grass layer, or a green roof constructed wetland. It can include a potential synergy with solar PV. Microclimate effects depend on the building height and accessibility, i.e. whether it is used as an accessible green space. As a certain volume is required for effective stormwater retention, only intensive green roofs fall into this category.

Depending on their service (e.g., biodiversity, reducing stormwater flow - cistern needs to be empty), green roofs need to be irrigated. Effective cooling of the PV panels through evapotranspiration may require irrigation. Excess water from rainfall is drained in the current technical configuration, but it could be additionally stored and used for on-site irrigation of greening, including the green roof itself.

A green roof for rainwater management economically only makes sense where a new roof is built.

Economic dimensions

The costs of no action result in increased pollution and potential damage from floods. Green roofs can be included as one type of solution in a mix of NbS[WT] or hybrid green-grey solutions. Advantages of the green roof over alternative stormwater management solutions are listed in table 19.

Table 19. Advantages and disadvantages of the retention and treatment green roof compared to alternative solutions

Alternatives	Advantages of green roofs	Disadvantages of green roofs
Ground-level bioretention systems	• No land use opportunity costs	• Less or no public accessibility - limits co-benefits of urban greening • Less cooling effect
Infiltration shafts	• No land use opportunity costs • Potential biodiversity benefits • Regenerative effects of greening if accessible green roof	• Maintenance of greening
Underground detention chambers or tunnels	• No excavation → savings of excavation and transportation costs and carbon emissions • Savings of concrete material and carbon footprint	• Higher transaction costs due to regulatory uncertainty, asset value accounting uncertainty and/or reliance on other urban actors, lack of established procurement and permitting processes • Limited level of service compared to the large volumes possible with underground chambers and tunnels • Different (new) maintenance tasks than purely grey infrastructure system
Synergy with solar PV	• Efficiency gains for power generation	• Possibly irrigation costs (pumping, water/additional rainwater storage)

Commercial dimensions

Companies have bought technologies from UFZ for implementation, which demonstrates private sector interest in applying and marketing this technology.

Financial dimensions

Table 20 below lists below lists the services provided by the green roof and corresponding possible revenue streams and funding sources.

Table 20. Possible types of revenue streams and funding sources

Revenue streams	Project funding
• Real estate sales revenue • Facility management fees • PV combination: feed-in-tariff, electricity savings	• Real estate development project for planning and installation • Property owners and tenants
• Water tariffs, taxes, transfers	• Larger stormwater management or infrastructure improvement project

Management dimensions

Possible governance and procurement strategies:

- Privately driven water stewardship investments
- Public-private partnership, for example, where the real estate developer takes on the role of financing and managing the green roof installation and maintenance, and the local public authority contributes by subsidizing or sharing some of the costs associated with the project.

Real estate developers can be motivated to plan and budget for the installation of intensive green roofs for rainwater management, if they are required to comply with precipitation or runoff discharge limits from the developed property, or the additional costs are subsidized by public actors, such as the municipality, sewer/wastewater managers, or co-funded by philanthropic actors.

Table 21 provides an overview of funding providers and commissioners, agents, and actors in charge of monitoring the level of service provision.

Table 21. Possible implementation arrangement

Project stage	Funding providers and commissioners	Agents	Monitoring
Planning and installation	• Real estate developer • Urban sewer manager (water utility or local public authority), as part of a larger stormwater management or infrastructure improvement project	• Supplier, green roof engineering company	• Permitting agency (local authority in charge of sewer or stormwater management and issuing permits for sewer connection) • Water utility in charge of sewer or stormwater management
O&M	• Real estate manager (e.g., the facility/property management company) • Urban sewer manager	• Facility manager	• Urban sewer manager

4.7 Treatment wetlands for wastewater treatment in Montana, USA

Sources of information

- Expertise and experience of the pilot leader (Montana State University, MSU)

Strategic and economic dimensions

Main services: Treatment of high-strength wastewater with increased nutrient removal

Main Innovation: Seasonally operational vertical flow treatment wetland with recirculation and partial saturation for increased nutrient removal from high-strength wastewater

The treatment wetland installed at the Bridger Bowl Ski Resort near Bozeman, Montana is a 2-stage vertical flow wetland that features a top cell, wherein the recirculating sand filters were replaced with native plants for enhanced nitrogen removal, and a bottom cell that facilitates nitrification (Bridger Bowl, n.d.). The wetland of 95 m^2 was installed at a cost material cost of €45,600 and treats circa 10,000 gallons of wastewater (from toilets and kitchen, no showers etc.) per day during the winter ski season.

Montana is a very rural region made up of a litter of smaller municipalities with an average of circa 10,000 inhabitants. The climate is cold and arid which can drive wastewater input temperatures down to as low as 3°C. The resultant treated effluent, which is qualitatively better than in other systems, is then not for direct reuse, but rather for direct groundwater recharge in this water scarce region.

The ski resort and treatment wetland (partially funded by the Montana Water Quality Agency, DEQ) is owned by a non-profit organization which has received an award from the Skiing Association for this innovation. The university (MSU, MULTISOURCE partner and pilot leader) are permitted to use the pilot for research purposes.

The wastewater treatment plant at Bozeman (Montana) has started with the construction of a French treatment wetland featuring the typical activated sludge wastewater treatment plant, with the backing of two public funders (Montana Department of Environmental Quality) and a substantial in-kind contribution by the university (MSU), which, if implemented successfully could lead the way for many more permits and even a new infrastructure bill.

Table 22. Advantages and disadvantages of the treatment wetland system compared to alternative solutions

Alternatives	Advantages of Treatment Wetland	Disadvantages of Treatment Wetland
Sewage lagoon wastewater treatment system	● Higher resultant water quality of discharge	● Land surface area requirement
Grey (biological, mechanical, chemical) wastewater treatment technologies	● Low-cost ● Low-maintenance, very robust ● Ecosystem services, biodiversity benefits	● Larger spatial footprint, land opportunity costs

Sewage lagoons are common in Montana, and these systems could be retrofitted or replaced.

Commercial dimensions

With installation costs of between circa €45,000 and €100,000 respectively and annual maintenance costs estimated under €1,000, the two-stage vertical treatment wetland offers a viable alternative to current systems and delivers qualitatively higher levels of water safety for direct recharge of ground water reserves. The City of Bozeman has also shown great interest in these MULTISOURCE tools and is eager to learn from other project pilots in order to integrate all concepts into their urban development.

Financial dimensions

Table 23. Possible revenue streams and project funding

	Revenue streams	Project funding
Private entities	● Real estate sale or rent ● Subsidies ● Utilities savings ● Compliance savings	● Real estate development project for planning and installation ● Property owners and tenants ● Grant or subsidy
Public/utility project on public property	● Water tariffs, taxes, transfers	● Larger wastewater management or infrastructure improvement project

Management dimensions

Possible governance and procurement strategies:

- Public-private partnership
- Collective public or public-private investment scheme
- Private business model or privately driven water stewardship investment

Table 24 lists possible implementation arrangements of suitable potential funding providers, project commissioners, agents, and actors in charge of monitoring the level of service provision.

Table 24. Possible implementation arrangement

Project stage	Funding providers and commissioners	Agents	Monitoring
Planning and installation	• Local public authority and/or regional water authority	• Treatment wetland engineering company • Wastewater manager (wastewater treatment plant/ water utility)	• Permitting agency (local authority in charge of sewer or stormwater management) • Wastewater manager
O&M	• Wastewater manager • and/or local public authority and/or regional water authority	• Startup-phase: TW engineer (engineering company) • Routine checks: wastewater manager • Major/specialized maintenance (troubleshooting): Treatment wetland engineering company	• Wastewater manager

5. HIGHLIGHTS AND FURTHER RESEARCH

This section provides an overview of highlights among the insights gained from the stakeholder processes for the development and establishment of business cases for NbS^{WT}. It illustrates the progress made in establishing NbS^{WT} as a viable solution for urban water management and outlines critical areas where further research could improve understanding, acceptance, and implementation of these systems.

Highlights

- **Examples of successful business cases are available** in the geographic urban context of the MULTISOURCE pilots, local and regional actors have largely been involved in these flagship reference projects and are aware of risks and possible mitigation solutions. These cases serve as proof of concept that encourage adoption on a larger scale.
- Relevant decision-makers are interested to invest in NbS^{WT}. The **current challenge is to establish procurement practices** that mainstream NbS^{WT} into public administration and urban development, as one of the default options for water infrastructure.
- Each MULTISOURCE pilot technology caters to a different set of urban needs and contextual requirements. Stakeholder feedback has confirmed that **these NbS^{WT} technologies are well-suited to address existing pain points in cities**.
- The spatial footprint of NbS is a prominent barrier to their wider adoption, mainly due to institutional and regulatory uncertainties of land use and ownership, as well as land opportunity costs. The MULTISOURCE technologies and stakeholder processes yielded several business model strategies to address these land use constraints:
  - **i. Technologies that minimize land use:** Green roofs and green walls do not consume ground surface area. Instead, they are integrated into building roofs or façades and therefore do not stand in conflict with other uses of space.
  - **ii. Collaborative approaches to land use:** Concession of land by public actors (e.g., municipalities, regional public entities) for a set period of time, or the retrofitting of hydraulic services into existing green spaces are tested strategies to access land for bioretention systems.
  - **iii.** Where necessary, the **purchase of private land** has been pursued to accommodate NbS^{WT} infrastructure.
- Multifunctional NbS design is hampered in practice by the uncertainty of the effectiveness (and in turn the cost-efficiency) of NbS compared to grey solutions, as well as **uncertainty of the specific costs of the intended multiple functions and** thus the uncertainty of **how to split costs among actors** responsible for these multiple different goals, functions, or services.
- **Targeted and evidence-based communication strategies** are essential to increase the understanding and acceptance of NbS^{WT} services. One-size-fits-all dissemination of information leads to an overload of the targeted actor groups and often results in key messages not reaching the target group. Although information is available and spread, the enabling actors are not equipped with the information they need to engage in NbS^{WT} projects. For example, decision-makers responsible for flood mitigation or sewer infrastructure management require information about the specific hydraulic services of NbS^{WT}. Often, information about NbS includes abstract information about many possible co-benefits, which distracts from the relevance for a specific actor's scope of work and decision-making. Conversely, there is a lack of specialized targeted planning and design information.

Further Research

- There is a need for more detailed reporting of **reference cases for cost-benefit analyses of NbS^{WT} and grey alternative solutions**. A set of references for diverse context-specific cases could provide useful orientation for decision-makers.
- Reference cases quantifying the **additional costs incurred by designing specific services into urban greening**, or the additional costs of designing water services into common practice urban green spaces, could shed light on the cost split among funding partners in a collaborative NbS project. In other words, urban green spaces are usually designed to provide regenerative and aesthetic benefits and their adaptation to provide increased hydraulic and treatment functions results in additional costs. This margin necessary to provide water services is more easily justified to be paid by water infrastructure budgets. Similarly, the additional costs incurred to design for other services of NbS, such as heat mitigation or biodiversity, could be quantified to enable initiators of NbS projects to facilitate collaborative funding across actors responsible for different urban policy areas or promoting different interests.
- **Effective communication of services NbS^{WT} and tailored technical guidelines:** Further investigation of actor-specific information needs is required to tailor key messages and to develop tailored technical planning and design guidelines, which provide practical information that matches decision-making criteria of enabling actors, from regional planners and funding providers to private real estate developers.
- **Integrating NbS^{WT} into established procurement practices and establishing collaborative procurement practices for NbS^{WT}**: This involves understanding the diverse procurement practices across various sectors of public administration and service provision. Based on this understanding, guiding resources could be developed to assist enabling actors to navigate the diverse procurement landscapes to facilitate the inclusion of NbS^{WT} in public planning and operations. These resources could include procurement blueprints, tender blueprints, and procurement best practices. Projects focused on piloting innovative procurement could provide a big push towards subsidizing additional transaction costs of adopting novel procurement processes and familiarizing actors with these practices.

PARTNERS INVOLVED IN THE WORK

The main conceptualization, development of the methodology, analytical work, and drafting of the deliverable was conducted by alchemia-nova GmbH (ALCN), as the task leader.

The following partners collaborated in conceptualizing, organizing, conducting, documenting, and analyzing the co-creation workshops: CMM, IRIDRA, OSLO, NIVA, AU, GIRONA, and ICRA.

The pilot leaders (IRIDRA, OSLO and NIVA, UFZ, RIETLAND, INRAE, ICRA, MSU) provided information and validation of results.

LIST OF REFERENCES

Altamirano, M.A., de Rijke, H., Basco Carrera, L., Arellano Jaimerena, B. (2021). Handbook for the Implementation of Nature-based Solutions for Water Security: guidelines for designing an implementation and financing arrangement, DELIVERABLE 7.3: EU Horizon 2020 NAIAD Project, Grant Agreement N°730497 Dissemination.

Bridger Bowl. (n.d.). Sustainability—Bridger Bowl Ski Area. Bridger Bowl. Retrieved April 30, 2024, from https://bridgerbowl.com/whoweare/sustainability

Boschi, N. (2023). Urban climate forecasts: From risk to resilience. Milan Innovation District's key design aspects for buildings and infrastructures. *Front. Clim.* 5:1130365.

European Commission. (n.d.). Nature-based solutions. Accessed 14.5.2023, at https://ec.europa.eu/info/research-and-innovation/research-area/ environment/nature-based-solutions_en

European Union Regulation (EU) 2020/741 of the European Parliament and of the Council of 25 May 2020 on minimum requirements for water reuse.

Karlstrøm, S. (2022, November 17). SV: Cost data on multisource pilot project [Personal communication].

ICRA. (2022). MEMÒRIA VALORADA DE MEMÒRIA VALORADA PER LA INSTALLACIÓ D'UN JARDÍ VERTICAL PEL TRACTAMENT D'AIGÜES GRISES A LA SEU D'ICRA A GIRONA, Institut Català de Recerca & de l'Aigua (ICRA).

IRIDRA. (n.d.). IRIDRA. MULTISOURCE. Retrieved October 18, 2022, from http://www.iridra.eu/en/ricerca-e-sviluppo-en/progetti-eu-en/multisource-en.html

Martens, M. (2022, August 23). Re: Requesting cost information on your pilot project [Personal communication].

Mayor, B., Toxopeus, H., McQuaid, S., Croci, E., Lucchitta, B., Reddy, S.E., Egusquiza, A., Altamirano, M.A., Trumbic, T., Tuerk, A., García, G., Feliu, E., Malandrino, C., Schante, J., Jensen, A., López Gunn, E. (2021). State of the Art and Latest Advances in Exploring Business Models for Nature-Based Solutions. *Sustainability* 13, 7413.

MULTISOURCE. (2021). MULTISOURCE, project description.

Optigrün. (2021). DACHBEGRÜNUNG + RETENTION.

Rizzo, A. (2022, September 2). Re: Requesting cost information on your pilot project [Personal communication].

Stein, O. (2022, September 22). RE: Requesting cost information on your pilot project [Personal communication].

Toxopeus, H., Polzin, F. (2021). Reviewing financing barriers and strategies for urban nature-based solutions. *Journal of Environ. Management*. 289, 112371.

Watercircle 't Hof Bellewaerde. (n.d.). How does it work? Watercircle 't Hof Bellewaerde. Retrieved October 13, 2022, from https://rietland.com/bellewaerde/hoewerkthet-en.html

ANNEX 1

The following figures 6, 7, and 8 show the group models created by the participants at the local stakeholder co-creation workshop in Oslo, Norway, in breakout groups 1, 2, and 3, respectively. Table 26 below lists the institutions and roles represented in each group.

Table 26. Participant affiliations and roles or topics of work by breakout group

Group	Represented organization	Participant roles or topic of work in the organization
Group 1	Agency for Urban Environment	• Rivers and aquatic biology • Road maintenance • Road planning
	Water and Sewerage Agency	• Pollution monitoring
	Agency for Planning and Building Services	• Stormwater planning
Group 2	Agency for Urban Environment	• Road planning • Environmental advisor
	Water and Sewerage Agency	• Water and sewerage planning in the city
	Agency for Planning and Building Services	• Stormwater planning
	NIVA	• Water and society research
Group 3	Agency for Urban Environment	• Rivers and water bodies • Road planning
	Water and Sewerage Agency	• Water and sewerage/pollution • Stormwater management
	NIVA	• Water quality research

Figure 13. Group model created by breakout group 1 in Oslo, Norway.

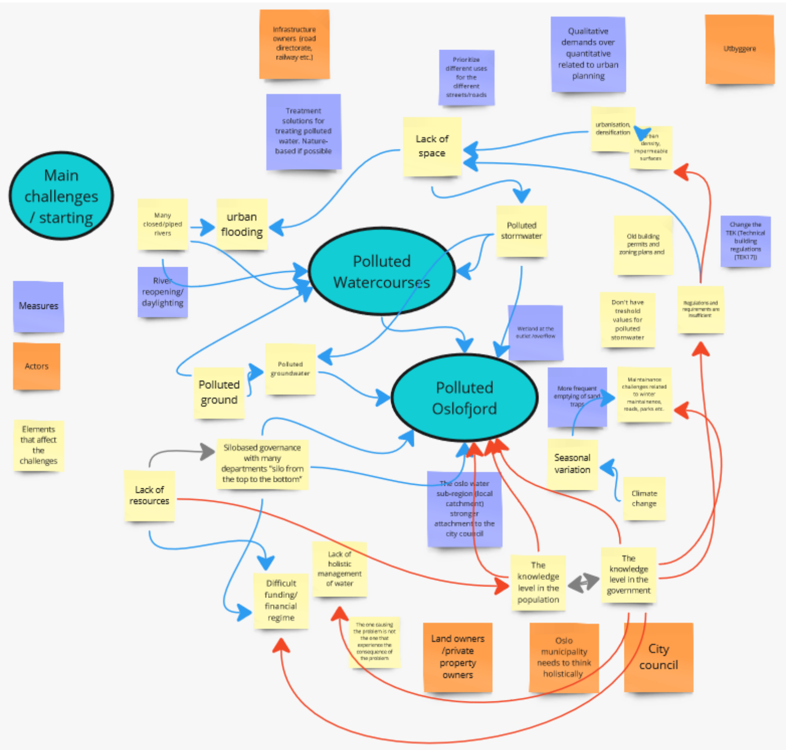


Figure 14. Group model created by breakout group 2 in Oslo, Norway.

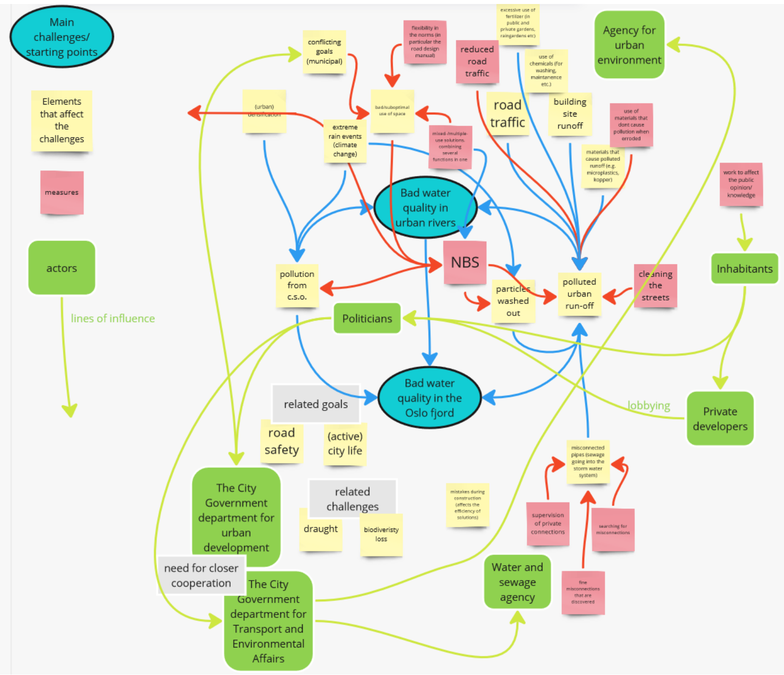
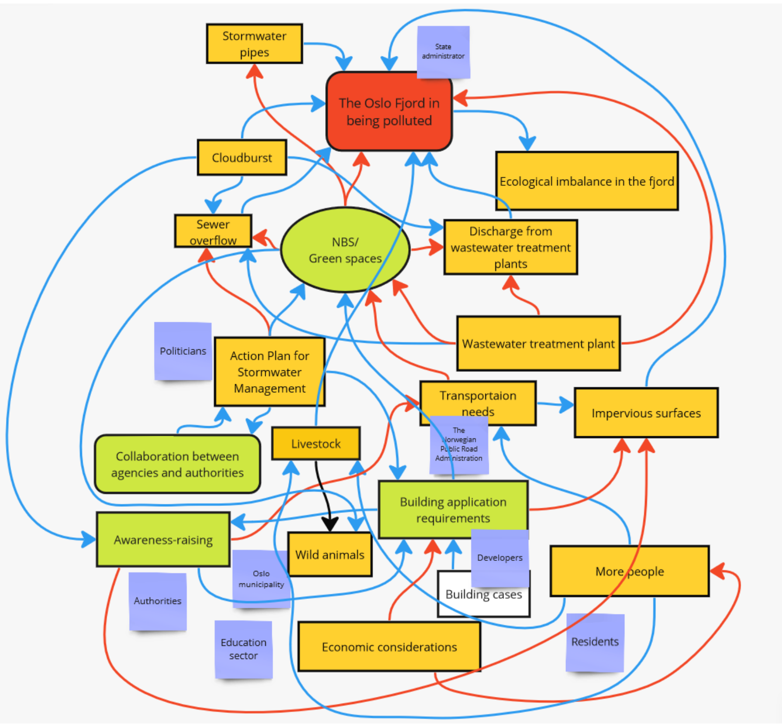


Figure 15. Group model created by breakout group 3 in Oslo, Norway.



LIST OF TABLES

LIST OF FIGURES

The overall goal of MULTISOURCE is to, together with local, national, and international stakeholders, demonstrate a variety of about Enhanced Natural Treatment Solutions (ENTS) treating a wide range of urban waters and to develop innovative tools, methods, and business models that support citywide planning and long-term operations and maintenance of nature-based solutions for water treatment, storage, and reuse in urban areas worldwide. The project includes seven pilots treating a wide range of urban waters. Two individual municipalities (Girona, Spain; Oslo, Norway), two metropolitan municipalities (Lyon, France; Milan, Italy), and international partners in Brazil, Vietnam, and the USA will contribute to each of the main project activities: ENTS pilots, risk assessment, business models, technology selection, and the MULTISOURCE Planning Platform. The use of urban archetypes in the Planning Platform will enable users to quickly classify regions (in both developed or developing countries) suitable for the application of nature-based solutions for water treatment (NBSWT) and compare scenarios both with and without NBSWT.

MULTISOURCE

enhanced natural treatment solutions

This project has received funding from the European Union's Horizon H2020 innovation action programme under grant agreement 101003527.