D1.1 Critical factors in NBS planning, implementation and maintenance

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1. Introduction

Cities are increasingly facing water-related challenges and water cycle disruptions. Urban floods and droughts, heat island effects and water quality deterioration decrease the quality of urban living environments. Climate change and continuing urbanization are increasing the problems. Extreme weather events are becoming more common and their consequences are exacerbated by intensified land use. Environmental misuse is often entwined with social inequality, and vulnerability to problems is highest in certain areas and social groups.

Water-related challenges underline the significance of sustainable urban planning and water management. Conventional urban water management targeted at water provision and draining haven't been able provide required solutions and have often led to the decline of groundwater resource, deterioration of surface waters, drying out of headwaters and related ecosystems. New kinds of technical, operational and behavioral approaches have been sought in nature-based solutions (NBS) that are inspired and supported by nature and provide multiple benefits through locally adapted, resource-efficient and systemic interventions (European Commission 2020).

During the last years, many cities have experimented a variety of NBS in water management and aim to mainstream their use. To be able to upscale the use of NBS, it is crucial to know, which issues has been critical in the process, what has prevented or impeded their use and what has guaranteed the success. The critical factors thus refer to various success factors and barriers in NBS interventions.

The ATENAS project is funded within European Union's Water JPI and the research is carried out by European Regional Centre for Ecohydrology of the Polish Academy of Sciences (ERCE PAS), Finnish Environment Institute (SYKE), FPP Enviro (Poland), and National Research Institute for Agriculture, Food and Environment (INRAE) (France). The project aims to contribute to closing the water cycle gap through securing water cycling and the quality of urban runoff by using NBS, but also increasing the resilience of urban systems to dry periods. The ambition is to increase project's impact through triggering learning process among the water users. For that purpose, the project develops real scale demo-sites in a gradient of urban pressures and urban dynamics, to embrace a range of conditions for future applications.

In the ATENAS project, critical points of NBS application have been analyzed by reviewing ongoing developments in different contexts, using data from research literature, project publications, recent inventories and case study workshops, to create basis for the selection and re-design of NBS. Critical factors have been considered in all phases of planning and implementation process and from technical, ecological, organizational, social and economic aspects. Through the analysis of local context-dependencies, we distinguish critical points for replication and up-scaling of NBS.

In this report, chapter 2 describes data and methods applied in the analysis of critical factors. Chapter 3 briefly summarizes findings from research literature. Chapter 4 presents findings on critical factors made in case study workshops. Chapter 5 includes the identification of critical factors in example cases, first on the city level and secondly in single NBS projects. Conclusions from findings are formulated in chapter 6.

2. Data and methods in the analysis of critical factors

2.1 Review on previous studies and projects

The analysis on critical factors is based on the publications of previous studies and projects. Findings are raised from scientific articles and systematic research reviews. Ongoing Horizon 2020 projects bring new insight into critical factors, and reports published in the projects describe barriers and success factors of NBS. There are several ongoing projects dealing with NBS and water management or social aspects, such as

UNaLab, Grow Green, Urban GreenUP, Connecting Nature, Think Nature, Urbinat and Reconect. Also nationally, NBS implementations have been analyzed and reported.

2.2 Three case areas and contexts

The ATENAS projects involves three case areas and studies. They include:

The City of Vantaa and Helsinki Region (Finland)

The Helsinki Metropolitan Area is the largest urban areas in Finland (Figure 1). The challenges in the area are related to stormwater management, water quality and ecological state of rivers and brooks. The problems are aggravated by climate change, increased soil sealing, runoff from traffic areas polluting brooks, and modified channels of brooks and rivers with decreased ecological values. ATENAS develops tools that will help to analyse the impacts of land use changes, apply green area factor, model surface flows and find acceptable targets for different areas. The project examines the reception and maintenance of recently implemented storm water retention measures, gathers data on the experiences of their benefits, promotes collaborative action for the restoration of rivers and brooks, and analyses opportunities and challenges in mainstreaming NBS. The application of bio-filtration in the treatment of runoff waters is supported by developing ways to include it in street planning practices. Based on existing experiences, the project enhances local participation in NBS development through co-design approaches, applying experiences from urban activism, and helping to maintain continuous monitoring and feedback systems.

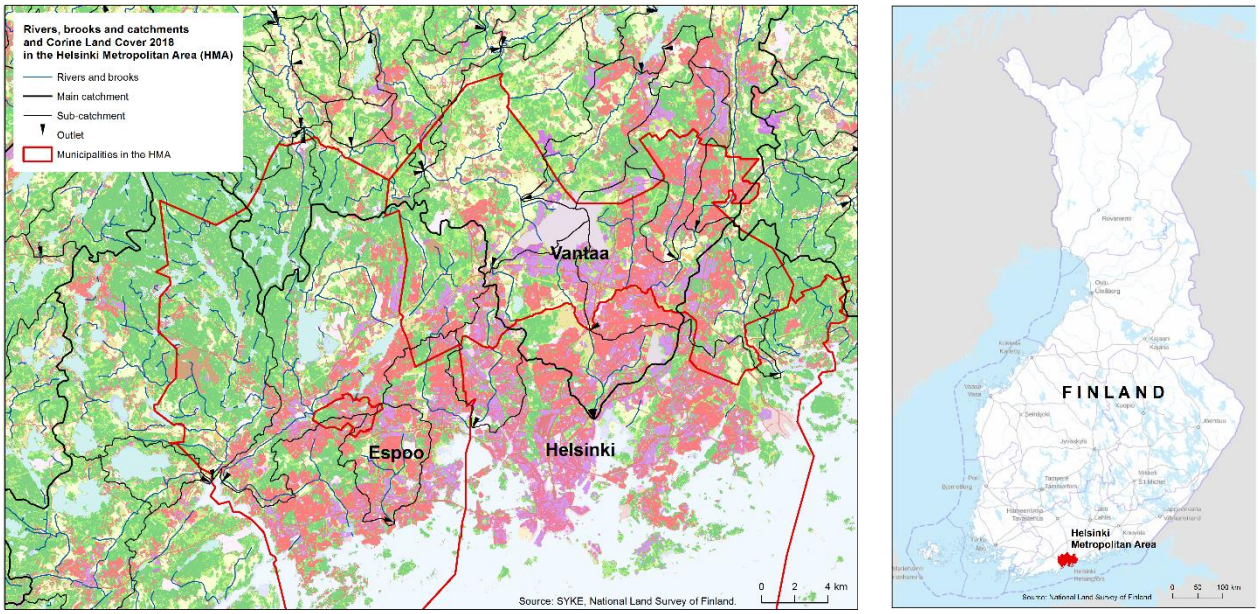

Figure 1. Catchments and Corine land cover and use in the Helsinki Metropolitan Area.

The upper catchment of the Łódka River (Lodz, Poland)

The challenge in the area is related to a permanent river turned into temporary stream due to limited urban runoff restitution amplified by geological conditions, pluvial flooding and drought (Figure 2). ATENAS project analyses of options for increased water storage and infiltration in urban commons through participatory design and implementation of demonstrative NBS as community building action (Figure 3). It helps to promote the idea of stormwater retention, to link citizens with small and medium sized enterprises (SMES) and decision makers, and to establish community of practice and strengthen local leaderships. ATENAS also supports the development of Sustainable Drainage Scenario for the area considering multifunctional spaces, which is the first step towards setting up the whole city hydrological monitoring network and development of hydraulic model (foreseen in the City plan for 2022-25).

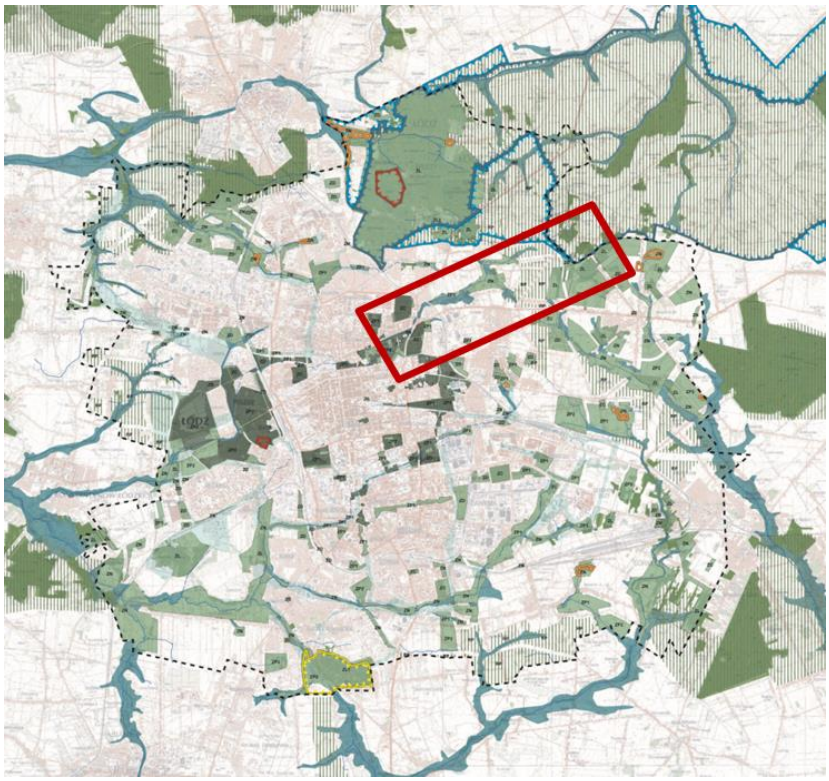

Figure 2. The location of the upper catchment of the Łódka River in the City of Lodz, Poland.

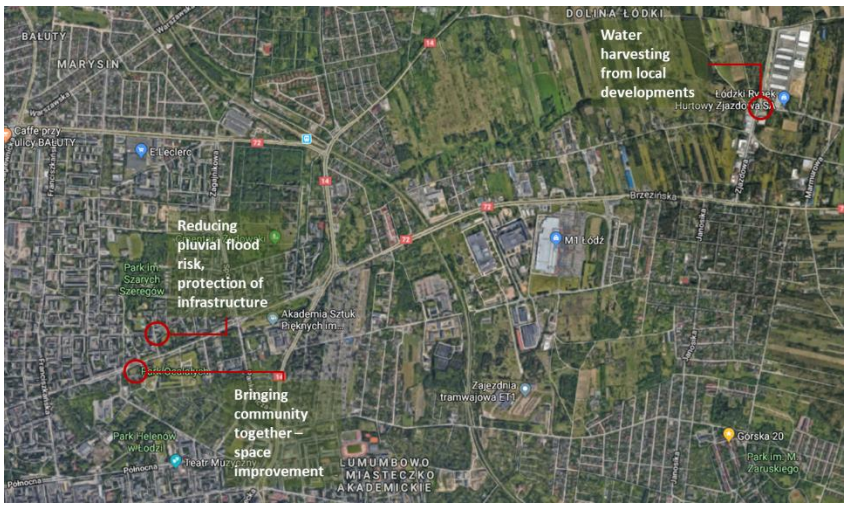

Figure 3. ATENAS interventional areas in the upper catchment of the Łódka River.

The West Lyon suburban basin (France)

The West Lyon suburban basin is representative of the rapid urban expansion that is taking place around large cities (Figure 4). The challenge in the area is related to the degradation of ecosystem services, such as self-purification provided by small rivers. To maintain these services, they must be identified in the territory and new management strategies need to be proposed. This involves training of decision-makers to understand the operation of NBS but also benefitting from their feedback on poorly managed NBS. The Lyon demonstration site develops the analysis of the self-purification capacity of the territory's rivers, lists the NBS, develops partnerships with stakeholders for the construction of three new NBS to amplify the self-purification capacity of small rivers, produces an educational video of this device from the design to the functional evaluation with stakeholders, and contributes to the rehabilitation of a NBS dedicated to the treatment of runoff urban area.

The study conducted by the SAGYRC (Yzeron River Union), between 2015 and 2018, on the sharing of the water resources of the Yzeron basin between human activities and ecological needs showed that 44 % uses to maintain a vital biological flow. This made it possible to build the Water Resource Management Plan (https://www.riviere-yzeron.fr/leau-une-ressource-a-partager/) which indicates that 70% of the water loss is linked to the drainage of underground water by the leaks of the 250 kilometers of aging sewerage pipes which collect the waste water of 22,000 inhabitants. Because the complete replacement of the network is not possible at a reasonable cost, the objective of the SIAHVY (Yzeron sanitation union) is to repair the portions of the network which drain the most groundwater while disconnecting rainwater runoff, to reduce flow rates in rainy weather and save local water resources, in accordance with the Yzeron basin water resource management plan. INRAE's contribution is expected in innovative solutions based on low-cost natural processes to ensure a return of water to rivers and achieve the objectives of good ecological quality for which SAGYRC is responsible.

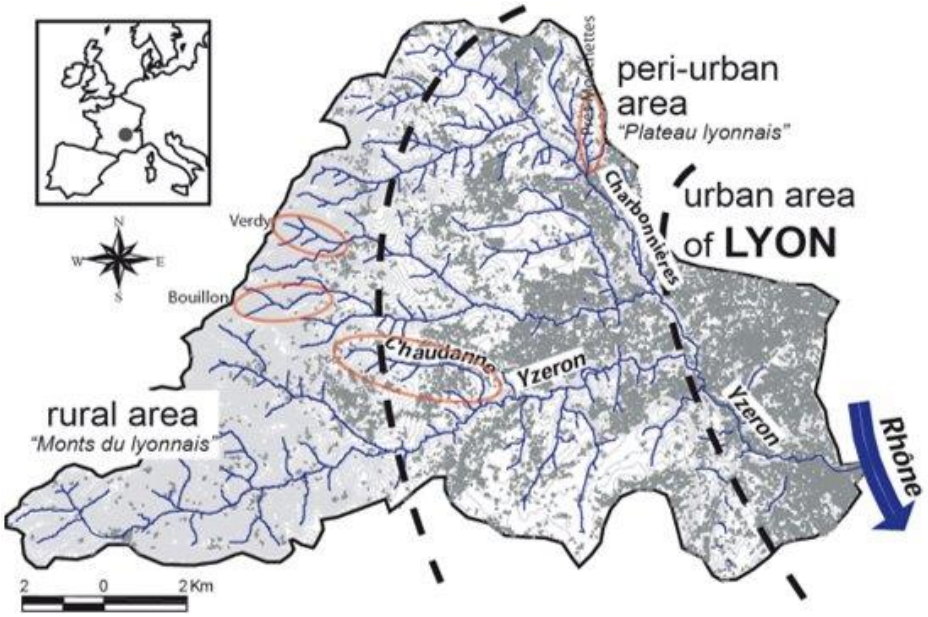

Figure 4. West Lyon suburban basin as a case area.

2.3 Organization of workshops in ATENAS project

Workshops on critical factors were organized in the three case areas. The aim was to bring together different stakeholders to discuss the critical barriers and success factors. The workshops had a common thematic structure that was drawn from the research literature. The main themes were: effectiveness and management of NBS; organizational aspects, governance and partnerships; public awareness and reception of NBS; and financial resources and valuation. Each of the workshops emphasized the themes that were relevant in the case context.

The Finnish workshop was arranged as an online event on 31.3.2020. The number of participants was 20 people. Two thirds of participants were urban planners working in the cities Helsinki, Espoo and Vantaa, Helsinki Region Environmental Services Authority and in the regional council of Uusimaa (the larger region where Helsinki metropolitan area is located). One third of participants represented consultancies or research institutes. The workshop consisted of presentations and a joint discussion, three parallel group discussions, each with a separate theme and a presentation of group work findings in a joint meeting and discussion. In the group work section, each of the three groups was facilitated by an ATENAS team member, who also took notes and wrote them in a Power Point, that was available for the participants of the online discussion.

Critical factors of NBS have also been discussed in other meetings with the planners of the cities of Vantaa and Helsinki on 20.5.2019, 18.12.2020, 7.4.2020, 18.5.2020, 26.6.2020, 12.8.2020, 22.9.2020 and 12.10.2020.

The Polish meeting with city authorities were arranged on 6.3.2020 at the City of Łódź Office. The number of participants was 9, involving representatives of ERCE PAS and departments of The City of Lodz Office responsible for the management of blue-green infrastructure, spatial management and investments in the city: Department of Municipal Services, City Planning Office, Department of City Greenery, Department of Ecology and Climate, Department of Municipal Investment Management.

Other meetings were organized on 31.1.2020 and 4.9.2020 with Bureau for Social Participation responsible for developing cooperation with non-governmental organizations; carrying out activities to prevent unequal treatment and social exclusion; and coordinating and supervising public consultation.

Critical factors of NBS have also been discussed in meetings with other stakeholders, mainly local activists representing associations and non-governmental organizations. The meetings were held on 18.9.2020, 5.10.2020. 12.10.2020, 14.10.2020 (Landscape Park Complex of the Lodz Voivodeship, Youth Climate Strike Lodz, Sports Fans' Association, City Guide, Revitalization School of Lodz, Social Tree Guardians, Energy for Cities, Yes for Lodz, Centre of Ecological Activities ‘Źródła’).

The meetings consisted of project aims presentations and a joint discussion about critical success factors and barriers for NBS implementation. During the meeting, the area of implementation of the new NBS in the city was also discussed: the best place, best solutions and reason for choosing.

The discussions were continued during individual online meetings or exchanged correspondence with the city managers and local activists (due to the COVID-19 epidemic no face to face meetings are recommended).

In the West Lyon case study, the first meeting was held in Vaugneray on 17.1.2020 in the presence of representatives of the sanitation union (SIAHVY), Yzeron river union (SAGYRC), the metropolis of Lyon, the community of communes, the regional Water Agency, the water police, various elected representatives of commissions delegated to town planning, environment, technical services, the company in charge of the maintenance of the network (SUEZ), the engineering offices involved and researchers from INRAE.
The purpose of the meeting was dedicated to:

➢ The feasibility study relating to the operation to rehabilitate the wastewater and unitary water network with the aim of reducing discharges from storm overflows into watercourses, reducing the quantity of water transferred in rainy weather to the Lyon metropolitan area's wastewater treatment plant, and maintaining as much water as possible in the Yzeron basin (Yzeron basin water resource management plan). To achieve this, promote innovative biofiltration/infiltration techniques or pre-treatment of uncontrollable discharges and amplification of the self-purification capacity of watercourses.

➢ The agreement between SIAHVY and INRAE for a partnership and assistance for this study.
This included identifying the data required for the feasibility study and defining the possible partnership between SIAHVY and INRAE for this project.

The second meeting of 18.2.2020 took place at the SIAHVY headquarters in Vaugneray, in the presence of representatives of the sanitation union (SIAHVY), the Yzeron river union (SAGYRC), the metropolis of Lyon, the community of communes, the regional Water Agency, the water police, various elected representatives of commissions delegated to town planning, environment, technical services, the company in charge of the maintenance of the network (SUEZ), the engineering offices involved and researchers from INRAE. The objective was to confirm the signing of the partnership agreement between SIAHVY and INRAE for expertise on solutions based on natural processes to treat wastewater and urban discharges from rainy weather. It was also a question of taking stock of the regulations for innovative solutions, both in terms of the quality of the water discharged and the possible quantities.

The third meeting took place on 26.6.2020 in Vaugneray in the presence of representatives of SIAHVY, SAGYRC, the municipality of Pollionnay, the Regional Water Agency, the Regional Health Agency, the management department of the Rhône territories, Lyon Metropolitan Area, Regional Environment Department, the sanitation network manager (SUEZ) and the research offices involved. The first objective of the meeting was to discuss the technical and regulatory feasibility of creating a biofilter to treat wastewater from part of the town of Pollionnay, located in the Yzeron basin. The second objective was to assess the possibility of reusing the treated water to irrigate the agricultural areas located nearby. The choice of the implantation area was a wetland partly drained by the defective sanitation network that crosses it. The rehabilitation of the network will help restore the wetland. This is a positive impact, but the installation of the treatment biofilter must consider the risk that the biofilter will be saturated with water by the wetland and therefore that the biodegradation flow of the wastewater will be strongly impacted. The biofilter will need to be elevated to function properly, which is quite feasible in the context of this study.

3. Research based findings on critical factors

In a study funded by EU Horizon 2020 project Urban Nature Labs, Sarabi et al. (2019) have carried out a systematic literature review on the significant barriers to and enablers of NBS. They screened scientific articles on NBS and found initially 250 publications of which 41 were identified as relevant for the analysis. In the analysis, main barriers identified were: uncertainty regarding implementation process and effectiveness of the solutions, inadequate financial resources, limited land and time availability, path dependency, institutional fragmentation and inadequate regulations. Main enablers included partnership among stakeholders, effective monitoring and valuation systems for implementation process and benefit, knowledge sharing mechanisms and technologies, economic instruments, plans, acts and legislations, education and training, open innovation and experimentation, combining NBS with other urban elements and gray infrastructures, and appropriate planning and design. In another study funded by Urban Nature Labs project, Sarabi et al. (2020) have found that barriers to the uptake and implementation of NBS are highly interdependent. They stress the need to identify the interdependencies for addressing barriers strategically. According their results, political, institutional and knowledge barriers have the most significant effect.

In the EU Horizon 2020 project Urban GreenUP, Deliverable D1.5 includes the identification of barriers and boundaries in the context of urban renaturing (Urban GreenUP). The significance of political, technical, legal, social and financial barriers is assessed and prioritized in renaturing NBS interventions of case cities. The report concludes that in most cities budgetary constraints limit the scope and depth of the NBS implementations. Local governments are skeptical about novel interventions from which there are only few previous experiences to show and of which the public acceptance is uncertain. According to the findings, short-term outcomes are often valued more than long-term impacts in political decision making. There is a need to better explain the wider impacts and returns from widespread renaturing NBS in the urban environment. The writers of the report found out that city administrations carry out thorough valuation studies, which are under-used in the decision-making. The report emphasizes the importance of embedding NBS planning in the overall planning processes of the city.

In the EU Horizon 2020 project CLEVER Cities, barriers and success factors have been identified from viewpoint of NBS co-creation for urban regeneration (VLEVER Cities 2018). Altogether ten common barriers are listed with references to potential success factors for overcoming these barriers. The identified barriers include: knowledge gaps, governance of multifunctional green infrastructure, balancing trade-offs while delivering multiple goals, citizen involvement, social inclusion, public acceptance, political support, financial support, challenges for evaluation, and challenges for upscaling.

Kabisch et al. (2016) have studied existing barriers and potential opportunities for increasing the scale and effectiveness of nature-based solution implementation in climate change mitigation and adaptation in urban areas. Potential barriers were clustered into the following categories: fear of the unknowns, the disconnect between short-term actions and long-term goals, the discontinuity between short-term actions and long-term plans, sectoral silos, and the paradigm of growth. Understanding the barriers and the factors that

reinforce them was seen essential for finding opportunities to address them. Opportunities that facilitate action for NBS were found first in exploiting the existing knowledge and experiences of successful NBS projects, but the success required the communication between new actors or stakeholders with those networks that are created or have acquired the experiences. NBS demonstration projects, knowledge platforms and NBS ambassadors were mentioned as examples of ways to promote NBS. Secondly, opportunities were identified in the collaborative governance and partnerships with different stakeholders.

In the EU Horizon 2020 project NATURVATION, Wamsler et al. (2020) have investigated the integration of nature-based approaches for climate change adaptation into municipalities' daily planning practices and associated governance. They state that despite of widespread discussion on NBS, there is an implementation gap in mainstreaming NBS in municipal planning. They have identified five strategies to promote the upscaling of NBS, including: targeted stakeholder collaboration involving private sector, academia and other cities; strategic citizen involvement to increase public awareness and improve consideration of NBS; outsourcing of implementation and using the help of citizens; the alteration of internal working structures to ensure consistent longitudinal integration; and concealed science–policy integration to increase pressure on both municipal staff and policymakers. The authors also stress the importance of individual mediating actors, relational approaches focusing on interactions, and the development of cognitive and emotional capacities to foster trust, inclusive communication and social learning.

The EU Horizon 2020 project Think Nature's Deliverable D5.1 Barriers Landscape and Decision Making Hierarchy for the Sustainable Urbanization in Cities via NBS describes NBS barriers and drivers (Think Nature 2019). Based on qualitative and quantitative results, the report stresses the importance of policy issues as fundamental in the driver-barrier landscape. The report also emphasizes that barriers and drivers for NBS are context- and case-specific. The report concludes in formulating suggestions for steps to overcome barriers and push drivers to adopt and implement NBS.

- Support recognition, appreciation and communication of the multiple benefits of NBS by decision-makers and authorities.
- Develop policies at all levels from municipal strategies, guidelines and funding to national standards and regulation and to EU-wide targets and financing.
- Invest courageously in multi-actor pilot designs and construction projects with NBS.
- Provide incentives to make NBS affordable where they are not yet (the return of investment for private investor may not be sufficient while the societal benefits are obvious).
- Finance transdisciplinary and cross-sectional knowledge-production of the benefits and performance of NBS.
- Establish projects with guaranteed resources for long-term development and monitoring, communication of results and collaboration with stakeholders.
- Conduct comparative cost-benefits assessments based on life cycle analysis and experiences from real cases between NBS and mainstream grey solutions for the same challenge faced.
- Innovate and test sustainable materials based on circular economy, including an analysis of the ecological-environmental impact of the new materials.
- Ensure efficient knowledge-transfer and easy access to reliable knowledge.
- Offer practical, detailed and locally adapted knowledge and education for NBS.
- Evaluate routines, planning processes and organizational traditions, and change where needed in order to support NBS.
- Learn from failures: improve processes from the idea to planning, construction and maintenance.
- Accelerate adoption of innovation – avoid silo-thinking, support agility, creativity and visionary thinking

4. Workshop findings on critical factors

4.1 Effectiveness and management of NBS

Technical effectiveness of NBS

In the Finnish workshop, participants brought up examples of NBS in stormwater management. In the City of Vantaa, altogether 40 NBS have been constructed for stormwater management, including infiltration basins, rain gardens, permeable pavements, bioswales, and constructed wetlands. The technical effectiveness has been studied in the planning phase and monitored often for a short term after the implementation, but a systematic long-term monitoring of the effectiveness is often lacking. In most examined stormwater structures, the technical functioning of NBS has been indicated. Many cases have also been studied e.g. in students' thesis works. Study results show that e.g. water quality objectives have not been met in every project. Workshop participants also mentioned that the technical functionality is not always verified. They noted that the aim of NBS is to bring multiple benefits, and pleasant environment for residents is an important outcome, even though the technical functionality has not been optimal.

The Finnish workshop discussion showed that NBS are still in a constant development process. The latest implemented NBS differ from the pioneer projects in the Helsinki region. Workshop participants explained that in new NBS projects, the soil and groundwater characteristics are usually studied carefully. The builder of the NBS is obliged to ensure the functionality and possibly maintain the NBS for the first two years. While there is growing experience and monitoring data on existing NBS, cities have become more ambitious in their projects. They have introduced new types of NBS or selected more demanding applications, bringing new needs for assessing the technical effectiveness and learning from previous experiences. The workshop participants emphasized that the technical functionality is revealed only in the course of time. Extreme conditions take place only seldom, and it is important to learn from them. Water overflow routes are revealed only during intensive rainfall events. The vegetation of biofiltration structures may change over the years, and only then it is possible to see if vegetation choices have been successful. In Finland, technical effectiveness is at a particular test in winter conditions with temperatures below or around zero degrees.

In the French case study, feedback on the technical effectiveness comes from exchanges through various thematic working groups (Rhône Alpes Water Infrastructure Group; Field Observatory in Urban Hydrology). The NBS are explored as an all-round paradigm shift to conserve urban runoff water in cities rather than quickly evacuating it to rivers with a polluting load. The concept of a sponge city is thus supported by the regional water agency, which finances construction projects. The metropolis of Lyon has carried out several NBS, but it is confronted with two difficulties: The first is that of the management of NBS in town, which raises the question of the competent services to ensure their design and maintenance. In fact, NBS are new and hybrid solutions between three technical services: roads, water, and green spaces, the coordination of which around NBS involves inventing new operating rules. The second difficulty lies in the bet that a paradigm shift based on the predominant use of NBS for the management of urban rainwater runoff will be effective while producing other services. On the hydraulic and biogeochemical levels, the models are not sufficiently validated because the spatial and temporal dynamics of the transfer and transformation processes in the NBS are not well known, because of the lack of sufficient experiments in the form of long-term demonstration site. Knowledge acquisition is underway via partnerships between research and application, but the organization of this knowledge is not yet sufficient and coordinated to achieve rapid success. The will, however, exists in particular under the pressure of the necessary adaptation to climate change. The climate of Lyon during summer is marked by intense thunderstorms in increasingly long periods of drought. The strategy is therefore to conserve rainwater where it flows and no longer to send it quickly to major rivers such as the Rhône and the Saône.

Important points emerge from the French stakeholders' feedback on NBS. In particular, it was pointed out that a natural-based solution inevitably evolves. This implies that the design must provide for the necessary maintenance practices, and the definition of performance indicators that are easy to follow for the technical

services, which conditions a rapid reaction in the event of changes in the natural system, and which considerably limits the intervention costs.

Ecological functionality and benefits

In the Finnish workshop, ecological functionality was discussed both in river and brook restoration cases and in stormwater management NBS cases. In restoration projects, it is important according to workshop participants that measures fit to the surrounding natural environment. In river and brook restoration, typical actions are related to turning the stream more natural, removing dams and other constructed elements and introducing sand, gravel, stones and wooden structures. Turning closed pipes to open streams has also taken place in some places. Different types of vegetation have been planted aiming to return the brook to a more natural state when allowed by the environment. Alien species are a problem on many river and brook banks and demand active interventions. Brook restoration has involved both voluntary and city actions, and new kinds solutions have been sought in co-operation. Ecological functionality has been most clearly indicated through key indicator species, such as trout, that has returned to restored rivers and brooks. In stormwater management NBS, ecological effects have been more difficult to measure, and even objectives may not have been specified. In single cases there has been studies of NBS functionality, but more information is needed on the state-of-the-art levels and comparable cases. Cities have produced guidelines for stormwater management, which help to take ecological aspects into account in a more systematic way. As the NBS have developed during the last years, new knowledge is accumulating on long-term functionality and ecological quality.

The Lyon case study has included an excellent example of a reconquest of biodiversity in the city, which has been discussed with stakeholders. A length of 2 kilometers of the Yzeron river has been restored by removing the concrete bed in the middle of the city. This has made it possible to reconnect the river with its water table, which allows the support of low water levels, thermal regulation for aquatic biocenoses, the installation of benthic and hyporheic macro-invertebrates, necessary for feeding fish, to recreate a hydrogeomorphological diversity, to eliminate an invasive plant (Reynoutria japonica), to create safe walking access, and an effect of urban freshness. The use of local trees has allowed the return of bird species that no longer frequented this area. This project also meets the objective of protecting the urban area against the thirty-year flood whereas the protection was ten-year with the old concrete bed. The multifunctionality of the place, however, presents antagonistic aspects on ecosystem services: it is not possible to put trash cans in the walking area because they would be washed away by the flood. As a result, detritus linked to night-time frequentation is found regularly (cigarette butts, bottles, etc.). Nighttime lighting is also reduced to a minimum so as not to disturb nocturnal animals and birds. The place is therefore not very secure at night in the sense of an urban inhabitant.

Implementation and maintenance

The Finnish workshop participants noted that implementation and maintenance is not always sufficiently considered in the planning. There are communication challenges in the planning-implementation interface as well as in implementation-maintenance interface. If plans include detailed design e.g. in structures allowing water to flow, it is not always considered at required accuracy in the building phase, leading to wrong kind flow directions. In some stormwater structures, such as permeable pavements next to street curbs, tolerance in measures is low. Therefore, the builder needs to be informed about the significance of accuracy. In the implementation phase, some changes to the plans are usually necessary. Environmental characteristics may require modifications to basic solutions already in the planning or latest in the implementation. For example, in many parts of the Helsinki Region, the soil is thin or rock is on the surface, which makes stormwater infiltration more difficult. In latest NBS projects, the cities have organized a feedback discussion with the builder to enable mutual learning.

The Finnish workshop participants pointed out that in the City of Vantaa, the aim is to build as simple structures as possible that require as little maintenance as possible. If too complicated structures are planned and constructed, they may be difficult to maintain. However, certain structures, such as biofiltration areas

necessarily require maintenance, such as cleaning of the drainage system. In many NBS, maintenance could be more systematic and based on constant monitoring. Maintenance needs are often brought up by local residents, who have noticed problems or repair needs in the area. Workshop participants also noted that planning ideology has changed, practices are more communicative and NBS are considered as standard solutions more often.

During the French meetings on the use of NBS, it was reminded of the fundamentals in order not to go to failure: design and maintenance are two key points for the success of NBS. To this must be added the development and performance indicators. Good maintenance means that maintenance operations are easy to perform. It is therefore necessary to provide for access and replacement or cleaning conditions from the design stage. Then, to intervene at the right time, it is necessary to have indicators that are easy to use so that the technical services do not let the natural system fall into an unwanted state and no longer fulfill its initial functions. This makes it possible to avoid additional maintenance costs.

Location and integration to urban structure

In the Finnish workshop, the significance of NBS location was discussed particularly from viewpoint of densely built areas. The availability of space is a restriction to NBS in areas, where building density is high, and the grey infrastructure and transport system need space. In dense areas, stormwaters have traditionally been managed by underground sewerage. The workshop participants noted that in dense urban environment there needs to be exact guidelines for street construction to reserve space for NBS structures, otherwise they are not applicable. If NBS solutions rely on structures located on private properties, it should be indicated in the land use plan, otherwise the situation needs to be dealt in building permission phase. In the discussion, it was noted that there should be more clarity in the detailed planning of NBS. In dense urban structure, there are underground parking spaces and constructed covers that cause problems for water management on the surface. The water volumes in surface retention are high, and the structures are difficult to realize in otherwise very constructed environment. The workshop participants saw a lot of potential in green roofs that are technologically advancing.

Most of the NBS in Łódź are located outside the city center, and their main role is to treat rainwater. Therefore, decision-makers as well as local leaders talked about the necessity of implementation in the strict center, which is most often measured against the effects of climate change (heavy rainfall and flooding, drought, air pollution). The current situation is based on combined sewage system. Most of the rivers, as a result of the rapid development of industry in the 19th century, were regulated and incorporated into the general sewage system. Consequently, during intensive precipitation, a great majority of water very quickly and directly goes into rivers, through the sewage system, which results in a shorter time of run-off concentration and increased culmination thereof. According to limited space in the city center, implementations should be based on small interventions such as rain garden, façade green, which can be implemented even by residents. However, implementation needs accurate guidelines for the NBS construction, and the guidelines included in the plans for the construction of streets, buildings, squares, backyards. This is to facilitate and force the implementation of NBS. Otherwise, the construction will take place in the traditional way.

In the French workshop it was noted that integration in dense urban areas is possible in the form of small local NBS distributed over water runoff paths or large open and multifunctional NBS, which are only possible during urban renewal operations. The insertion of NBS in the continuum of runoff paths and their polluting loads is a necessity to ensure global and not only local efficiency, and to increase resilience to extreme phenomena (intense rains, droughts) and local dysfunctions.

Combining traditional and nature-based solutions

In the Finnish workshop, combining traditional and nature-based solutions was considered both as a challenge and an opportunity. Preparation for extreme rainfall events can take place by reserving green areas for flood ponds or by having enough capacity in traditional sewer systems to handle the water. Having

separate sewers for wastewater and stormwater makes it easier to combine traditional solutions and NBS. Building NBS with traditional sewers may cause extra costs compared to having only sewers, but highest costs come from possible flood damages that can happen, if the capacity of sewers is exceeded.

During the Polish meeting with stakeholders it was pointed out that nature-based solutions, especially in the densely city center should be supportive for traditional infrastructure, which during the heavily rainfall is inefficient. However, new solutions, due to compact underground infrastructure and densely build-up surfaces, can be difficult, or even impossible. Furthermore, stakeholders pointed out that not every NBS instead is safe instead of traditional solutions, for example for sanitary reasons. Due to this combination of both types and, using NBS which does not require additional space comparing to the traditional situation are recommended.

In the French workshop it was noted that the integration of gray and green techniques is to be imagined in areas with high space and risk constraints. A transition period will be necessary, and the pipes will serve as a safety system in the event of failure of the NBS. This dependence will however have to be erased in the decades to come to keep only the minimum number of pipes, the maintenance cost of which is not sustainable in the long term.

4.2 Organizational aspects, governance and partnerships

Organizational silos and path dependence

In the Finnish workshop, it was noted that there are several reasons for the slow pace of NBS uptake. It can be a question of skills, attitudes and financing. Within a certain administrative sector, such as planning department, NBS use may be set as an objective, but it is not fully realized. There may be certain path dependence within the sector sticking to traditional solutions. Collaboration with different stakeholders is also an area to improve, and it often means breaking the traditional silos. It was also stated that the builder and maintainer of NBS should be invited to participate in the planning process.

During the Polish meetings, several aspects that may affect the implementation of NBS were identified, which are related with city organization, financial and legal issues, as well as attitudes.
The blurring of responsibilities between city departments, the scattered competences, lack of communication between departments were pointed out as the limitation of activities in blue-green infrastructure implementation. Similarly, the lack of standards for implementing NBS in the city limits both as an activity of citizens and officials themselves. Lack of assured money to maintain the investment after the implementation is a barrier limiting activities. The city requires a paradigm shift in approach to spatial design, which should include new investments in environment friendly solutions. In previous years the low activity of Department of City Greenery, which should be lobbying for greenery, is considered to be one of the causes of negligence in the city in terms of both old and new investments.

There are no examples of small NBS implementations in Lodz taken by City Office that could encourage people to change their behavior and implement on private grounds rain gardens, permeable surfaces etc. Officials state that City Office must start changes with itself and set an example of NBS solutions. Due to challenges of climate change, requiring people to make sacrifices and changes without changing City Office own behavior and practices can be pointless. Top-down initiatives can be seen as a platform for establishing cooperation with people.

Critical factor pointed out by decision-makers is Łódź the socio-economic situation. Especially in densely built-up center, city face more urgent issues, such as poor condition of home infrastructure, lack of water-sewage installation or central heating solutions, poverty and social exclusion. This puts investments in blue-green infrastructure in the second place in some citizens' and city officials' opinions, reducing their interest and support.

In the French stakeholder interaction, there were discussions on urban rainwater management. The experiments carried out with NBS in the city of Lyon have shown that the multifunctionality of an NBS raises the question of the collaboration in management services. A green space designed as a park and for managing rainwater involves water, road, green space and user safety services. The choice to generalize the NBS as a solution in the future would imply the creation of a new service or a transversal service to the others to ensure efficient management.

Experimenting and demonstrations

The Finnish workshop participants argued that it is important to provide examples of NBS to show that the solutions really function. The need for demonstrations applies to many kinds of NBS, including stormwater management structures, green roofs and meadows, and other green areas. If good examples exist, it lowers the threshold to introduce NBS to the planning table and implementation. Demonstration and evidence are particularly important, if there are worries about possible risks of NBS. The functioning of green roofs in the Nordic climate is an example of NBS that is often questioned. The workshop participants thought that there is a lack of knowledge and evidence that green roofs are a reliable option, when even traditional flat roofs have a bad reputation. However, it was pointed out that green roofs are already well productized and presented in building information files and standards. Experiments and demonstrations were also called for the integration of traditional infrastructure (pipes) and nature-based solutions.

In the stakeholder opinion, Łódź city requires the introduction of exemplary NBS solutions, visible and accessible to residents for several reasons. Firstly, the participants of the workshops in Łódź recognize the need for visibility, because the lack of such solutions (especially small NBS) does not encourage residents and private investors to act. The official statements point that the city's activities should be an example of good practice. Such actions, with the support of moderators, social animators, can mobilize people. Secondly, a good and functioning example of NBS shows the effectiveness of actions that interact with nature and strengthen it, helping address societal challenges. Spreading additional information about benefits such as discounts, savings on bills or expenses can mobilize citizens even more. Thirdly, the lack of knowledge and evidence, especially on the security of solutions, increases the reluctance of residents to support their implementation. Demonstration and evidence are particularly important, if there is a lack of citizens engagement and support, and existence of other important issues.

In the French stakeholder interaction, three types of NBS currently have been discussed with operational staff and decision-makers and are at different stages of assessment. (I) The vertical filter planted with reeds to purify wastewater from a village is a technique mastered by INRAE and the design offices which ensure its transfer. (II) The filter planted to treat thunderstorm overflow discharges before returning to a watercourse has been being tested on a demonstration site for several years in the Yzeron basin. It is functional but comes up against the regulations regarding the discharge of phosphates. Work is progressing to manage the adsorption of orthophosphates. (III) The porous groynes intended to amplify or restore the self-purification capacity in small seasonal rivers under urban influence. A demonstration site has been set up as part of the ATENAS project. It follows on from an experimental pilot site followed for ten years on a small stream in the Yzeron basin. The water police have no contraindication since the device improves the quality of the water once it has arrived in the watercourse.

Legislation and regulation

In the Finnish workshop, it was noted that legislation does not oblige to certain solutions, but rather instructs planning authorities. In 2014 Finnish land use and building act (682/2014) was added a chapter on stormwater management. The law aims to develop systematic stormwater management in areas with a detailed plan, promote infiltration and retention of stormwaters, prevent damages caused by stormwaters also considering climate change, and decrease the use of combined sewers. The stormwater target in the law is perceived as challenging and responsibilities are difficult to identify.

During the meetings with decision-makers in Łódź, it was pointed out that there are no regulations that require water retention solutions in the new investments. In the regulations there is information what area of the plot of land should be arranged as an area of biologically active land, and this is not enough to expect NBS. Thus, it is postulated that decision on land development and land use conditions (WZiZT) (the decision is a spatial planning instrument, its purpose is to determine whether a given investment project – building- will not violate the spatial order, may regulate the height of the building, its shape, color of the elevation) should consider NBS. Therefore, from the implementation point of view, it is necessary to analyze legal path for land development, to indicate critical points for broader implementation of blue-green infrastructure. Another problem is lack of local development plans for the whole city area, which leads to uncontrolled development. The problem with the plans results from the large area of the city, the duration of the plan setting as well as human resources.

In the French case, legal issues have been discussed particularly in the NBS project carried out by the Yzeron sanitation union (SIAHVY). The water police must give its approval for the project and considers that a device which purifies the discharges of thunderstorm overflows of the unitary network, must respect the standards of discharges which are required for a station of sewage treatment. This is not possible for the phosphate forms because the biological processes of the device are essentially optimized for the mineralization of nitrogenous organic materials. The question is discussed at the level of the Ministry of the Environment in a more general way. But this is a brake on the development of this NBS.

Planning practices

The Finnish workshop participants noted that the planning of NBS requires the co-operation of planners and experts from several departments and fields. In the municipality administration, usually both land use planning and water management departments are involved. Co-operation is needed on different phases of the planning process. Planning of a neighborhood or part of town usually begins by defining the planning framework that sets guidelines for detailed planning. The planning framework includes planning principles, area typologies and zoning on a general level, and it is important to consider NBS already at this stage. Planning of NBS can be greatly enhanced with help of planning tools, such as the calculation of green area factor (relation of green/permeable area to the total area). The workshop participants considered green area factor as a practical and easy method that supports the application of NBS. They also stated that green area factor should be put into practice through stormwater strategies and political guidance.
Utilizing the green factor as part of planning (at the block level) requires the expertise of several experts to make the collaboration successful and possible.

In the Finnish discussion, a current doctoral thesis by Elisa Lähde (2020) was mentioned as bringing many valuable insights to the challenges related to collaborative planning in Finland. In the study by Elise Lähde competence, attitude or funding were mentioned as reasons for not achieving the objectives (e.g. for green roofs) in terms of strategy.

During the Polish workshops and discussions, the need for a paradigm shift in planning practices was identified. The announcement of a tender for the development of design documentation for reconstruction/extension, should already include the obligation to NBS inclusion, even in the context of simple solutions such as permeable surfaces. This requires knowledge and awareness enhancement among officials. Consequently, the new approach should take the cooperation of different experts into account.
In addition, the voices of residents should be considered in the design process, so that the residents are co-responsible for the new place. The officials have experienced that what they built and maintained was destroyed by the inhabitants. Co-design can be an instrument to prevent this. An example is the redevelopment of one of the city's areas resulting from the City Office workshop “Streets of Old Polesie”, where the residents, according to the guidelines received from the urban planners (need to include greenery, parking spaces, any obstacles of underground infrastructure), chose what they wanted.

In the French stakeholder interaction, it was noticed that the coordination between the sanitation union and the river union are the guarantee of an integrated approach at the level of the Yzeron basin. Indeed, the river

union ensures its missions to achieve the good ecological state of rivers and protection against the effects of floods and droughts. It has thus defined its water resource management plan at the watershed scale, which is based on the principle of conserving rainwater in the basin as long as possible. The sanitation union manages part of the water resource and produces most of the pollution in the waterways. The regulatory and compulsory improvement of the sewerage network is addressed by the local purification of wastewater, the improvement of the quality of urban discharges during rainy weather and the restoration of the self-purification capacity of the many small streams. All these NBS-based actions contribute to the objectives of SAGYRC. Scientific experts bring their knowledge to this overall approach.

Partnerships with stakeholders

In the Finnish workshop, it was pointed out that urban planning is developing towards multi-stakeholder co-design practices. It was seen important to involve relevant stakeholders in the planning from the beginning of the planning process. Possible implementers, such as building companies and maintainers should also be involved as early as possible. Participants found many weak points in the planning-design-construction-management chain: The municipal authority does not have enough knowledge or understanding about possible NBS to support the external expert (consultant company) who makes an actual plan and finally the builder does not have the expertise to implement the planned NBS.

Participants agreed that is crucial to involve key stakeholders and actors (e.g. planners, managers, citizens) already at the early stage of design. This has implications for the resource planning that should carefully include stakeholder involvement. Collaboration requires new ways of thinking and adaptation of new cross-sectoral collaboration instead of traditional silo boundaries. It is important to pay attention to the ways in which different actors can participate. Participants saw that no one has a ready answer, and therefore learning together is important. It is also essential to develop operating models that help ensure that the solutions work. The specific features of the site must be taken into account at the design stage.

During Polish meetings it was established that design should consider needs, knowledge and experience of different stakeholders (including scientists, practitioners and residents). These engagement practices have already started in Łódź, through activities such as organization of Citizens' Panel on City Greenery and co-designing workshops on streets rebuilding. Citizens inclusion creates a sense of co-responsibility. But, the success of co-operation is dependent on City Office implementation of developed solutions. In previous years, due to disregard for the opinion of the inhabitants, trust in the actions taken by the City Office has been lost (this aspect is addressed by residents and local leaders).
The exchange of knowledge between planners, managers and citizens reduces the risk that the solution will not be well received. Cooperation requires new ways of thinking, undertaking cross-sectoral cooperation and develop effective tools supporting the cross-sectoral cooperation. Since the city authorities are criticized for not coping with the challenges of climate change, including residents in the early stages of design and management is one of the options.

In the French collaboration, the partnership agreement between INRAE and SIAHVY was signed in April 2020. For its part, SAGYRC signed a letter of support for the ATENAS project. It has already provided the location for the meetings area demonstration site and carried out the work to set up the NBS in the river. SIAVHY is a member of the SAGYRC management committee. All the links confirm the integrated level of coordination between the actors of the Yzeron basin. The participants in the meetings include representatives of decision-makers and funders. It is an operational necessity.

4.3 Public awareness and perceptions of NBS

Awareness and knowledge gaps of different NBS options and benefits

In the Finnish workshop, participants stated that benefits NBS provide for people should be clearly communicated. In awareness raising, one needs to remember that the inhabitants of the city are a large and

wide target group for communication. Demonstrations and exhibitions of NBS can concretely showcase NBS in function. There are a few excellent exhibitions also in Finland; e.g. in Marketanpuisto in the City of Espoo where different methods for the management of run-off waters are exhibited. Workshop participants mentioned that targeted magazines could also be used for sharing information; e.g. magazine of Home Owners Association.

Finnish workshop participants noted that educational aspect would be good to include in all NBS. Through different methods, such as gamification of environmental monitoring for school students or phenomena-based learning at schools, it is possible to get students involved in NBS interventions. If a school is located in an area where NBS are planned it is possible to involve teachers and students in the planning process. Workshop participants mentioned that in Stockholm each school has been reserved one week or at least some days for getting acquainted with cities water systems, the students visit an exhibition where city guides explain the students the water management systems, including NBS. In Helsinki region, there is no centrally steered communication, but stakeholders and cooperation organizations carry out communication by themselves.

During the Polish meetings with stakeholders, it was argued that it is necessary to spread information about NBS ant its benefits for society. Such information should include the costs of establishing NBS, as well as various profits, i.e. discounts, savings in bills and expenses, and information on environmental benefits, i.e. protection against flooding, droughts, or improvement of air quality. This information should also include examples of solutions applied in the city. This, on the one hand, will serve as a tool to raise the knowledge and awareness of the residents and, on the other hand, can support discussions with authorities (to push certain solutions socially). City activists reported that such data will help them when officials take advantage of the data gap to discourage action, informing them that implementation is not possible because it is too expensive, technically impossible, or there is lack of appropriate legal regulations.
Information sharing, via social media or social action in public space, should also be used to stimulate city community on multiple levels, to think, reflect, see the need for change and, naturally, to take action.
Education should take place on many levels. The need to educate and involve schools in the implementation of new NBS is very much emphasized. Children are treated as an important factor of social change, their involvement can translate into interest among parents.

It was also pointed out that the communication (showing the benefits) needs to be adjusted to the needs of the community and directed not only to people who know or are interested in this issue, i.e. to extend the communication beyond the groups of environmental activists.

In the French collaboration, public consultation in projects is considered for large-scale operations, in fact those involving works that will have an impact on the daily life of local residents. This was the case for the restoration of 2 kilometers of a channelized watercourse in the highly urbanized part of the Yzeron basin. Awareness-raising actions on water and river management are developed for pupils who take part in field work and school projects with SAGYRC.

Citizen engagement in planning, maintenance and monitoring

The Finnish workshop participants argued that participation in NBS planning depends on the type of the area. In a new area that is still be developed, it is challenging to identify stakeholders. New inhabitants of the area are not known yet. Stakeholders can be found in neighboring areas, but their viewpoints may differ from the future inhabitants of the area. In an existing neighborhood, it is much easier to identify stakeholders. It needs to be decided on which spatial level and scale you should arrange participatory actions, catchment, city quarters or real estates.

From the NBS planning perspective, Finnish workshop participants considered it important to get ideas from citizens who know the local environment. It would be good to identify activities where voluntary people can take bigger responsibility and arrange possibilities for people to be active and do things by themselves. This requires additional resources e.g. tools for the work that could be provided by the city. Collective work needs

also management and guiding, otherwise people may implement controversial or obsolete solutions. In the best case, it is possible to find coordinators or persons who are ready to take responsibility for collective work among the active participators. Another good solution is to utilize groups that are already organized (local environmental groups, fishing clubs for river and brook restoration, etc.). It was also discussed what kind of actions are most suitable for citizen involvement. Stormwater management is the responsibility of the real estate owners and the city water company is responsible on a larger scale. The restoration of brooks was mentioned as a good example of voluntary action on NBS. Voluntary participants have carried out restoration measures with successful results: trouts have returned to brooks for spawning.

Conflicting opinions about implementing NBS plans in the brook Kumpulanpuro, Helsinki

The brook Kumpulanpuro, locates in the heart of Helsinki. The proportion of open channels of the brook is low (ca. 22 %), and most of the brook runs in storm-water drainages or water pipelines (Ruth and Tikkanen 2007). Only a fragment of the open channel is in its original condition. The brook is iron rich, which makes the water color brownish. The iron concentration of the water has been extremely high for example appr. 9700 µg/l in 2013, and the annual iron load was estimated to be ca. 27 tonnes into the Baltic Sea, which is over ten times greater than in other urban streams in Helsinki (Vierikko & Niemelä 2016). Urbanization, increased land-use density and soil sealing have changed hydrological processes in the catchment area, which have caused changes in the water regulation capacity (Ruth and Tikkanen 2007, Alberti 2008, pp. 133-152). The brook Kumpulanpuro suffers from the 'urban stream syndrome' (Kondrad and Booth 2005, Walsh et al. 2005), including polluted urban run-off water, nutrient loads, high water temperatures year-round, and low flow volumes during summer. Furthermore, sudden storm-water inputs have caused peak flows and drastic flooding in the allotment garden in 2005, 2007, 2010 and 2011.

Local residents were participated in the planning process and their input was gathered, but not in successful and efficient way which caused local environmental conflicts. Vierikko & Niemelä (2016) studied a local environmental conflict related to a nature-based storm-water management planning of the brook Kumpulanpuro. Stakeholders (locals, managers and politicians) expressed a total of 47 perceived values related to the urban brook and the public park. Values were divided into four types: 1) use and experience, 2) existence, 3) symbolic, and 4) bequest and moral. Locals assigned more use and experience values to the park and the brook than other stakeholder groups, most likely because they use the area and are well aware of other activities in the park. Vierikko & Niemelä (2016) noticed a great difference between the meanings and values of locals, managers and politicians. Managers expressed negative values towards the park, while locals more commonly expressed symbolic values. Vierikko & Niemelä (2016) concluded that strong place identity of locals increased the number of attached values towards the brook, while managers were more pragmatic towards the area and attached more negative values to justify their management plan. They suggested that by using integrated value mapping of ecosystem services, they assigned socio-cultural values of local blue-green infrastructure, and evaluated how these values could be taken into account at the early stage in the storm-water management planning.

In the Polish experience, proposed and implemented NBS should be adapted to the realities of social problems in a given region/district, because people who live in a given place create its identity (the City Office imposes visions of the place and convinces its inhabitants). This requires the involvement of residents on many levels, whether planning, executing, maintaining or monitoring the effects. Only in this way, bearing in mind social needs, is it possible to build co-responsibility for actions and for the place. In other cases, the actions of the City Office may meet with reluctance or even vandalism.
Lack of citizen involvement in the planning activities has been explained by lack of sense of community and common space, lack of time, no reason to get involved, and lack of trust among citizens toward City Office. If citizens are convinced that their voice will not change anything, they do not participate (considering it as a waste of their time). As factors enabling engagement were mentioned: interesting initiative, with a strong focus on improving the quality of life, and significant role of community leaders in initiating and implementing various environmental project. For citizen engagement, there is need for a lot of education and activation measures (community animation, streetworkers) to build communities around the initiative because of the high level of mistrust.

Based on the Polish stakeholder interaction, the planning stage should involve the widest possible range of experts who will present the possibilities according to the accepted scientific knowledge and technical possibilities and standards for the city. This procedure will help to avoid disappointment of the residents, which was found out in the case of the City Office workshop “Streets of Old Polesie” with the residents. Urban planners informed citizens about terms and conditions, which has helped to avoid a situation where residents have chosen extreme solutions that cannot be implemented. Only dialogue supported by expert knowledge allowed to choose optimal solutions.

In France, the involvement of the local population in major works is regulated to include the presentation of the project and its possible options. The project is subject to the public enquiry process. It is not a vote, but it allows arguments for and against the project to be put forward. The final decision rests with the local authorities and the State if the project has an extra-regional scope. For the NBS it seems possible to involve citizens in the choice of possible solutions and the monitoring of malfunctions. Maintenance cannot be entrusted to citizens because it requires specific technical knowledge and safety reasons.

Social inclusion and ownership

The Finnish workshop participants emphasized the significance of citizen engagement that creates sense of responsibility for the environment among dwellers. During the COVID-19 epidemic, no face to face meetings are recommended, and participation in the planning must be arranged online. It was discussed whether internet-based tools / questionnaires treat people equally. Some social groups, especially young adults, are very practical with the e-participation tools (e.g. public participation GIS), but some groups (e.g. elderly, different language groups) can be excluded.

During Polish meetings and discussions with citizens, decision-makers and local activists, the need to create a sense of cooperation and co-responsibility for solutions created in the Łódź was raised. This strengthens citizens' activities and gives them the opportunity to take care of the area. The problem can be the excluded social groups, the elderly, the poor, who even before the COVID-19 epidemic, which moved the activities to the Internet, could have difficulties in participating in online and onsite meetings. The epidemic also reinforced by the existence of other, more important problems than blue-green infrastructure problems. Together with local activists and animators, solutions are being sought on how to involve and integrate excluded groups. One of the propositions is putting up posters with a request to write down thoughts, attitudes and needs.

Based on French experiences, citizens concerned about the loss of biodiversity and the effects of climate change on the distribution of water resources can get involved in planning processes. However, in France, mayors are responsible for the security of their citizens. This responsibility has led mayors to close public access to parks developed for rainwater management. Nevertheless, there are experiences in large cities where municipal staff can manage public alerts and evacuation in the event of heavy rainfall, as in Lyon.

Expectations and experiences of NBS

The Finnish workshop participants mentioned several NBS cases that have been experienced very positively and bought multiple benefits for local inhabitants. The rather new residential area Kartanonkoski (see more below) was named as one example of an area, where NBS for water retention form a central element of the area and fit well to nice-looking buildings and environment. Including NBS as a core theme of the area and successes in the implementation guarantee a wide public acceptance.

The Finnish workshop participants discussed about negative attitudes and reactions towards NBS that local residents sometimes may have, when they don’t know the purpose of the facility. For example, the river valley of Mätäoja in the city of Vantaa has been kept in a natural state to treat run-off waters and restore biodiversity. At the same time, the city has received several complaints for not building it to a nice park instead of area of dense vegetation and shrubs. In the brook Kumpulanpuro in the city of Helsinki, there was

opposition to restoring a brook and building retention ponds as people were suspecting the waters would be coming from polluted area (Vierikko & Niemelä 2016). The retention ponds have been accused of being ugly when they are dry, and people think it should be a nice pond which is unintentionally left without water. People have also been worried about safety, thinking that ponds pose a risk of drowning for small children. The city technical department has proposed fencing of the ponds, but that would reduce the recreational value of the water element. People have also been worried about the ponds which gather waterfowl near by the airport. There might be a risk of bird collision of airplanes. It seems, that in many cases, when NBS are planned and implemented, the best way to achieve good results without opposition is to involve citizen already at early stage of planning (e.g. Vierikko & Niemelä 2016). However, constant information and communication is important to keep the level of awareness on a high enough level. The interaction of stakeholders is also key to success. Different authorities should be kept informed of planned actions to be implemented. In the waterfowl vs. airplanes example, the planners of NBS should contact the National Aviation Authorities to discuss whether there really is a problem and how to solve it.

In Łódź, both residents, authorities and leaders emphasize the role of knowledge and information dissemination at every stage of NBS planning. It helps to avoid dissatisfaction of the residents and may arouse their interest, sense of community and co-responsibility. When there is a lack of awareness of the role of a given solution, personal fears may block certain solutions, e.g. detention basins or dry detention ponds are associated as places where children may drown. Residents also expect orderly, functional places, where regulating services are supporter occasionally and in small matter.

On the basis of French experience, it is difficult to talk about expectations regarding NBS because the concept is too recent to have been disseminated to the population. It is not even clear to the authorities. The term "natural space" in an urban environment is easier to grasp. The services provided are only evaluated by comparing the costs that would be incurred if they had to be created by technical means. This is the way to convince people today of the usefulness of NBS. The restoration of watercourses is appreciated in cities only because it is confined to specific areas where people can go for walks. Moreover, the unmaintained nature is problematic because it is considered to be abandoned and is conducive to illegal activities. Therefore, there is an important work of communication and training to be developed in order to bring citizens to understand the interest of naturalness in the city.

4.4 Costs, financing and valuation

In the Finnish workshop, green roofs were discussed as an example of NBS where costs and risks are often weighed. There is great concern whether a green roof works and whether it causes damage to structures, particularly in winter conditions. Reimbursements from insurance in case of water leaks or other accidents is one question considered. Overall, there is lack of information and evidence. More examples of NBS are needed (e.g. on green roofs, meadows, fields and other NBS) on how solutions work to lower the threshold for inclusion in design and implementation. The need on make real cots of NBS visible was highlighted in the Finnish workshop. At the same time, it is important to understand NBS benefits broadly, including ecosystem services, positive health impacts, and image benefits in communication.

Two of NBS example have been introduced in Łódź city based on external finances (LIFE+, 6 FP EU), and have been based on mostly in the river channel. Currently there are other projects in the city which go beyond the river channel and focus on establishing Nature-Based Solutions for sustainable water management in intensely urbanized area.

During the Polish meeting, it was discussed whether there are any local programs in financing of residents' activities, especially in intensely urbanized area. Since the actions taken may vary in scale and relate to different land, the costs may be different for each NBS, and too high for the household. During subsequent discussions with Polish authorities, the existing (since July 2020, October 2020) programs enabling application for funding for rainwater and snowmelt water collection systems have been shown. One of them is financing by City Office and can be applied by the housing communities of the city ("Łódź zbiera deszczówkę") and the second is for single-family building from the whole region ("Moja Woda") offered by

Voivodeship Fund for Environmental Protection and Water Management. In both cases the subsidy amounts to 80% of the investment costs (not more than 10 000 PLN or 5 000 PLN in second case).

Based on the French case study interaction, NBS are considered to be low-cost solutions. This is what is of interest to decision-makers today. However, it is necessary to go back to the basics of the dynamics of any natural system that is evolving. This implies spending energy and therefore a cost to maintain the natural system in a stable state. These costs are rarely built into projects, whereas NBS are sold as resilient and therefore long-term solutions. Incentives for these solutions are beginning to be offered: the regional water agency is financially supporting the implementation of NBS projects for communities. The LIFE+ ARTISAN project ("Increasing the Resilience of Territories to Climate Change by Encouraging Nature-based Adaptation Solutions") supports the creation of 10 demonstration sites in France with the aim of analysing the obstacles and levers of these actions in order to generalise their use. It is too early to make an assessment of the costs and benefits of the actions carried out on NBS at this stage.

Investments in NBSs are mostly public and very recent. The large water and development companies are positioning themselves on NBSs with large urban rights-of-way. However, there is still a lot to be done in terms of implementation, monitoring and maintenance. Moreover, the regulatory aspects can be blocking because they are unsuitable. They need to be changed. The costs involved can be misleading.

5. Case examples of critical factors

5.1 City level

Cities of Vantaa and Helsinki, Finland

The city of Vantaa has published its stormwater management programme in 2009 prioritizing infiltration and retention of stormwaters (City of Vantaa 2009). The aim is to incorporate NBS as a default solution across different planning sectors and parts of the urban area. To support the implementation of the programme, an operating model and manual for planners and implementers was published in 2014 (City of Vantaa 2014). Despite the general goals and instructions, NBS have, according to city planners interviewed in meetings, only partly established the default position in detailed planning, such as in street construction. Traditional methods still prevail in many cases. In dense areas, the lack of space prevents the actions that would follow the operating model.

The city of Vantaa has been preparing a new master plan since 2017 and a plan proposal is displayed for public inspection in 2020. The main goals in the new master plan are public transport, refraining from new land uptake, ecological network and the quality of existing neighborhoods. The planning of green corridors that function as NBS has been one theme in the planning process. The key question is how much space should be reserved for green corridors located around urban brooks to preserve their ecological values and functions. There is also a need for research-based knowledge to justify chosen planning solutions. The use of Green area factor is promoted in planning, but there is a need for research-based justification for its use. The city of Vantaa also commissioned a mapping on ecosystem services in the city that helps to identify spatial differences in the provision of ecosystem services and reconcile ecological and development objectives.

The city of Helsinki has put much effort into water-management in recent years to improve the hydrological conditions of brooks and in managing urban stormwaters. The first storm-water management plan was accepted in 2007 and updated in 2018 as a part of EU interreg Central Baltic Programme "Water – Integrated Storm Water Management" (City of Helsinki 2008, 2018). However, the water-management processes commonly adopt a techno-ecological approach, i.e. values are defined by engineers and experts, which fails to recognize the plurality of meanings and values associated with the allocation, use or conservation of water (Ioris, 2012).

The city of Helsinki has put a significant effort in the developing of NBS in a few flagship areas that are new residential areas, such as Kuninkaantammi. In existing areas, it has been more challenging to include e.g. new stormwater management structures in the area, but NBS are becoming more prominent issue also in infill development areas.

The Finnish cities are able to take advantage of a number of guidebooks that give instructions for comprehensive management of stormwaters and present different NBS options for different situations (e.g. Association of Finnish municipalities 2012; Climate-Proof City – The Planner's Workbook 2020). The guidance materials include concrete examples of NBS implementations, but largely lack assessments of NBS effectiveness and challenges in their implementation and maintenance.

The city of Łódź, Poland

The city of Łódź is characterized by very limited natural water resources, land with significant slopes (for a city in central Poland) and poor retention capacity. Currently the city wants to develop in line with the concept of the sponge city, which locally retains water, it is more resistant to droughts, heat waves, as well as safer in case of heavy rainfall and potential floods. The more water stored, the more effective the process of field evaporation (evapotranspiration) and thus the less severe the effect of an urban heat island.

Collaboration among scientific institutions and public authorities, (on the basis of launched in 2006 Learning Alliance 'LA' stakeholder platform to exchange knowledge and information) lead to developed the vision for Lodz 2038 "Łódź Mądrze Korzysta z Wody" ("Lodz Uses Water Wisely"). This document includes scenarios concerning the development of Łódź and includes practical recommendations. The LA group formulated two proposals for the 2010 Study of Determinants and Directions of Spatial Development for Lodz: to incorporate entries on sustainable management of stormwater and to implement the Blue-Green Network. One of the goals of the Blue-Green Network concept (Zalewski et al. 2012; Wagner et al. 2013) was to enhance water retention in the landscape. The Blue-Green Network concept was officially adopted by the City of Lodz in 2012 as one of the components of the Integrated Development Strategy for Lodz 2020+ (City of Lodz Office 2012). It also includes activities aimed at improving the urban environment in Łódź, such as revitalization of Sokołówka river and revitalization of Arturówek reservoirs. The Blue--Green Network concept was adopted in the city's strategy in Lodz Municipal Council's resolution no XLIII/824/12, of 25th June 2012. However, the Blue-Green Network is very slowly being incorporated into operational urban management.

Social network analysis carried out in Łódź (Kronenberg et al. 2016.) showed poor cross-sectoral cooperation, stakeholders primarily cooperate with entities of the same category. However, cooperation between the authorities, researchers and expert NGOs has increased in recent years. There is still much neglect, but the authorities seem to be increasingly open to such collaboration.

The various institutional failures related to functioning Łódź city, such as incompleteness and inconsistency of regulations which hinder collaborative action and downplay the importance of urban greenery, limited funding and a lack of long-term planning, inconsistencies in the decisions made at different levels of decision-making and a limited sense of responsibility (Kronenberg 2015)

Pressure from the UE, with its political objectives and funding mechanisms provides and important context for decision regard urban nature. Pressure from bottom-up movements, including NGOs and members of society protesting against unfavourable decisions (cutting trees, designation the green square for the development), is becoming more commonplace, speeding up the transition process in Łódź toward more green city (Kronenberg et al. 2017).

The authorities in Łódź have started to adapt to these pressures, by taking many actions. In recent years, local authorities in Lodz have attempted several times to improve the management of blue-green infrastructure, by consolidating different units responsible for urban greenery (at 2012 - Department of City Greenery, at 2019 - Department of Ecology and Climate).

Lodz has one of the biggest participatory budget in Poland, which the inhabitants create and select projects they consider important. However only part of them is for green, thus the idea to create separate green participatory budget which includes all new solutions and knowledge.

The city of Lyon, France

The city of Lyon is testing innovative methods of managing urban runoff. The issue of this management is shared by many cities in France. Old sanitation networks are deteriorating and their complete replacement is costly. Moreover, the discharge of polluted urban water into rivers is punishable by law. The concept of a sponge city meets this objective of keeping rainwater on site by infiltration into groundwater or treatment by natural processes before returning it to the rivers. This paradigm shift is however risky because there are no reliable models of the efficiency of NBS operating in interaction at the scale of a city. It is very different from hydraulic modeling of a flow in a pipe. There is no knowledge of early warning indicators of dysfunction. There is no perspective on the behavior of NBS in the face of extreme events such as heavy rains and long droughts. In this new strategy, pedology, anthroposol and hydrogeology are spatial variables to be integrated into the hydrological and bio-geochemical balance. However, public awareness has started. Thus the "umbrella" software is an easy-to-use interface for dimensioning a rainwater management installation on the scale of a private plot. The characteristics of soils, topography and sewerage networks are known via a GIS. It allows the owner of a future home to find the solution that suits him best. The study is now mandatory in the filing of a building permit. The different options are green roofs, rain gardens, infiltration basins (Grand Lyon 2020).

5.2 Examples of NBS in three countries

Multiple benefits of stormwater NBS in residential area Kartanonkoski, Vantaa, Finland

Kartanokoski is a modern suburb, build to mimic the classical style on 1920's. Illenpuro brook, located at its center, forms the core for its runoff management by acting as an integrated urban brook (Figure 5). It is suspect to large runoffs with impurities from a nearby shopping mall and its adjoined industrial area. To tackle this, the brook has been turned to an NBS that collects and holds stormwater. The channel of brook is planted with aquatic vegetation. These filter impurities and cause sedimentation to improve the water quality.

Illenpuro flows to the brook, which is an important nature reserve, before joining up to the main river of Vantaanjoki. Therefore, the NBS needs to be planned in a way that doesn't cause risk to the river ecosystem. Stormwaters entering Illenpuro from the impervious built areas often contain large quantities of impurities. Before sedimentation and filtration, these impurities might pose a risk to the people living near these entry areas. Some of the local citizens also considered the brook as a danger to small children, due to its location in the middle of the neighborhood (Arvola et al. 2010).

As an NBS, the whole brook requires maintenance. Sedimented silts and impurities need to be cleaned from the bottom of the ponds from time to time (Climate-Proof City – The Planner's Workbook 2014). The high levels of stormwaters introduced to the brook often erode the banks downstream, causing more solid matter to end up to adjoined water systems (Janatuinen 2011). Also, during dry seasons, the brook might start smelling, becoming a nuisance to the residents. With the right conditions and care, it improves the neighborhood, creating a refreshing water element in the middle of the suburb, that opens the area to make it feel more spacious. If the brook is handled properly, it creates an efficient and long-lasting stormwater NBS.

Figure 5. Stormwater ponds integrated to the neighborhood provides multiple benefits. Photo: Jussi Torkko

Adoption of NBS as regulating stormwater and runoff water in a new Kivistö sub-center in Vantaa

Kivistö is a recently built new neighborhood, where different nature-based stormwater management solutions are strongly adopted in the planning phase. The area is still under the large development projects and growing fast. Current NBS for stormwater management in Kivistö include e.g. biofiltration, green roofs, permeable surfaces, urban farming, and open-faced stream that leads to a retention basin. The area was previously covered by forests and fields, so the development will add lots of impervious surfaces, so need for stormwater handling increases. Stormwater is meant to be handled by block but if that is not possible, the excess is led to regional retention basin via an open-faced stream (City of Vantaa 2015).

Kivistö area has some special construction principles like 70% of parking house roof area needs to be covered by green roofs and every block should have at least 20 meters of continuous green space (Vantaa City Council 2015, City of Vantaa 2020). Part of the neighborhood used green index for planning the green structures on the properties (Sanaksenaho 2015).

The NBS structures have been integrated into parks, roadsides, children's playground, roundabouts and rooftops in the residential area (Figure 6). The NBS provides green and blue elements in the densely built blocks and encourage people to spend time outside, affect the air quality positively, and decrease the risk of flooding. Using lots of space for nature-based stormwater control and making the structures visible but integrated in the neighborhoods is part of the branding of Kivistö (City of Vantaa 2020). As for maintenance, the stream and retention basin water quality need to be monitored so that they will not release a nutrition load to Vantaanjoki river, and they will not start smelling. All the structures need regular maintenance like weeding, replanting, erosion control and removing sedimented material from the retention basin.

Figure 6. Examples of local NBS in the Kivistö residential area. Open-faced stream on the left, city gardening in the middle and biofiltering on the right. Photos: Sonja Koivisto

Effectiveness of biofiltration of stormwater in Aviapolis, Vantaa, Finland

There are two underground wetlands about to be constructed in Aviapolis to treat the runoff from different sides of Helsinki-Vantaa airport. Airport has vast impervious surfaces which proposes a challenge for stormwater management. Additionally, the runoff from the airport contains remnants of antiskid treatment, de-icing fluids and possible oil or sewage leaks that cause stress for organic material and create shortage of oxygen in the waters (Aluehallintovirasto 2017).

The stormwater that is directed to the underground wetlands, is first infiltrated through sediment and biofilm and then distributed evenly to the wetland with pipes. The stormwater is aerated so that the wetland will not freeze during winter and a layer of plants on top of the treatment layer works as insulation (Finavia 2019). The waters from Terminal 2 area also have a retention basin that can regulate the amount of water released to the wetlands at a time and retain sediment and impurities. The entire stormwater structure is inclined towards west and the wetlands are terraced in the same direction, so water naturally flows from retention basin to wetlands to flood basin and finally to Veromiehenkylänpuro stream (Aluehallintovirasto 2017). Flood basin stores the water during heavy rains and prevents flash flooding in the brook Veromiehenkylänpuro.

Harmful substances might deteriorate the soil in the retention basin or underground wetlands over the long run. Therefore, it is important to drain the retention basin and remove excess sediments and sludge from the bottom (Climate-Proof City – The Planner's Workbook 2014). The maintenance of underground wetlands can be technically challenging. The banks to the flood basins were quite steep which increases the erosion risk, but this can be minimized by planting deep-rooted vegetation on the banks.

Street scale biofiltration for stormwater management on the road Meiramitie, Vantaa

There have been built five biofiltration sites along the road Meiramitie (Figure 7). Once the water level in the cobblestone area surpasses the height of the sill, the water flows to the biofiltration area. Three different plant species that thrive in modest environments were chosen for the areas. Besides the biofiltration areas with perennial plants, suitable tree species also contribute to the biofiltration along the entire road. The cobblestone area retains sand and trash and can be cleaned with a street cleaning machine (Juvankoski & Jormola 2018).

There are infocards next to a bus stop about stormwater biofiltration, which raises awareness about nature-based solutions to stormwater management when people read while awaiting their bus. To keep the

structures in good condition, they need regular replanting, removal of trash and sludgy soils and replacement of the casing layer every 5 years (Climate-Proof City – The Planner's Workbook 2014).

The structure is sensitive to errors in the construction phase; minor errors affect the functioning of the structure critically. In Meiramitie, the curbs were constructed a bit too high, so most of the stormwater flow to stormwater drains. Also, the sill to the biofiltration area is too high, so the water can only reach the filtration area during heavy rains (Lehikoinen 2015). It would be important that the waters from light rain could be infiltrated too because it contains more impurities than the water from heavy rains. Furthermore, frost heaving can move the structures, so they should be checked annually. For proper implementation, the involvement of the stakeholders in the planning phase is important as well as close supervision in the construction phase (Lehikoinen 2015).

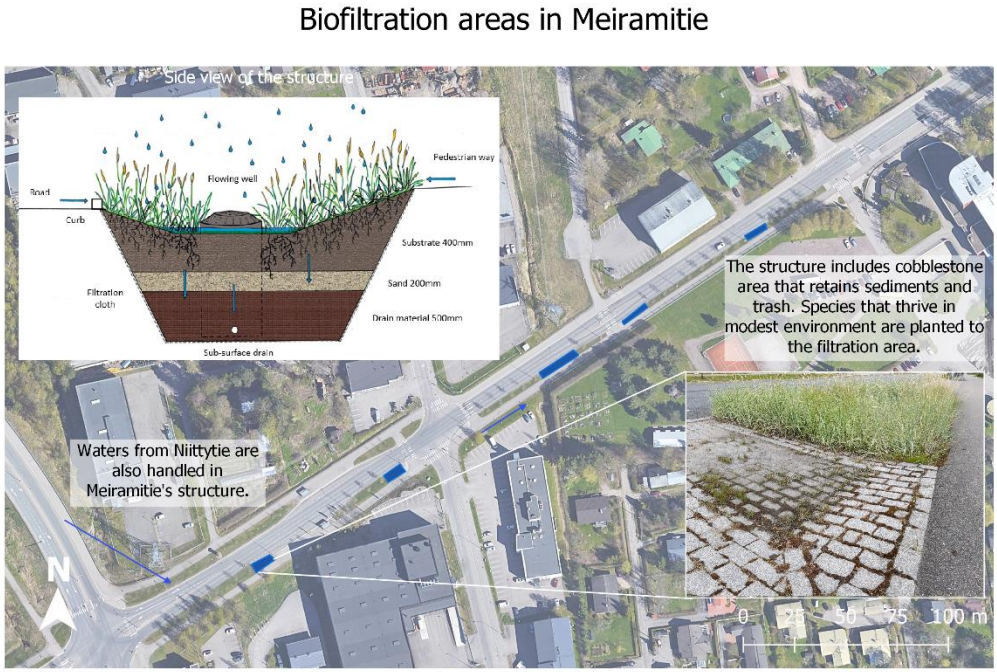

Figure 7. Biofiltration areas in Meiramitie consist of a curb, a cobblestone area and a sill to the planted area. Some soil has gathered in the cobblestone area and this should be cleaned with street cleaning machine. Photo: Sonja Koivisto

The urban brook Mätäjoki – an example combined natural and human constructed NBS in Vantaa

The brook, known as Mätäjoki in Helsinki and called Mätäpuro in its upper wetlands in Vantaa, is an urban brook located in the hearth of the capital region (Figure 8). It is the old channel of the region's main river Vantaanjoki, which changed course due to post-glacial rebound (Ruth 2004). Due to its historical background, it runs in a wide base, forming a more wetland-type character especially in the city Vantaa side and is protected as a nature reserve (Fig. 9). Due to its unique nature, it can accept a lot of runoff before its limits are reached and so forms an important base for the area's runoff management. Drastic changes in the flow rate of Mätäpuro are minimal, due to its wetland type characteristics being able to stabilize excess runoffs. Increased runoff from the new paved areas can be used to balance the water levels in the brook during the dry season. This is done to improve the flow rate and quality of water. Returning the channels to a meandering state delays runoff creates ponds and substrate for wetland vegetation, which together with aquatic vegetation increases local biodiversity (Vantaa Kaupunkisuunnittelu, 2010)

As an important nature area, the runoffs leading up to it should be filtrated before reaching it. Currently many of the smaller creeks reaching it have old man-made pond structures, which might not be sufficient with the future's increased runoffs. Positively, the new urban areas built around the brook have had improved runoff infrastructure and promoted brook restoration. Mätäjoki has often suffered from low water

levels during the summer months, for which the new impervious areas and their increased runoffs to the brook can be helpful for. Previously this has been done by pumping water from a nearby lake (Ruth 2004). The slowing flow of meandering brook with wetland vegetation improves holding capacity and delay mechanism for runoffs. Stormwater ponds delay and hold urban runoff before distributing it to the brook. Restoration of the smaller channels into natural conditions.

Constant supervision and maintenance, along with upgrades for the stormwater infrastructure will be needed for the brook to flourish in the future. The wetlands should be first and foremost seen as an important nature area, instead of a wastewater dumping ground. For example, in 2013 a solvent leak from a nearby factory killed most of the brook's aquatic life downstream. Currently the brook and its adjoined wetlands form an important nature area with flood meadows, groves, trout, rare birds and insects. Future development can be done in a way which promotes both human needs as well as improvements for the whole nature ecosystem.

Figure 8. The surrounding vegetation of the brook is partly naturally developed and dense, blocking visual connection to the stream. Photo: Jussi Torkko

Public-private partnership in Osumapuisto, Vantaa

A private company could not fulfill the requirements for stormwater handling within their property, so they made a deal with City of Vantaa to finance the construction of retention basin in the park owned by the city (Figure 9). The basin will hold the stormwaters from the company-owned industrial area, parking lots and nearby busy roads before releasing them to Krakanoja brook via a small, open channel. This is to regulate the amount and quality of water in Krakanoja which the sea trouts can climb in fall (Jormola et al. 2017). In flood situations, the water will flood to the surrounding meadow, which is slightly inclined towards Krakanoja brook (Jormola et al. 2017). The flood meadow has a big holding capacity and will decease flooding downstream and increase flood control (Jormola 2019).

The stormwater pond provides an attractive water element in the green area and creates a better environment for aquatic life in Krakanoja by improving the water quality. Therefore, the company fulfilled their obligation to take care of stormwaters in a way that many citizens passing-by can enjoy the view and which also improves biodiversity of public green space.

As for maintenance, the basin should be drained regularly to remove the impure material accumulated to the bottom of the basin (Climate-Proof City – The Planner's Workbook 2014.). Also, the channel that leads to Krakanoja needs to be taken care of so that it doesn't get blocked by branches, trash, or ice. A barrier for constructing similar solutions might be that they take up a lot of space and usually need to be well-integrated into an existing park that has the right inclination angle.

Figure 9. Stormwater retention pond with adjacent wet meadow vegetation. Photo: Sonja Koivisto.

Ecohydrologic rehabilitation of recreational reservoirs Arturowek as a model approach to rehabilitation of urban reservoirs, Łódź, Poland

Reservoirs in Arturowek represent one of the key recreational areas for Lodz residents. They are severely impacted by anthropopressure, which affects their water quality, and limits its functionality. Implementation of comprehensive rehabilitation-focused solutions was made under a European Project LIFE+ (LIFE08 ENV/PL/000517). The project combine the knowledge in the fields of biology, hydrology and engineering to limit inflow of pollution to reservoirs and reduce the problem of toxic cyanobacterial bloom formation. A sequential sedimentation and biofiltration system (SSBS) has been applied in Arturowek. SSBS is 3 step water purification system using the process of solids sedimentation and removal of phosphorus and nitrogen compound by their reaction with limestone and dolomite contained in the geochemical filter and then their incorporation into the structure of plants (biofiltration). Combined with the underground settlers and separators systems stabilizes runoff from the urban watershed and minimizes the flood risk. The system is installed in the reservoir's basin in the section where the river, canal or stormwater outlet enter the reservoir. The system can be modified depending on the volume and size of the inflow and morphology and hydrological characteristics of the reservoir. The structure use the area along the reservoir shoreline. The structure do not require any extra area. The system removes c.a. 90% of suspended matter, 85% of Total Nitrogen (TN), and c.a. 80% of Total Phosphorus (TP), transported with rainwater from streets to river. The

guarantee of maintaining good water quality in the reservoirs is provided by a system of training courses addressed to students, teachers, public administration employees, decision-makers and institutions responsible for water quality (Jurczak et al. 2015).

Sequential Sedimentation - Biofiltration System for the purification of a small urban river (the Sokolówka), Łódź, Poland

The Sequentional Sedimentation-Biofiltration System (SSBS) was built on the Sokolowka river in Lodz (Poland) as an implementation of SWITCH project (Sustainable Water management Improves Tomorrow`s Cities' Health,6 FP EU, GOCE 018530). It was constructed to purify a small urban river whose hydrological regime is dominated by stormwater and meltwater. The SSBS was constructed on a limited area as multizone constructed wetlands. The SSBS consists of three zones: sedimentation zone with structures added to improve sedimentation, a geochemical barrier made of limestone deposit and biofiltration zone (Figure 10). Sokolowka River became a demonstration project for testing ecohydrological approaches and system solutions to enhance city sustainability based on water resources management (Wagner and Zalewski, 2011). SSBS in the Sokołówka valley resulted in a reduction of suspended matter content by up to 90% and a reduction of total nitrogen and phosphorus load by more than 50% during the first years of the project. The study demonstrated that the SSBS provided high pollutant removal rate, especially while considering its relatively small surface area to the total catchment area (Szklarek et al. 2018).

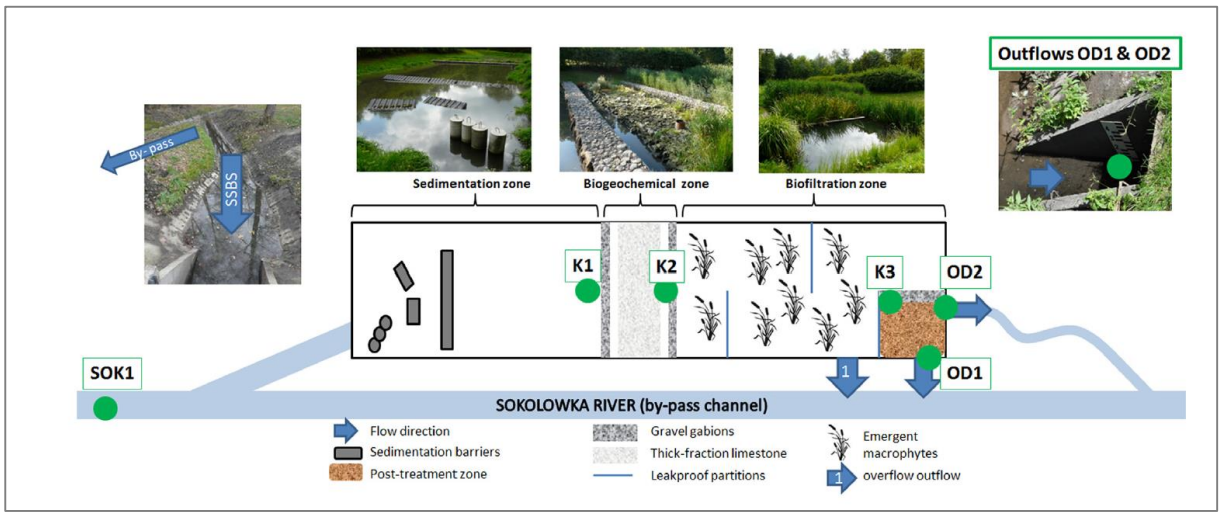

Figure 10. SSBS on the Sokołówka river, Poland, cleaning part of the high-flowing water directed to the SSBS directly from the stream by a “by-pass system”. EU SWITCH Project (Szklarek et al. 2018).

River restoration in Oullins, Lyon, France

The most significant transformation of the Yzeron took place right in the center of Oullins, with the removal of the concrete bed, the restoration of the bed and the banks and the development of hiking trails. Today in 2016, the watercourse regains a more natural functioning, an ecological and landscape quality that urban pressure had made it lose, thus allowing everyone to enjoy a whole new living environment. The fishermen have reinvested the river. In a few figures: 1.4 km of restored river; 1.1 km walking path with 3 new pedestrian bridges; 2000 shrubs planted; 50 trees planted; 1.5 ha planted with grass; protection against the thirty-year flood; 7.4 M €.
https://www.riviere-yzeron.fr/premiere-phase-oullins/
https://www.riviere-yzeron.fr/videotheque/
https://www.riviere-yzeron.fr/oullins-apres-grands-travaux-lentretien/

Ramps in the small seasonal rivers of the Yzeron basin, Lyon, France

The small seasonal rivers of the Yzeron basin have very low to zero low flow rates. Their quality is greatly degraded by urban discharges of rainy weather. They have also lost their natural geomorphology under the influence of rectifications imposed by urbanization. INRAE has followed for 10 years through several research programs the effect of a sequence of porous ramps implanted in one of these small rivers (1-2 m wide). The objective was to evaluate the capacity of biodegradation, by the sand bed accumulated upstream a porous ramp, of the organic matter discharged by urban runoff and combined sewer overflows. The experiment was conclusive and a demonstration device was installed on a wider river (3 to 4m, Figure 11). The device is made up of two porous ramps. It received the support of SAGYRC which provided the means for the works and the place (public area) for the installation. This is the demonstration site of the ATENAS project.
https://www.riviere-yzeron.fr/epurer-leau-in-situ-experimentations-en-cours/

Figure 11. Porous Ramp System in the Ratier River - Equipped with wooden sticks upstream to monitor the formation of the sand biofilter. (Construction: Green Style, INRAE Designer, Owner: SAGYRC - Syndicate fluvial France).

Filter basis in the Yzeron river basin, Lyon, France

A feedback on an NBS developed in the Yzeron basin deserves to be mentioned here. It is a filter basin planted with reeds to purify urban runoff water before it reaches a small stream. The regional water agency had agreed to finance 50% of the work of separating the rainwater network of a few hectares of urban area on the condition of setting up the filter basin. The operation was carried out but without training the technical services in the operation of the device. The annual cutting of the reeds was not carried out, which quickly filled the basin with dead stems and the release of organic matter. The basin was filled with very fine sediment which was no longer visible to the technicians. It clogged the surface. The water was no longer able to infiltrate transported pollution in a stormwater basin located just downstream before the watercourse. The frequent overflows destroyed the structure which was rebuilt in a bad way. The overflows also caused the clogging of the canal which allowed the water treated by the biofilter to reach the river. The river therefore lacked a water supply during the low flow period during summer storms. This experience shows that in the absence of a good understanding of the operating principles of this NBS and in the absence of operating indicators, natural systems drift very quickly and become expensive to restore to working order.

6. Conclusions

6.1 Policies and measures required to enhance the success of NBS

The findings in the three case studies support the findings in the research literature. In NBS applications, the local contexts play a crucial role, and therefore it was important to examine barriers and success factors carefully in the case areas. Many challenges were identified in the way of NBS mainstreaming, but also many opportunities. The knowledge on important factors is accumulating both in the cities and in academic research and EU-funded projects. NBS are also being actively developed. When the first generation of NBS have been in operation for several, there is already monitoring data and citizen feedback on their effectiveness and possible problems. Previous experiences and new research findings are used in the latest developments.

Although many technical and ecological improvements can be sought, biggest development steps can be taken in the political arena, institutional collaboration and knowledge production. Main barriers to NBS applications where often found in governance, regulation, organizational interaction, and planning practices. Challenges are typically not confined to one issue but intersect many sectors and phases. A common example mentioned in workshops were the links between planning, implementation, maintenance and monitoring. Provision of evidence on NBS benefits and demonstrations of concrete examples of effective NBS promote the acceptance and application of NBS among planners, decision-makers and other stakeholders. Partnerships of different partners are crucial in most cases. In the future work, more attention should be paid to critical inter-dependencies and collaborations (see also Wamsler et al. 2020). It is important to identify all actors and processes involved and target actions at them.

Location of NBS in urban areas was affects the variety of applicable NBS and their barriers. In all three case areas, there NBS development was significantly dependent on the availability of space, and surrounding environment. In densely built areas, NBS can be small and numerous and usually newly constructed for the purpose, in medium density areas more space can be reserved for NBS enabling larger infiltration and retention areas, and in low density areas there are more opportunities to use natural ecosystems as NBS.

Costs of NBS are in many cases a critical issue. Municipalities are forced to consider their investments very carefully. Short-term costs and impacts are often over-emphasized in the decision-making, even though NBS should be assessed as long-term solutions. In the current situation, more information and comparisons on cost-effectiveness are required.

6.2 How to apply the results in other WPs in ATENAS project

The summaries of workshop discussions in three case areas showed that most of the critical issues are shared, even though the environmental challenges and planning contexts differ. This finding confirms that there are good opportunities for learning from each other in the ATENAS project.

The results of this report can be used in the other work packages of ATENAS project:

- The findings help to develop modelling and identify the key issues that need to be addressed when interpreting modelling results (WP2)
- The study has identified local barriers and success factors that are important to be taken into account, when selecting best solutions for each area. The case descriptions of critical factors also support the production of NBS cookbook (WP3)
- The results support actions for NBS strategy setting and upscaling by presenting organizational, institutional, social, and economic constraints and opportunities (WP4)
- The analysis also supports stakeholder involvement actions and mutual learning activities by indicating critical points in the collaboration processes (WP5)

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